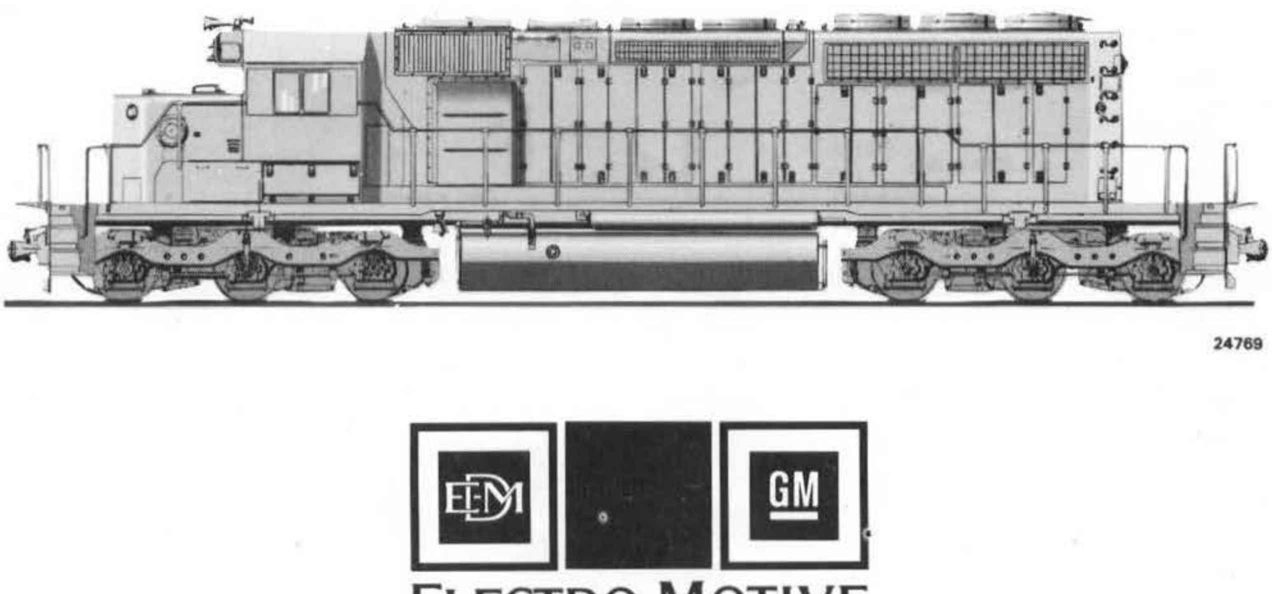
SD40-2

LOCOMOTIVE SERVICE MANUAL

8th Edition



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ELECTRO-MOTIVE

• • • • **A Service Department Publication** • • • •

Electro-Motive Division Of General Motors La Grange, Illinois 60525

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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. The material included is applicable to the basic locomotive and common extra equipment. The presence or absence of coverage for any particular system or component in no way implies that the equipment is or is not part of any specific locomotive.

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 manufacturer's publications covering special equipment.

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 some sections of the Locomotive Service Manual. This page provides the following:

1. Reference to applicable Maintenance Instructions and technical manuals.

2. Reference to applicable tool and testing apparatus numbers.

3. Specific system values for operation or testing.

METRIC MEASUREMENT

Units of measurement appearing in this manual are shown in metric units and U.S. standard units. A conversion table is provided at the back of this manual to convert U.S. standard units to metric units.

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GENERAL INFORMATION

Model Designation	SD40-2
Locomotive Type	(C-C) 0660
Locomotive Horsepower	3000
Loaded Weight On Rails (Approximate)	166 925 kg (368,000 lbs.)
Diesel Engine	
Model	645E3C
Operating Principle	Two Stroke Cycle
Number Of Cylinders	16
Cylinder Arrangement	45°-"V"
Compression Ratio	16:1
Rotation (Facing Flywheel End)	Counterclockwise
Bore And Stroke	9-1/16" x 10"
Idle Speed (Normal)	318 RPM
Low Idle Speed (When Equipped)	255 RPM
Full Speed	904 RPM
Main Generator	
Model	AR10JBA
Maximum Continuous Current	4200 Amperes
Maximum Voltage DC	1250
Companion Alternator	
Model	D18
Nominal Voltage AC	215
Number Of Poles	16
Frequency At 900 RPM	120 Hz
Auxiliary Generator	
Voltage DC	74 VDC
Rating	10 kW
Voltage (55 VAC)	74 VDC
Rating	18 kW
Air Compressor	
Type	Water Cooled
Number Of Cylinders	
Basic - Model WLN (WBO)	3
Special - Model WLG (WBG)	6

Lube Oil Capacity - Nominal
3-Cylinder Model . . . . . 38 Litres (10 Gallons)
6-Cylinder Model . . . . . 68 Litres (18 Gallons)

Compressor Displacement At 900 RPM
3-Cylinder Model . . . . . 7.2 m^3/Minute (254 Cu. Ft./Min.)
6-Cylinder Model . . . . . 11.3 m^3/Minute (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 Amperes with PF17
1090 Amperes with PF18
1120 Amperes with PF29

Gear Ratio	Max. Speed	Minimum Speed For Full Horsepower	Minimum Continuous Speed	Tractive Effort At Minimum Continuous Speed
Basic Performance Control - PF17				
62:15	104.6 km/h (65 MPH)	–	17.9 km/h (11.1 MPH)	83,100
61:16	112.7 km/h 70 MPH)	–	19.3 km/h (12.0 MPH)	76,700
60:17	122.3 km/h (76 MPH)	–	20.9 km/h (13.0 MPH)	70,900
59:18	132.0 km/h (82 MPH)	–	22.5 km/h (14.0 MPH)	65,900
Low Speed Extra Performance Control - PF18				
62:15	104.6 km/h (65 MPH)	20.0 km/h (12.4 MPH)	11.6 km/h (7.2 MPH)	87,400
61:16	112.7 km/h (70 MPH)	21.6 km/h (13.4 MPH)	12.6 km/h (7.6 MPH)	80,700
60:17	122.3 km/h (76 MPH)	23.3 km/h (14.5 MPH)	13.7 km/h (8.5 MPH)	74,650
59:18	132.0 km/h (82 MPH)	25.1 km/h (15.6 MPH	14.7 km/h (9.1 MPH)	69,300
Low Speed Extra Performance Control - PF29				
62:15	104.6 km/h (65 MPH)	18.0 km/h (11.2 MPH)	13.7 km/h (8.5 MPH)	90,470

Trucks – The HT-C truck is not interchangeable with previous SD truck models.

Model . . . . . HT-C
Wheel Diameter . . . . . 1 016 mm (40″)
Basic Bolster . . . . . Solid
Basic Brake Rigging . . . . . Single Composition Shoe
Basic Journal Boxes . . . . . JEM
165 mm x 305 mm (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 . . . . 13.259 m (43′6″)
Truck Wheel Base . . . . 4.150 m (13′7-3/8″)
Axle Spacing . . . . 2.023 m, 2.127 m (79-5/8″, 83-3/4″)

Characteristics
Static Wheel Load
(Basic locomotive weight of 166 925 kg [368,000 Lbs.]) - Nominally 13 953 kg (30,760 Lbs.)
Dynamic Wheel Loads
(Variation due to journal spring deflection) - 3 175 to 4 082 kg (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 . . . . 3 629 to 4 536 kg (8000 to 10,000 Lbs.)
10° Curve . . . . 5 897 to 6 804 kg (13,000 to 15,000 Lbs.)
Dynamic loads at rail joints or transient rail irregularities on tangent track at 104.6 km/h (65 MPH) . . . . Common - 4 536 to 5 443 kg (10,000 to 12,000 Lbs.)
Occasional - 6 804 to 9 072 kg (15,000 to 20,000 Lbs.)
Air Brakes 26L
Curve Negotiation Capability

58.826 m (193 Ft.) Radius - 30° Curve –	Represents minimum single unit curve negotiation for an SD40-2 basic single shoe truck as limited by truck negotiation.
58.826 m (193 Ft.) Radius - 30° Curve –	Represents minimum single unit curve negotiation capability for an SD40-2 equipped with clasp brake truck as limited by truck negotiation.
70.104 m (230 Ft.) Radius - 25° Curve –	Represents minimum curve capability for two SD40-2 locomotives in multiple as limited by coupler swing.
109.423 m (330 Ft.) Radius - 17° Curve –	Represents minimum curve capability of an SD40-2 coupled to standard 15.24 m (50′) box car as limited by car coupler swing.

Supplies
Lube Oil Capacity
Basic Oil Pan . . . . 920 Liters (243 Gal.)
Increased Capacity Oil Pan . . . . 1 495 Liters (395 Gal.)
Usable Oil
(Volume between "Full" and "Low" on dipstick)
Basic Oil Pan . . . . 178 Liters (47 Gal.)
Increased Capacity Oil Pan . . . . 697 Liters (184 Gal.)
Fuel Capacity
Basic . . . . 12 113 Liters (3200 Gal.)
Special Available . . . . 15 142 Liters (4000 Gal.)
13 627 Liters (3600 Gal.)
9 842 Liters (2600 Gal.)
6 435 Liters (1700 Gal.)
Cooling System Capacity . . . . 1 041 Liters (275 Gal.)
Sand Capacity . . . . 1.586 m^3 (56 Cu. Ft.)

Major Dimensions

Distance, pulling face of coupler to centerline of bolster	3.860 m (12′ 8″)
Distance between bolster centers	13.259 m (43′ 6″)
Distance, pulling face front coupler to rear coupler	20.980 m (68′ 10″)
Width over hand rail supports	3.127 m (10′ 3-1/8″)
Height, top of rail to top of cooling fan guards	4.755 m (15′ 7-3/16″)
Width over basic arm rests	3.150 m (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.

	kg	Lbs.
16-645E3C Diesel Engine	14 742	32,500
Starter Motor	36	80
Starter Motor Bracket	27	60
Engine Governor	54	120
Turbocharger	817	1800
AR10 Main Generator Assembly	7 258	16,000
Auxiliary Generator And Blower Assembly	454	1000
Inertial Air Filter	272	600
Inertial Filter Screen	16	35
Inertial Filter Compartment And Hatch	2 132	4700
Inertial Filter Hatch (Less Filters)	227	500
Fuel Tank 3200 Gal.	3 016	6650
Fuel Tank 4000 Gal.	4 509	9940
Truck Assembly (Single Shoe; Solid Bolster)	25 946	57,200
Traction Motor	2 722	6000
Axle	601	1325
Wheel	460	1015
Gear 62 Tooth	186	409
Bearing - Inner Race	15	33
Air Compressor	1 055	2325
Air Compressor Shaft	62	136
Air Compressor Shaft Guard	31	68
Air Compressor Coupling	22	48
Lube Oil Cooler	383	845
Lube Oil Filter	306	675
Fuel Pump Assembly	37	81
Fuel Suction Strainer	4	8
AC Cabinet Assembly	113	250
Fuel Filter	27	60
Temperature Switch Manifold	9	20
Load Regulator Vane Motor	16	36
Dynamic Brake Fan Assembly	345	760
Dynamic Brake Resistor Grid	175	385
Dynamic Brake Grid Shorting Contactor	16	35
Fan Grill Assembly	86	190
Radiator Fan Assembly	318	700
Radiator Core	147	325
Cab Heater	32	71
Storage Battery	131	289
SCR (Generator Excitation)	13	29

GENERAL DESCRIPTION

The diesel engine operates on a two-stroke cycle, with power applied on each downward stroke. At the bottom of each downward stroke, 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, with 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 differential low water pressure detector is connected to the intake and discharge sides of the centrifugal pump 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 companion 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 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 cylinders at a precise moment in the firing cycle. The engine governor operates injector gear racks to maintain the proper amount of fuel needed for engine speed and power level called for.

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 companion 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 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 VDC)
BCT	Brake Current Transductor
BKS	Brake Handle Switch
BR–	Brake Relay
BRA–	Brake Auxiliary Relay
BVR	Throttle 5 Auxiliary 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
CRL	Compressor Relay
CT–	Current Transformer
DBI	Dynamic Brake Interlock
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
EBR	Electric Bell Relay
EBT	Electric Blowdown Timer
EFL	Engine Filter Latching Relay
EFS	Engine Filter Switch
ELT	Excitation Limit Transductor
EL–	Excitation Limit Module
EP–	Engine Purge Module
EQP	Equipment Protective Relay
ER	Engine Run Relay
ESR	Engine Stop Relay
ESS	Emergency Sanding Switch
ETS	Engine Temperature Switch
FBR	Filter Blower Relay
FCR	Fan Contactor Relay
FCT	Field Current Transductor
FC–	Fan Contactor
FFCT	Field Forcing Current Transformer
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
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
GOV	Governor
GPT	Generator Potential Transformer
GR	Ground Relay
GV-	Generator Voltage Module
GX-	Generator Excitation Module
IPS	Independent Pressure Switch
IS	Isolation Switch
LOT	Lube Oil Transfer Relay
LR	Load Regulator
LSC	Locomotive Spotting Contactor
LTT	Load Test Transfer Switch
LW-	Locked Wheel Module
LWR-	Locked Wheel Relay
LWX	Locked Wheel Auxiliary Relay
MB	Motor-Brake Transfer Switch
MCOX	Motor Cutout Auxiliary Relay
MCO-	Motor Cutout Relay
MR	Motoring Relay
MRA	Motoring Relay Auxiliary
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
NIR	Normal Idle Relay
NVR	No (AC) Voltage Relay
OCP	Open Grid Circuit Protective Relay
OCL	Open Grid Circuit Latching Relay
ORS	Overriding Solenoid
PCR	Pneumatic Control Relay
PCS	Pneumatic Control Switch
PF-	Performance Control Module
PR	Parallel Relay
PRA	Parallel Relay Auxiliary
PRX	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– Radar Speed Module

RVF Transfer Switch Forward Relay

RV– Directional Transfer Switch

SA– Sanding Module

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

WD– Wheel Delay Relay

WL Wheel Slip Light Relay

WO– Wheel Overspeed Module

WS– Wheel Slip Control Module

WST– Wheel Slip Transductor

ELECTRO-MOTIVE

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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 207 kPa (30 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.

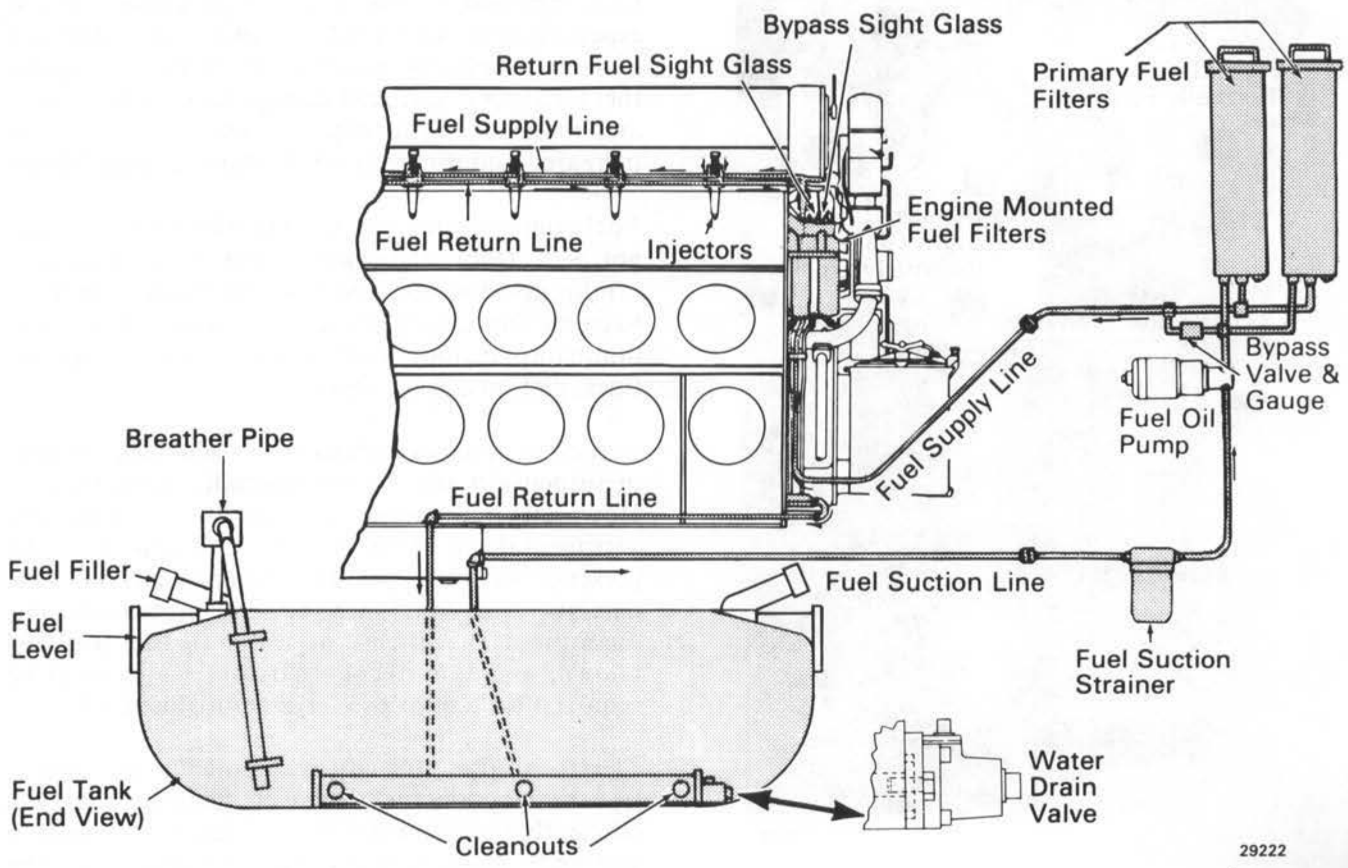

Fig.1-1 – Fuel Oil System, Pictorial Diagram

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.

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.

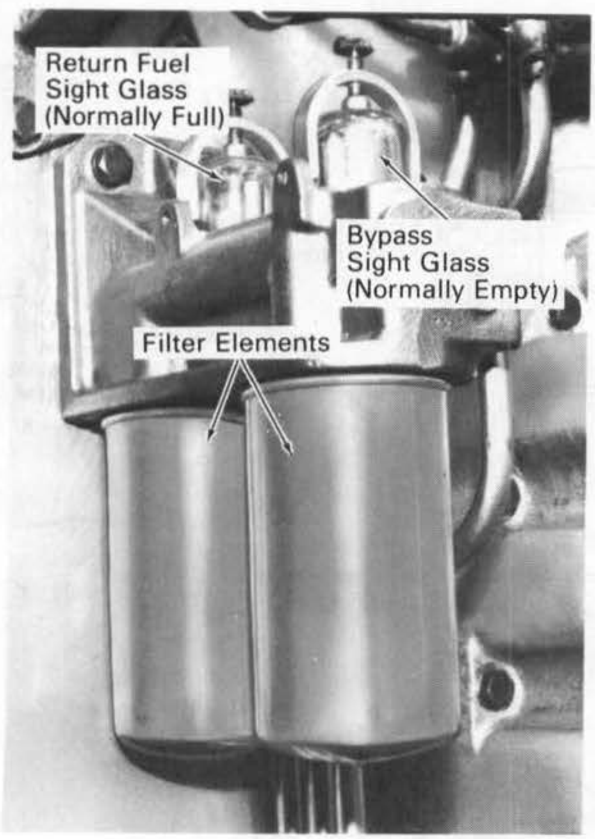

Fig. 1-2 - Engine Mounted Fuel Filters, With Sight Glasses

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

Effective wayside fuel filtration is necessary to ensure cleanliness, quality, and uniformity of the fuels supplied to the engine fuel tanks. This is especially true since 1974, due to a general decrease in fuel cleanliness resulting from more frequent fuel turnover (shortened storage tank settling time), and reduced fuel inventories (which can result in increased agitation of tank bottoms during filling).

Fuel contaminants can be classified into two categories; soft or deformable, and hard. Soft contaminants include micro-organisms (such as bacteria and algae), waxes, and water. Hard contaminants include rust, scale, cracking catalyst fines, dirt, and wear metals.

Soft contaminants such as waxes generally are kept in suspension and do not normally cause trouble. However, both water and micro-organisms are detrimental to fuel system components. The presence of slime on fuel filters indicates that bacteria and fungi are present in troublesome quantities. The effects of water in fuel are well known, and it is recognized that water must be removed or kept at the lowest possible level.

Electro-Motive strongly recommends the utilization of wayside fuel filtration facilities that will efficiently remove water and contaminants 2 micron size and larger, and provide fuel that meets the cleanliness specifications given in the applicable Maintenance Instruction.

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 downhill to facilitate condensate drainage. A ball valve drain, Fig. 1-1, is provided for this purpose. To drain, simply remove the pipe plug and position flow indicator to "open."

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 filter. This gauge indicates the fuel level from the top of the tank to about 114 mm (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 screen strainer, and should be periodically inspected. Also check the condition of the filler cap gasket and replace with a new one if necessary. See Service Data.

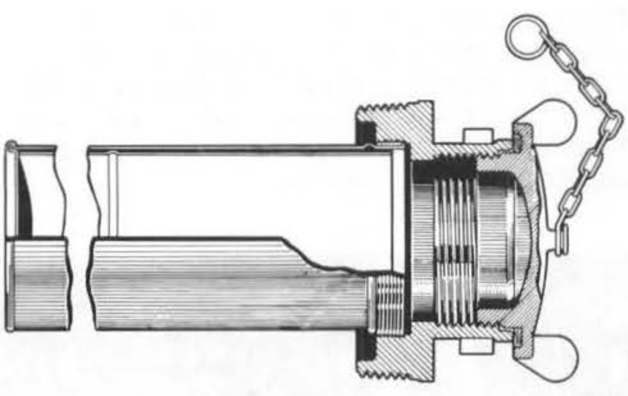

Fig. 1-3 – Fuel Filler Assembly

FUEL SUCTION STRAINER

The fuel suction strainer, Fig. 1-4, 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.

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

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

4. Clean the 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 82° C (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

The primary fuel filter element, Fig. 1-5, should be changed at the intervals stated in the Scheduled Maintenance Program or at shorter intervals if operating conditions warrant.

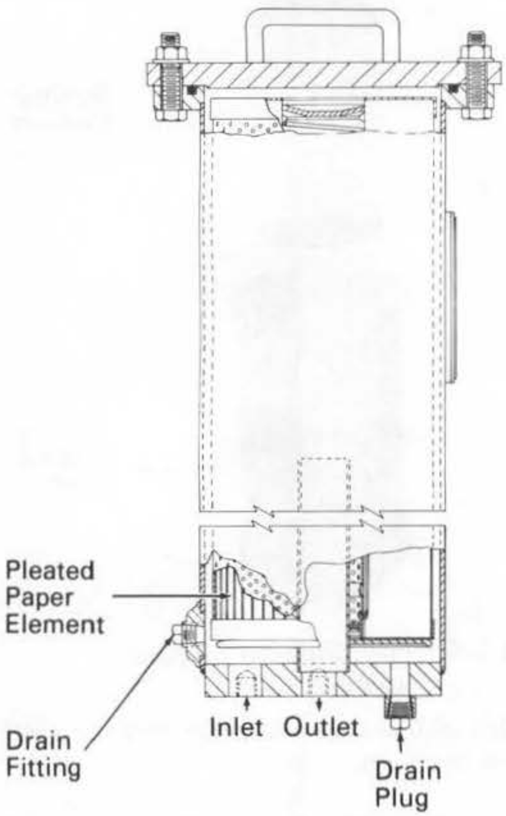

Fig. 1-5 - Primary Fuel Filter Element And Housing

CLEANING PROCEDURE

1. Stop the diesel engine; place isolation switch in ISOLATE position.
2. Place a container which will hold approximately 19 Litres (5 gallons) to catch fuel drainage, and remove drain plug 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 pleated paper 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. Tighten drain plug securely.
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

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 in the green zone.

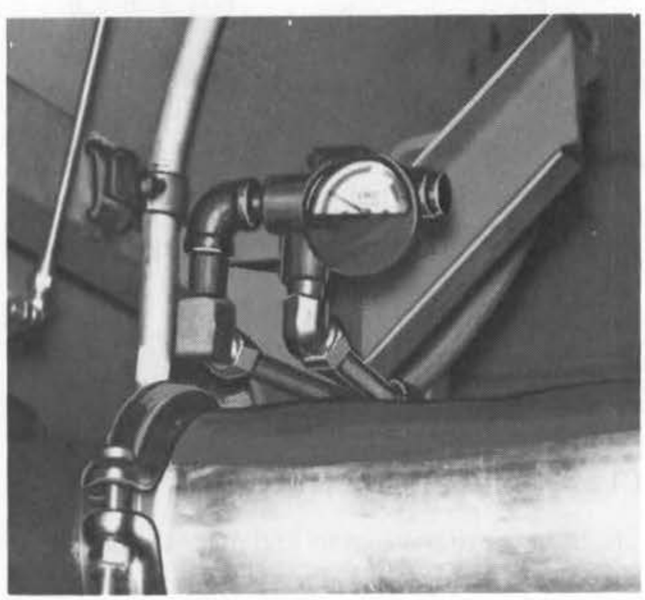

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Fig. 1-6 - Primary Fuel Filter Bypass Valve And Gauge

As the filter element becomes plugged, the indicator will read higher until it reaches the red CHANGE FILTER zone, at approximately 207 kPa (30 psi) pressure differential. At this point, the bypass valve will begin to open, allowing fuel to bypass the primary filter. Renew filter element when the indicator reaches the CHANGE FILTER zone.

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 maintained in accordance with the instructions in the Engine Maintenance Manual.

1. Shut down the engine.
2. Unscrew and discard the elements. Use a strap wrench if necessary.
3. Clean the filter assembly and sight glasses.
4. Apply a film of oil to the element gaskets.
5. Apply the elements to the filter body. Hand tighten until the gasket contacts the filter body, then tighten one-half turn.
6. Check for leaks after the engine is started.

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.

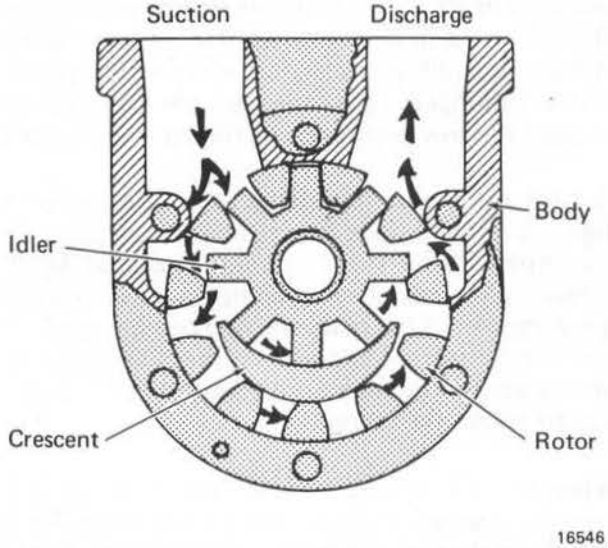

Fig.1-7 – Fuel Pump Cross Section

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.

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.

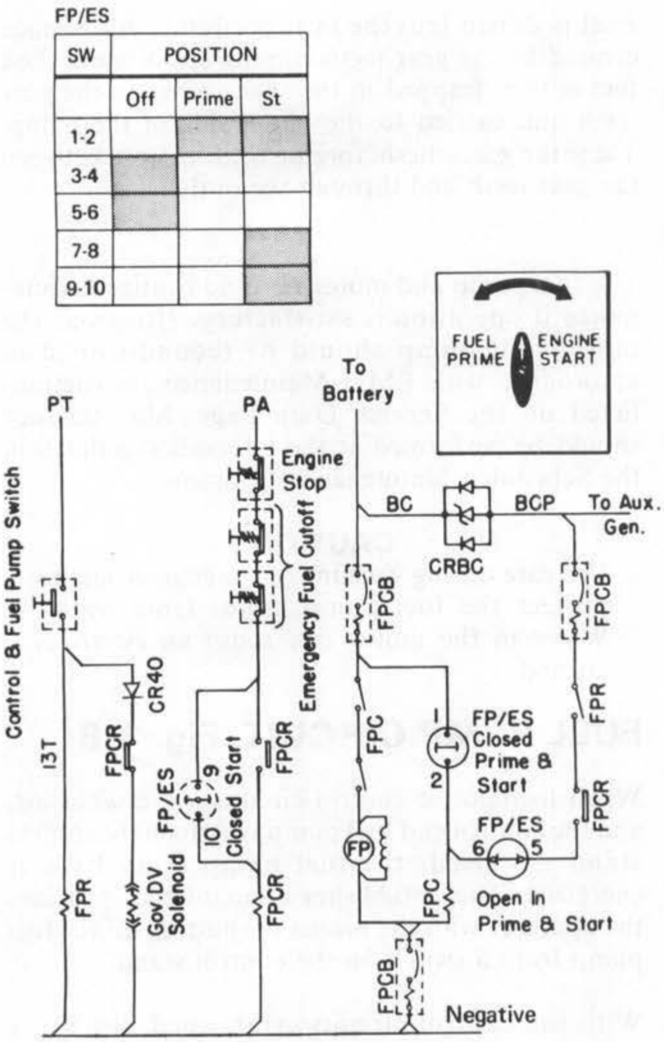

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Fig.1-8 - Fuel Pump Circuit

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 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,

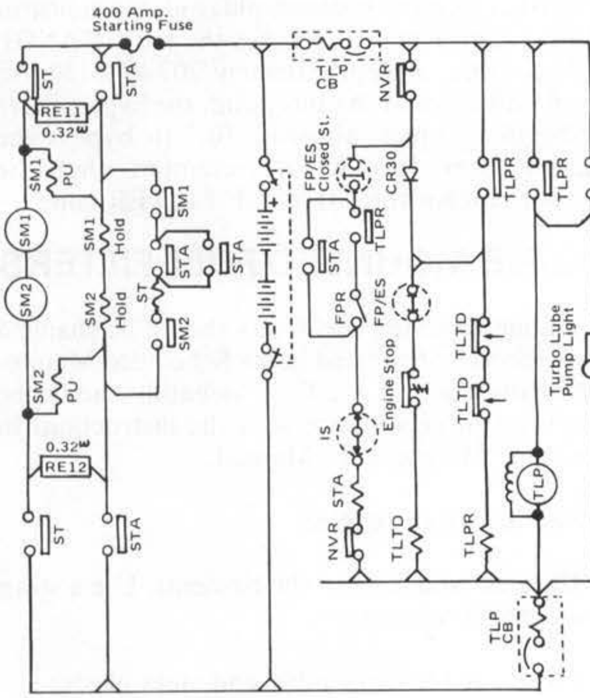

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Fig.1-9 - Engine Starting Circuit, Simplified Diagram

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.

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 drops out first. This then opens the circuit to the ST coil. As the solenoid plunger is driven out, the SM contacts also 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

CAUTION

Before attempting to start a new engine, an engine that has been overhauled, or an engine that has been shut down for more than 48 hours, perform PRELUBRICATION OF ENGINE procedure contained in Section 2.

If engine temperature is below 10° C (50° F) the engine should be preheated prior to starting.

1. Check oil level of engine, governor, and air compressor, and add oil if required. Check engine oil level in strainer housing and, if required, add oil to strainer housing until it overflows into the oil pan.

NOTE

On units equipped with top fill Michiana lube oil filter tank, check sight glass (bull's eye) on filter tank. It is not necessary to check strainer housing unless sight glass is empty.

2. Check engine coolant level.

3. Open cylinder test valves and bar over the engine at least one revolution. Observe for leakage from test valves. Close the test valves.

NOTE

It is a good practice and highly recommended that the engine be barred over one complete revolution with the cylinder test valves open before starting. If any fluid discharge is observed from any cylinder, find the cause and make the necessary repairs. This practice should apply particularly to engines that are approaching a scheduled overhaul after several years of service or have had a history of water or fuel leaks.

4. Remove the starting fuse. Check that all other fuses are installed, are in good condition, and are of the proper rating.

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

6. Place the local control and the control circuit breakers in the ON (up) position.

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

8. Place generator field and engine run switches in the OFF (down) position.

9. Place the isolation switch in the START position.

10. Place turbo lube pump circuit breaker to ON position. Remove rear oil pan handhole cover and open top deck covers.

11. At the equipment rack in the engine room, momentarily place the Fuel Prime/Engine Start Switch in the PRIME position.

12. Check turbo lube pump operation by observing lube oil flow at camshaft gear train.

NOTE

Observe camshaft bearings. If lube oil flows from camshaft bearings with turbo lube pump running and engine shut down, inspect turbo filter outlet check valve for proper operation.

13. Replace and securely close handhole covers and engine top deck covers.

14. Check that the starting fuse is in good condition and of the proper rating. Install starting fuse, Fig. 1-10.

15. 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.

CAUTION

Do not crank engine for more than 20 seconds or "inch" engine with battery power. After cranking, allow a minimum of two minutes for starter cooling before another starting attempt.

If engine is equipped with purge control system, do not push injector rack control lever (layshaft) until engine has cranked for six seconds.

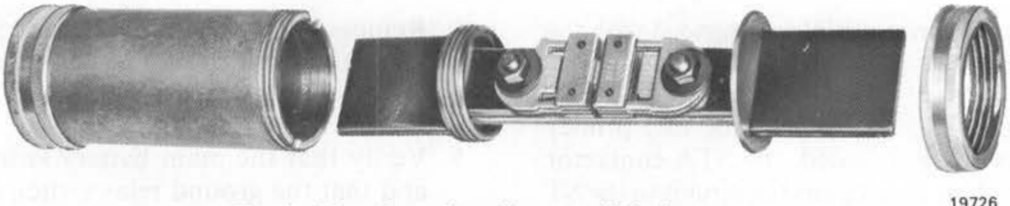

Fig.1-10 – Starting Fuse - 400 Amperes

16. Position the injector control lever (layshaft lever) at about one-third rack (approximately 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.

17. Release the injector control lever when the engine comes up to idle speed. Do not advance lever to increase engine speed until oil pressure is confirmed.

18. Check that the low water detector is not tripped. If the detector is tripped, wait for one-half minute after engine start, then press the reset button and hold for five seconds to reset. If the detector trips again, verify engine oil pressure, then slowly position the injector control lever to increase engine speed momentarily before resetting the button.

19. Check that cooling water level is satisfactory, that lube oil pressure is satisfactory, and that governor oil level is satisfactory.

STARTING MOTOR MAINTENANCE

Maintenance should be performed as indicated in the Scheduled Maintenance Program, and may be performed when checks are being made on the motors.

1. Clean the brush holder and commutator area. Remove the most accessible brush inspection plugs from each motor assembly, and direct a high pressure air hose at either opening to drive foreign matter out of the other opening. Use only dry air. Reinstall and secure inspection plugs.

2. Saturate the oil reservoirs and wicks at the bearing positions located at the front and rear of each motor assembly. Use only SAE No. 10 oil.

3. Manually press the pinion in a direction away from the ring gear to make the overrunning drive spline accessible for oiling. Use only SAE No. 10 oil.

4. Examine all connections in the high current (heavy cable) circuit to ensure that they are clean and secure.

5. Remove cabling at the battery terminal posts. Clean the terminals with a soda solution and a wire brush. After cleaning apply a clean coating of petroleum jelly on the posts and cable connectors. Reinstall cabling and secure in place.

SOLENOID REPLACEMENT PROCEDURE

1. Remove the starting motor guard cover and disconnect all wires to the solenoid after noting location of each wire connection.

2. Remove the solenoid from the motor by removing the four hex bolts.

3. Remove the front inspection cap in the plunger housing.

4. Check the number of threads exposed beyond the plunger stud adjustment nut inside the housing. If more than three threads are visible, hold the plunger to prevent its rotation, then back off the adjustment nut to a three-thread exposure plus or minus half a thread.

5. Thoroughly wipe the plunger clean of any surface contaminants, with a clean shop rag.

6. Install new solenoid 1115536 in exact reverse order of removal procedure.

CAUTION

Three types of starting motor solenoids are presently in use. Solenoids part numbers 1115539 and 1115536 may be intermixed on a unit. However, solenoid part number 1115515 must be used only with another solenoid part number 1115515. When a good solenoid part number 1115515 is removed to avoid intermixing, test and retain solenoid for use as a replacement part.

7. Reconnect all solenoid wires.

8. Follow the above Steps to renew the second motor solenoid.

9. Replace the guard cover and the ring gear cover.

SERVICE DATA
FUEL SYSTEM AND ENGINE STARTING

REFEREMCES

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

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

FILTERS

	Part No.
Primary Fuel Filter	9502100
Pleated Paper Element	8345482
Cover Gasket	8358905
Engine Mounted Filter Assembly, Spin-On Type	8479355
Filter Element	8423132
Fuel Filter Body	8479301
Suction Strainer	8341983
Mesh Element	9324489
"O" Ring, Housing-To-Cover	8343161
Pressure Differential Gauge With Bypass Valve	9323489

FUEL PUMP

Flange Gasket	8426889

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 on 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 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 time out, TLTD contacts identified on Fig. 2-2 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 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 reestablish the timing cycle and turbo lube pump operation.

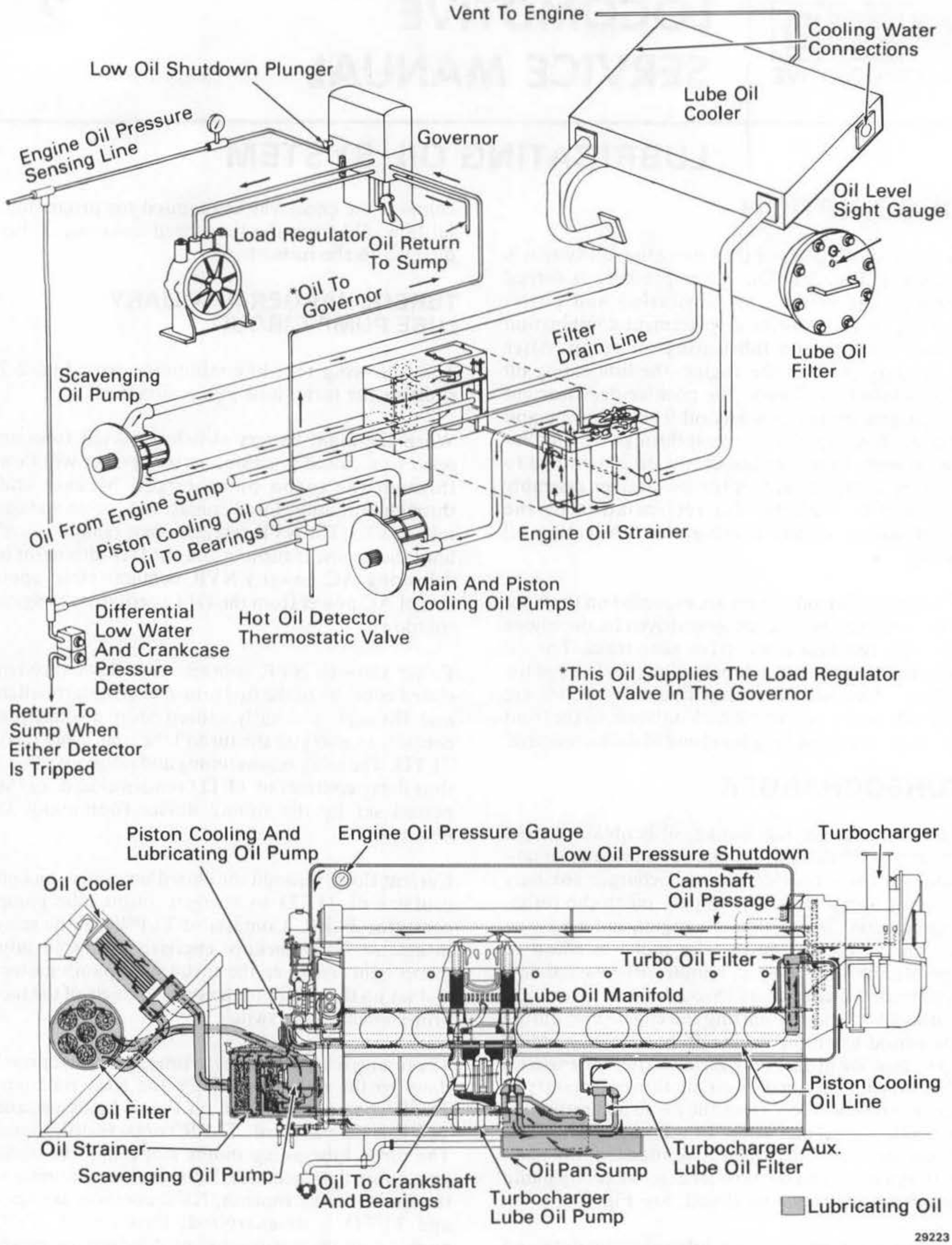

Fig.2-1 – Lubricating Oil System
Pictorial And Schematic Diagram

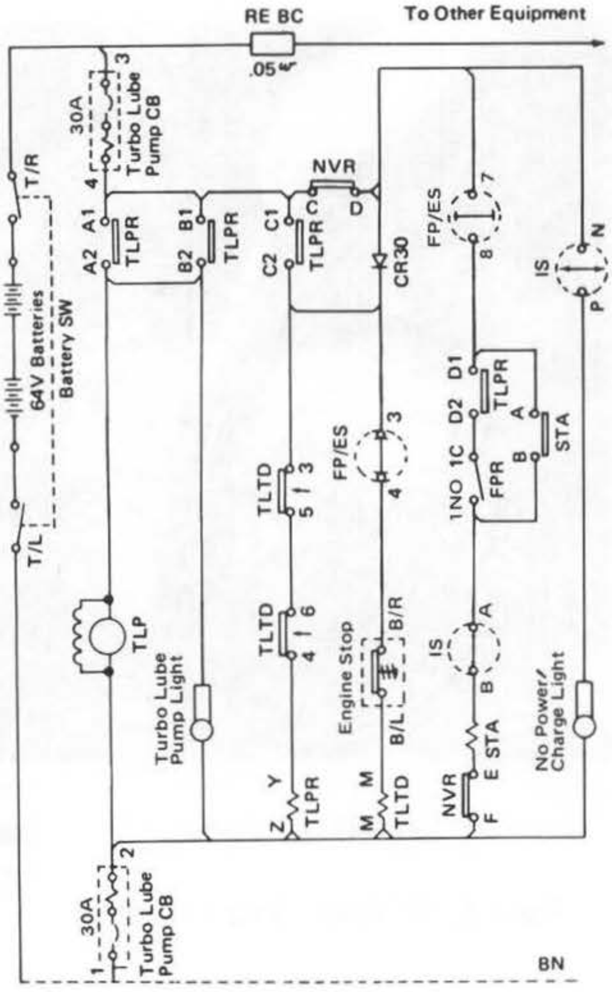

Fig.2-2 – Turbocharger Auxiliary Lube Oil Pump Circuit

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 pressing on the engine stop pushbutton.

MAINTENANCE

FILLING OR ADDING OIL TO THE SYSTEM

When filling or adding oil to the system, it is recommended that the oil be poured into the strainer housing through the square opening as shown in Fig. 2-6. Should it be found more desirable to add oil through a handhole opening in the engine oil pan, it is imperative that the strainer housing be filled before starting the engine. Failure to do this may result in serious engine damage due to the time delay before oil is completely circulated through the system and then to the working parts of the engine.

If the system has not been drained, oil may be added to the strainer housing with the engine running or stopped.

WARNING

Do not remove the round caps from the strainer housing while the engine is running as hot oil under pressure will come from the openings and serious injury could result.

PRELUBRICATION OF ENGINES

Prelubrication of a new engine, an engine that has been overhauled, or an engine which has been inoperative for more than 48 hours, is a necessary and important practice. Prelubrication alleviates loading of unlubricated engine parts during the interval when the lube oil pump is filling the passages with oil. It also offers protection by giving visual evidence that oil distribution in the engine is satisfactory.

NOTE

On units equipped with top fill Michiana lube oil filter tank, check bull's eye on filter tank. Prelubrication is not required unless bull's eye is empty.

Perform prelubrication as follows:

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. Prelube engine at a minimum of 69 kPa (10 psi) for a period of not less than three and not more than five minutes (approximately 3.8 litres/min. [15 gpm] using a 1.1 to 1.5 kW [1-1/2 to 2 hp] motor).

2. While oil pressure is being applied, open the cylinder test valves and bar the engine over one complete revolution. Check all bearings at the crankshaft, camshafts, rocker arms, and at the rear gear train for oil flow. Also check for restrictions and excessive oil flow. Check for fluid discharge at the cylinder test valve. If fluid discharge is observed from any cylinder test valve, find the cause and make the necessary repairs.

3. On new or overhauled engines, 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 cylinder test valves.

5. Pour a liberal quantity of oil over the cylinder mechanism of each bank.

6. Check oil level in strainer housing and, if required, add oil to strainer housing until it overflows into the oil pan.

7. Replace and securely close all hand hole covers and engine top deck covers.

NOTE

When an engine is replaced due to mechanical breakdown, it is important that the entire oil system, such as oil coolers, filters, and strainers, be thoroughly cleaned before a replacement engine or the reconditioned engine is put in service. A recurrence of trouble may be experienced in the clean engine, if other system components have been neglected.

In some cases engines have been removed from service and stored in the "as is" condition by draining the oil and applying anti-rust compound. When these engines are returned to service, before adding oil and prelubing, care must be taken to see that any loose deposits are flushed out before adding a new charge of oil. The entire engine should be sprayed with fuel, to break up any sludge deposits, and then drained, being careful that the drains do not plug. Fuel should not be sprayed directly on the valve mechanism or bearings, as lubrication will be removed or dirt might be forced into these areas. The surfaces should then be wiped dry before the new oil is added to the engine.

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.

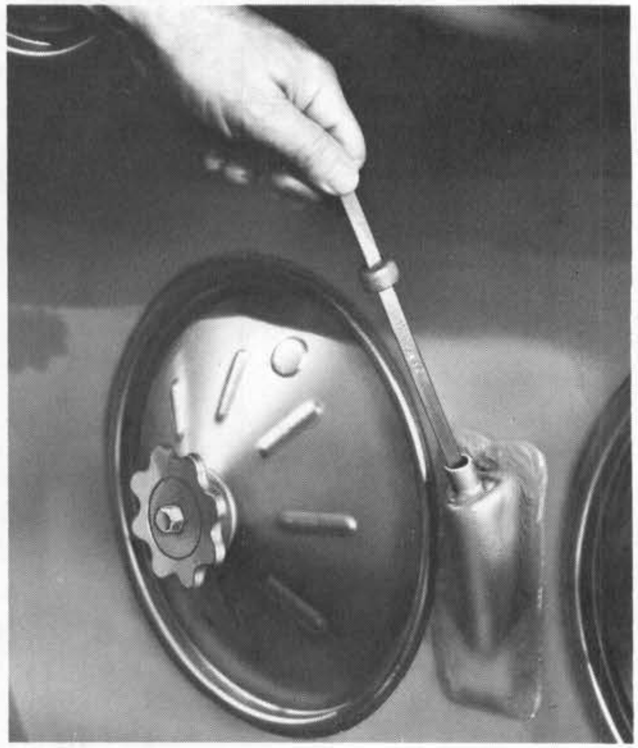

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Fig.2-3 - Oil Level Gauge - Dipstick

2. Shut the engine down and remove the starting fuse.

3. Obtain the oil sample (normally .5 litre [1 pint]) at the center of the engine oil pan half-way 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 lube 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 and inspection of the engine. Maintenance Instructions for cleaning and repair of the 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.

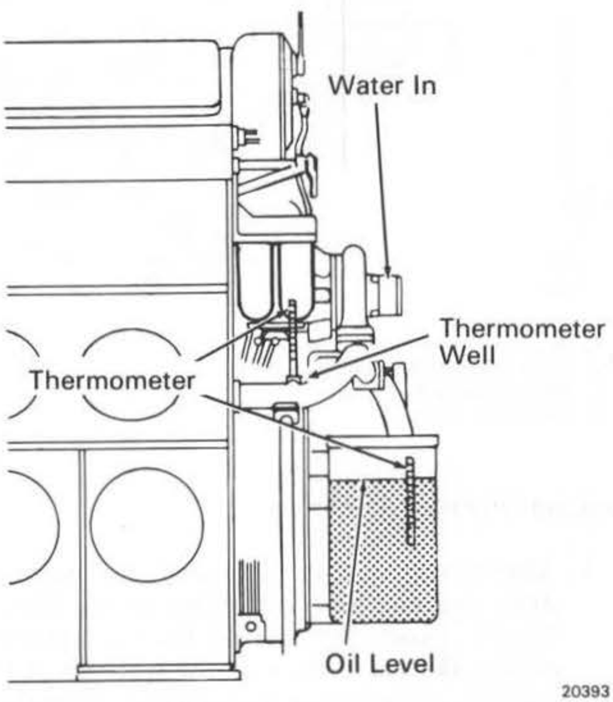


Fig.2-4 – Location Of Thermometers To Determine Oil And Water Temperature Differential

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

Many standard load boxes are not of sufficient capacity to fully load the locomotive.

3. Remove the square cover from the engine mounted oil strainer and hang a cage 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 3 until water temperature is above 54° C (130° F). Operate at full load and speed until engine water inlet temperature is stabilized. It may be necessary to block the shutters open to maintain a constant temperature.

NOTE

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

6. Record temperature readings and compare them with lubricating oil cooler service limits provided in Maintenance Instruction 928. When oil temperature for a given water temperature is higher than limit indicated, oil cooler should be serviced in accordance with Maintenance Instruction listed on Service Data page.

OIL FILTER INSPECTION AND MAINTENANCE

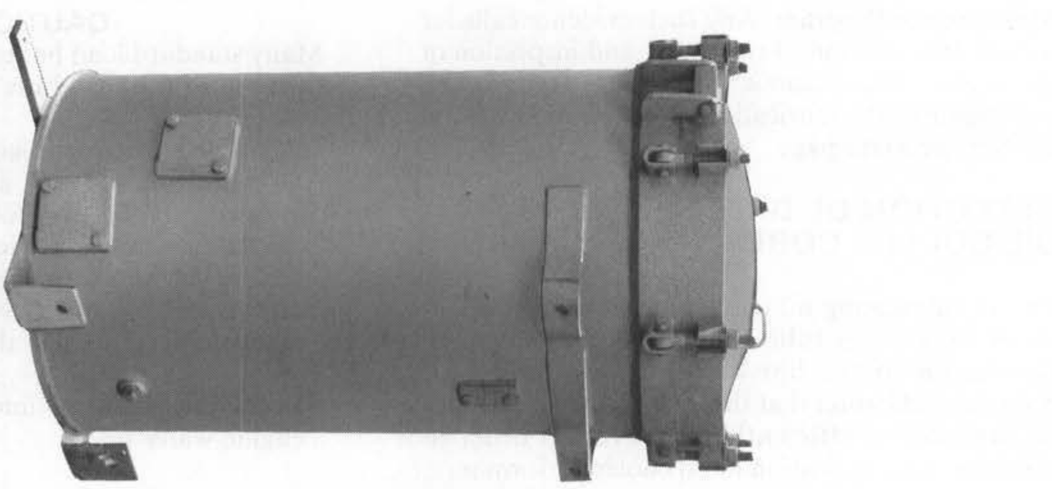
Oil filter elements, Fig. 2-5, should be replaced with new elements at the intervals stipulated in the Scheduled Maintenance Program. Use only approved element combinations as indicated on the Service Data page.

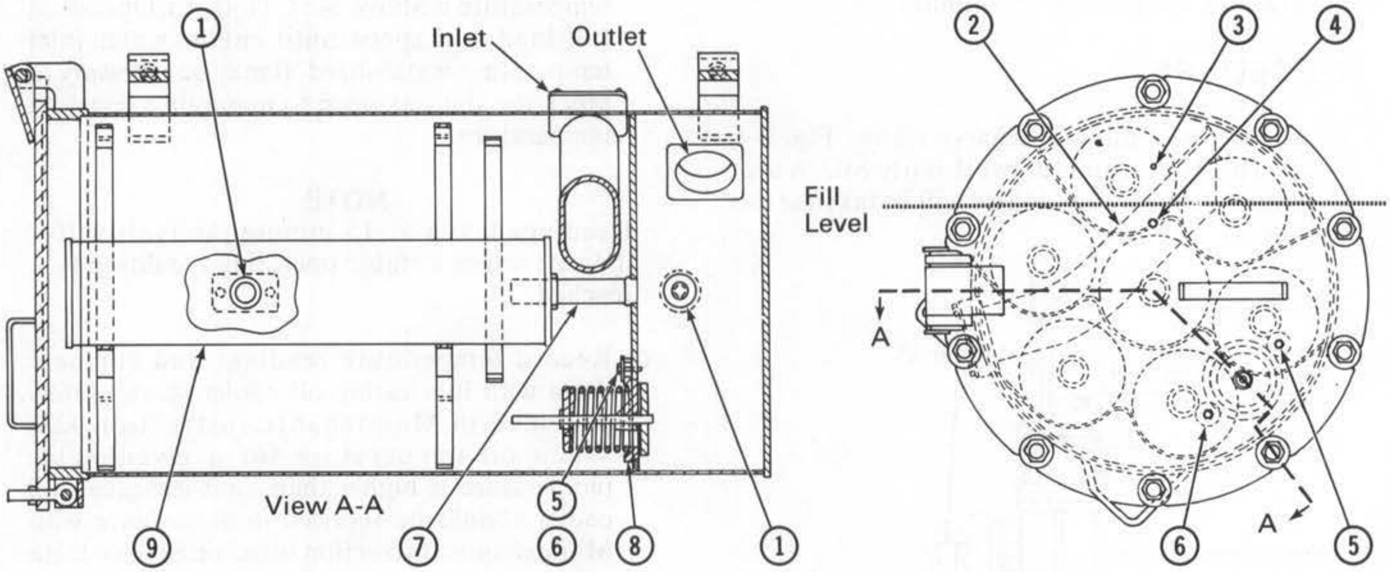
FILTER ELEMENT CHANGE PROCEDURE

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





1. Drain
2. Fill Standpipe
3. Pressure Test Fitting
4. Sight Glass
5. Bolt 3/8"-16 Hex
6. Washer
7. Filter Element Standpipe
8. Relief Valve Assembly
9. Filter Element

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

filter housing into the engine sump. It is not necessary to move the valve handle that drains the oil strainer housing.

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

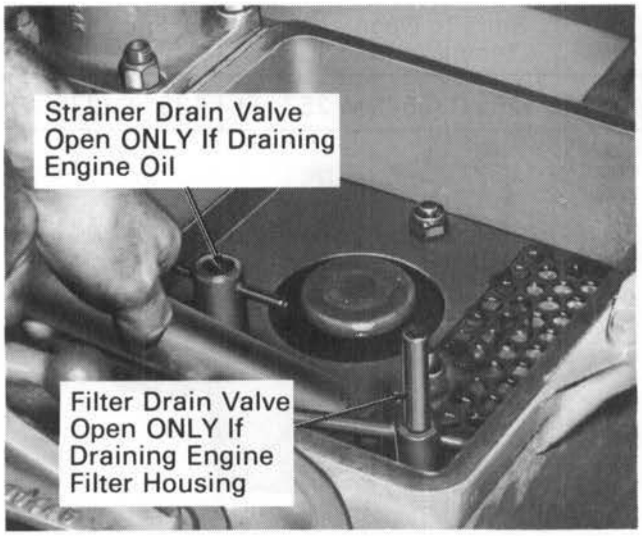


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Fig.2-6 - Filling Or Adding Oil To System

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 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 complement 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, to 82 N·m (60 ft-lbs.)

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.

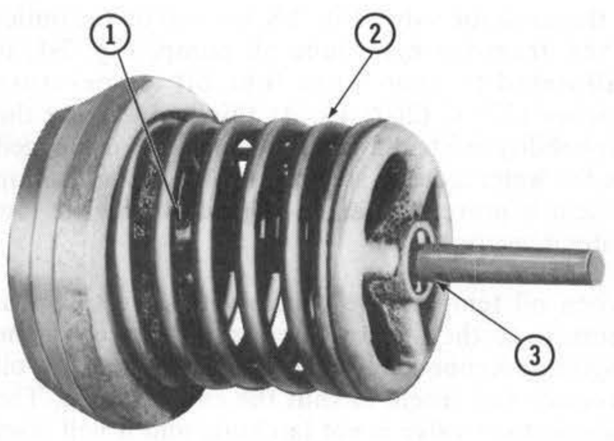
15. Before starting the engine, check the oil level, using the dipstick. Oil level should be above the full mark on the dipstick with engine shut down. Start the engine and allow it to run at idle speed. Check the oil level at the dipstick. Add oil if necessary. See Fig. 2-6.

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 Lube Oil Filter Maintenance Instruction listed on the Service Data page.



1. Valve Guide
2. Valve Spring
3. Poppet Valve And Stem

28999

Fig.2-7 - Filter Bypass Relief Assembly

BYPASS VALVE CHANGE PROCEDURE

1. After the oil has been drained from the filter housing, remove the hold-down bolts from the bypass valve. The valve may be removed by applying a length of pipe to the valve stem.

NOTE

The use of socket wrench extensions and an appropriate length of pipe that will slip over the protruding 13 mm (1/2″) diameter valve stem is recommended for ease of removal.

2. Reinstall qualified bypass valve assembly in filter (or replace, if necessary). Properly seat the assembly and tighten the hold-down bolts to 33 N·m (24 ft-lbs) torque.

   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.

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

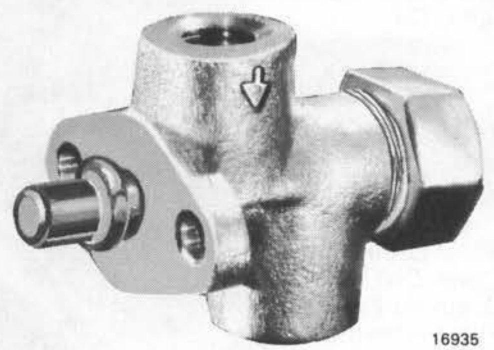
A thermostatic valve, Fig. 2-8, located on the outlet elbow from the main lube oil pump, Fig. 2-1, is calibrated to open when lube oil temperature reaches 127° C (260° F). At this temperature the probability exists that the lube oil cooler is plugged on the water side, or steam pressure in the cooling 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.

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 before attempting to restart the engine. Also check

Start To Open Temperature	Full Open Temperature
122° to 125° C (252° to 257° F)	135° C (275° F)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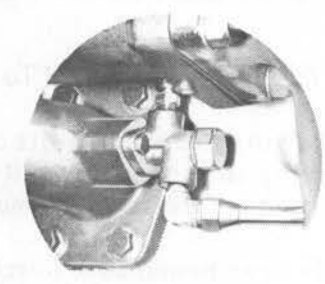
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Fig.2-8 – Hot Oil Detector Thermostatic Valve

engine water temperature. Do not add cold water to an overheated engine.

HOT OIL DETECTOR QUALIFICATION TEST

Remove detector from engine and test as follows:

1. Connect air lines to and from valve so that flow is in direction of arrow.
2. Place valve in an agitated liquid bath so that half the valve body is immersed. (Dow glycerine, USP Grade 96% recommended.)
3. Heat the bath. When the bath reaches 113° C (235° F), the rate of rise must not exceed 0.6° C (1° F) per minute.
4. Apply 345 kPa (50 psi) air pressure and observe for leaks. Leaks between the valve body and cap are not permissible.
5. At 121° C (250° F) the maximum rate of leakage is 10 SCFH. (Standard cubic feet of air per hour.)

6. Remove air flow to avoid chilling.

7. Raise temperature to 126° C (258° F).

8. Turn on air. Minimum rate of flow to be 20 SCFH.

QUICK DISCONNECT FITTING

The lube oil filter tank cover is equipped with a male quick disconnect fitting, Fig. 2-9, to accept a female coupler. The fitting facilitates application of a pressure gauge to monitor filter tank pressure, which indicates the condition of the filter elements. Part numbers for the quick disconnect fittings are provided in the Service Data pages at the end of this section.

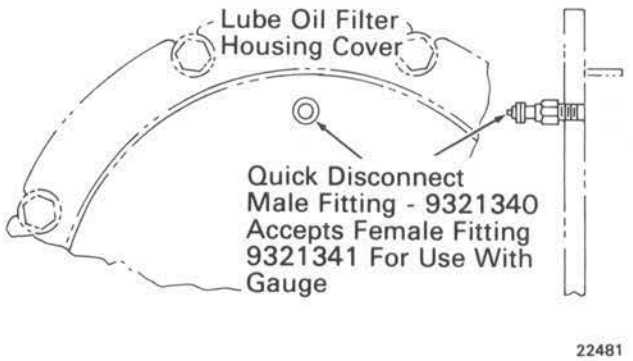


Fig.2-9 – Lube Oil Filter Quick Disconnect Fitting Application

Periodic pressure readings will help prevent undue engine wear by alerting the maintenance crew when filter element plugging and bypass are about to occur. If a locomotive has a short filter element life, there may be water leaks or a heavy dirt load. The engine probably needs maintenance.

Lube oil filter pressure checks are to be made *weekly or oftener;* the engine may be loaded or unloaded. However, the best time to perform these tests is soon after a unit comes in from a run, thereby ensuring an adequately high degree of lube oil temperature. (Readings must be taken when lube oil temperature is at least 66° C [150° F.]) Since there is no convenient gauge to indicate lube oil temperature, perform test when *water* temperature is a minimum of 66° C (150° F.)

Filter elements must be renewed if filter tank pressure reaches:

172 kPa (25 psi) at throttle position No. 8;
48 kPa (7 psi) at normal idle engine speed.

Readings taken at throttle No. 8 engine speed are the most reliable. Therefore, if a marginal reading is obtained at idle engine speed, verify filter element condition at No. 8 engine speed.

CENTER BEARING LUBRICATION

Two liters (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 TIME OF TRUCKING

Remove oiler pipe plugs, Fig. 2-10, before trucking or untrucking the locomotive. Apply oil as follows:

If the bearing is dry, add 1.7 liters (3-1/2 pints) of oil before trucking, and add another 1.7 liters (3-1/2 pints) after the unit is trucked.

Reapply oiler pipe plugs after unit is trucked and oiled.

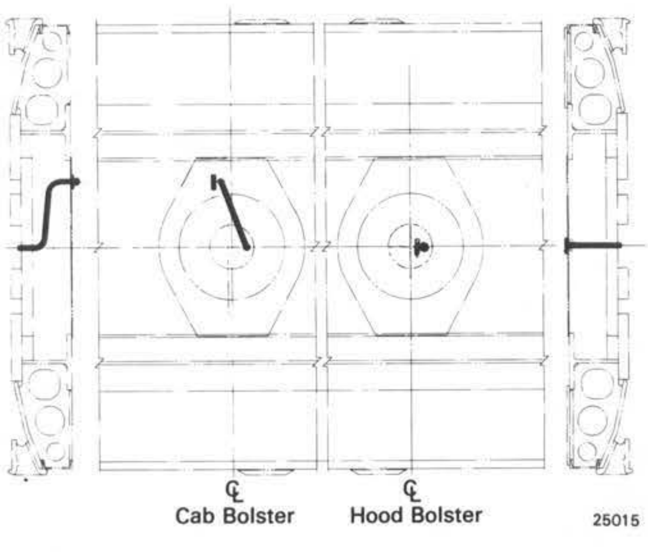


Fig.2-10 – Center Bearing Oiler Pipe Location

SERVICE DATA

LUBRICATING OIL SYSTEM

REFERENCES

Lube Oil Filters	M.I. 926
Lube Oil Cooler	M.I. 927
Lube Oil Cooler Service Limits	M.I. 928
Lubricating Oil For Domestic Locomotive Engines	M.I. 1752

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

	Part No.
Pleated Cotton-Paper Elements (7 per housing)	8345482

NOTE

Filter changeout recommendation will be found on the applicable Scheduled Maintenance Program.

Filter Housing Cover O-Ring	9544431
Filter Housing Cover Gasket	8268756
Bypass Valve Assembly, 276 kPa (40 psi)	8320705
Bypass Valve Port Cover Gasket	8296030
Internal Bypass Valve Assembly, 40 psi	9536955
Hot Oil Detector	8427032
Hot Oil Detector Gasket	8430611

NOTE

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

Quick Disconnect Fitting	9321340
Female Coupling	9321341
Kit; Lube Oil Tank Pressure Test (0-100 psi gauge, hose and female coupling)	9325061

SPECIFICATIONS

Weight required to compress filter bypass valve spring to a height of 92 mm (3-5/8") must not be less than 191 kg (420 lbs.) or more than 227 kg (500 lbs.).

Lube Oil System Capacity	920 litres (243 U.S. Gal.)

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

SECTION 3

COOLING SYSTEM

DESCRIPTION

The cooling system is pressurized to provide uniform cooling throughout the operating range of the diesel engine. A pictorial diagram of the system is shown in Fig. 3-1. Coolant is pumped by the engine mounted pump 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 pump 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.

A two position dual valve (two valves, single operating handle) is located in the cab heater supply and return lines. When the operating handle is positioned parallel with the heater supply pipes, engine water is directed to heaters. When the handle is positioned perpendicular to the heater supply pipes, engine water is not supplied to the heaters and water remaining in the heater system is drained. This valve, along with an engine and compressor drain valve are located at the sump between the engine and engine equipment rack.

To drain the entire cooling system, open system drain valve, and dual valve in the heater supply and return lines. If it is necessary to independently drain the heaters, open the dual valve only, leaving the system drain valve closed.

CAUTION

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

On units equipped with heater shutoff valves located in the cab, the valves must be opened during heater draining.

FAN AND RADIATOR ARRANGEMENT

As shown in Fig. 3-2, the cooling system radiators are assembled in a hatch near 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 are located in the roof above the radiators. Dividers are used to form a separate exhaust chamber for each fan, thus controlling distribution of cooling air and to prevent the fans from working against each other. The fans are numbered 1, 2, and 3 from front to rear, with the No. 1 fan nearest the short hood end. Fan inlet grills and shutters are located adjacent to the radiators.

Each radiator bank consists of 6-row cores in a parallel arrangement. A bypass is provided between the radiator input lines and the discharge lines to reduce the velocity of fluid in the radiator tubes. Coolant from the engine is piped to the headers of each bank. The paralleled radiators discharge coolant to the oil cooler, and from there to the water pumps and back through the engine.

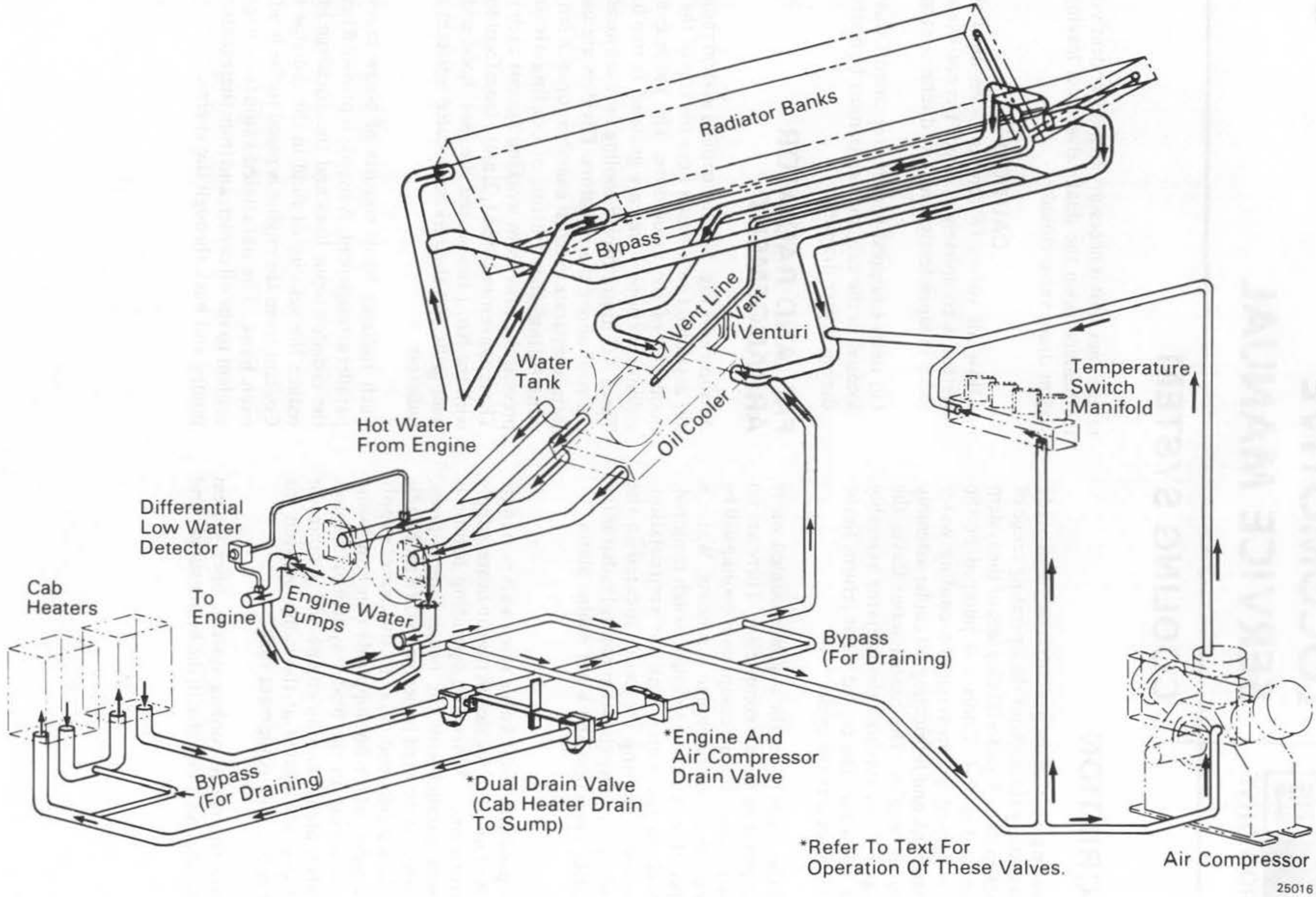


Fig.3-1 – Cooling System Pictorial Diagram

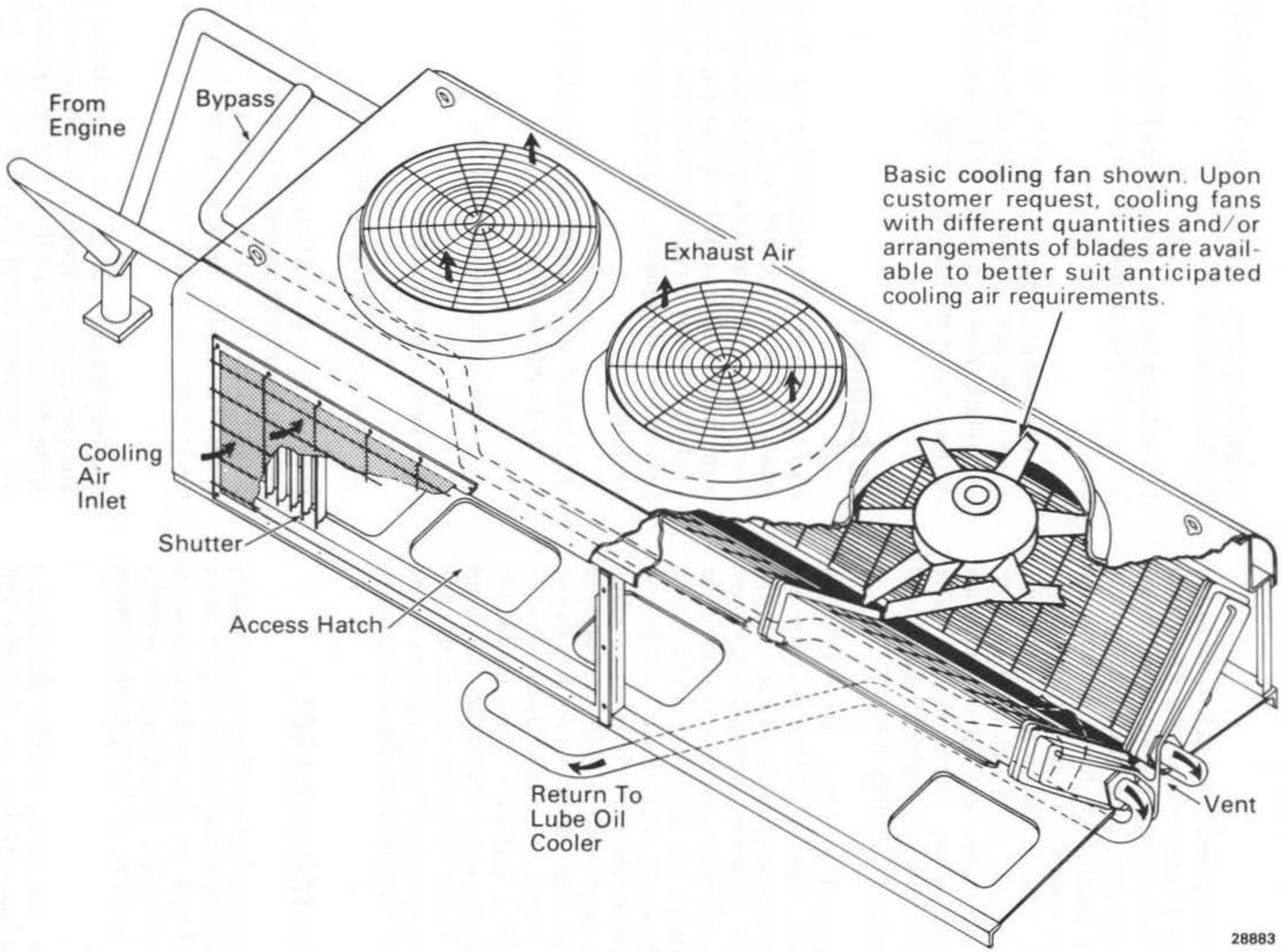


Fig.3-2 – Radiator Cooling Fan And Shutter Arrangement

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. 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 fans and shutters, and thus of the water temperature, is entirely automatic.

Temperature control switches, Fig. 3-5, 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. 3-5. When energized, they electrically connect their respective AC cooling fans to the alternating current supply from the alternator to run the fans.

FAN AND SHUTTER CONTROL

When the fan contactors are de-energized, normally closed interlocks energize the shutter magnet valve MV-SH, Figs. 3-3 and 3-4. 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.

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.

TB picks up next. This energizes FC2, which starts the No. 2 cooling fan.

TC picks up last. This energizes FC3, which starts fan No. 3. 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 switches are listed in the locomotive wiring running list.

AC CABINET

Fan contactors are mounted in the AC cabinet located at the equipment rack in the engineroom. The contactors operate to supply 3-phase AC power from the D14 alternator to the cooling fan motors. Each fan motor circuit is protected by two 200 ampere fuses designed to open and protect against the following:

1. Locked motor rotor due to bearing seizure or ice-bound fan blades.
2. Single phase motor windings.
3. Faulty fan contactors.
4. Faulty electrical plugs or cables.

The fuses are a bolted lug type with fusible elements within a reinforced melamine cylinder. The cylinder is sand filled to absorb arc energy when the fuse opens. The fusible elements cannot be renewed. A blown fuse is to be discarded.

A spring loaded indicator is connected in parallel with the main fuse element. When the main element opens, the indicator will also open, and a small rod will protrude from the end of the indicator. Whenever open fuses are indicated, the fan motor and circuits are to be inspected before new fuses are installed.

If inspection reveals a single blown fuse, always renew BOTH fuses in the motor circuit. This is

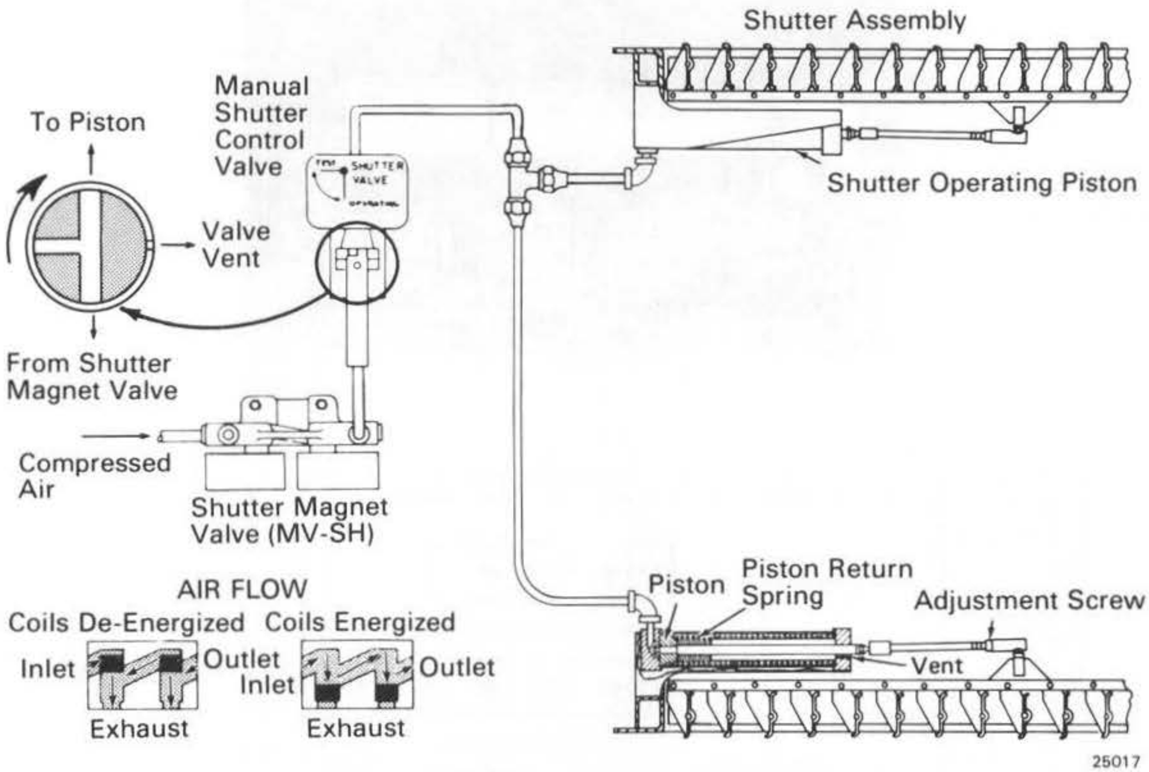


Fig.3-3 – Shutter Operating Piston Arrangement

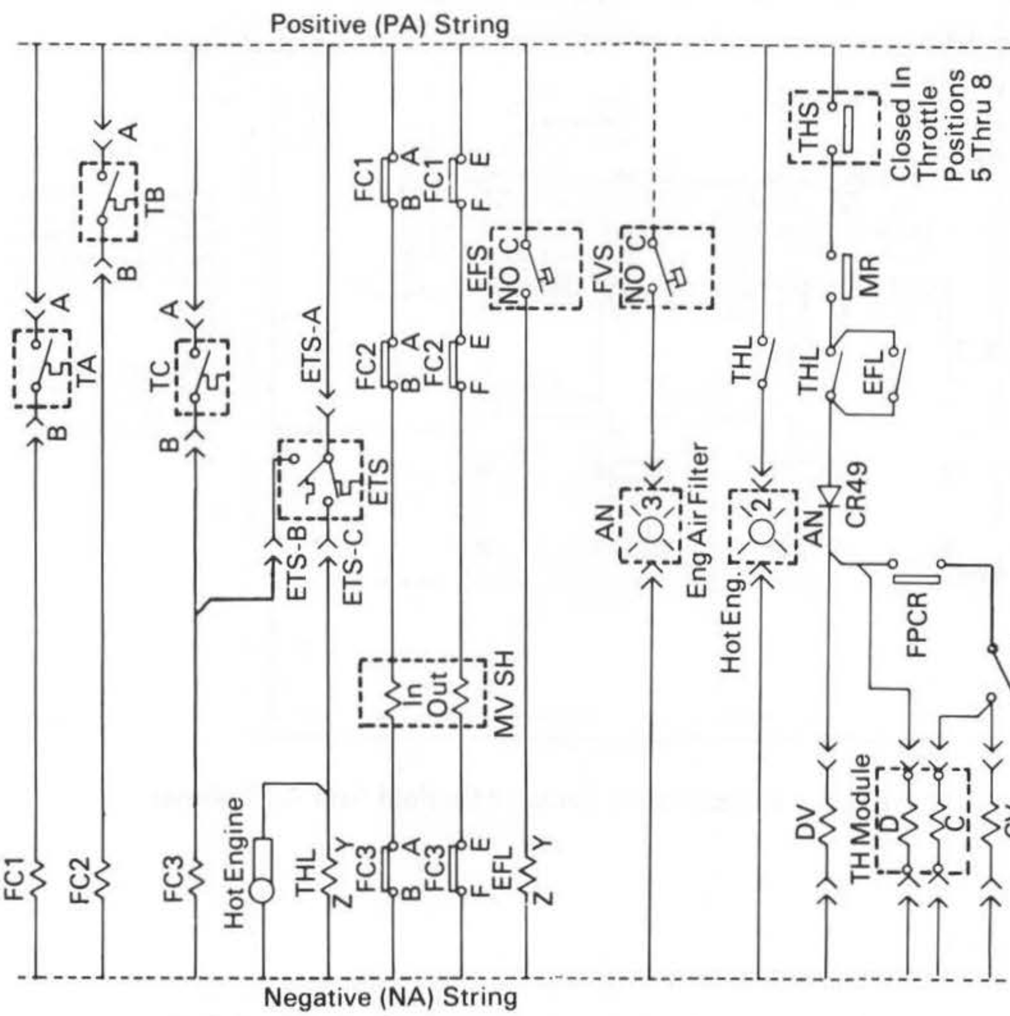
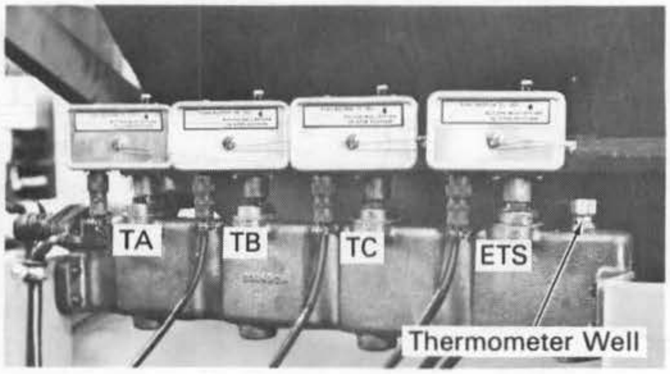


Fig.3-4 – Engine Temperature Control Circuit Diagram



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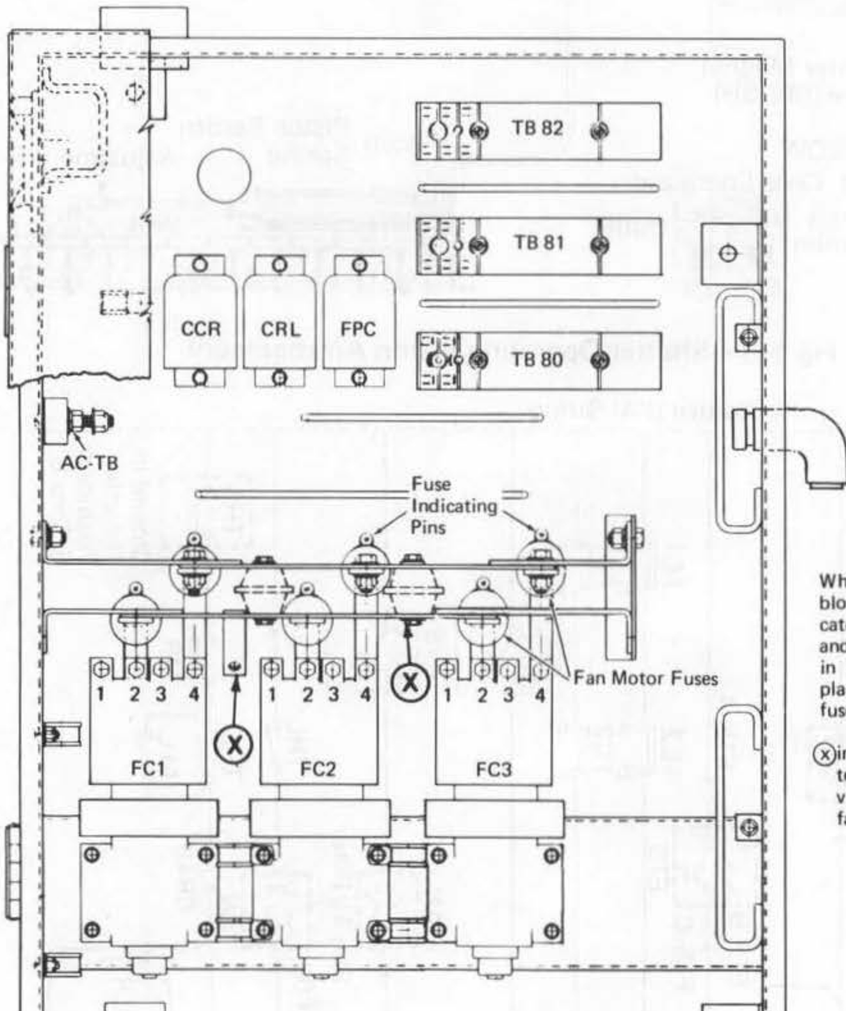


CAUTION

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

(x) indicates AC cable terminals to be reversed for reverse fan operation.

23901

Fig.3-5 – Temperature Switch Manifold And AC Cabinet required because the second fuse, while perhaps good in appearance, will in all probability be degraded and will open the next time the fan is called upon to start.

Whenever fuses are removed during maintenance, always remove both fuses in the motor circuit, so that the motor is completely isolated.

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 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 test 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 test position. 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 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 operating and test positions, then return the valve to the operating position. The shutters will close.

ENGINE TEMPERATURE SWITCH

An engine temperature switch ETS, located in the temperature switch manifold, senses the water temperature into the engine. ETS switch picks up when water temperature at the inlet to the engine water pumps approaches the boiling point of water under normal system pressurization.

When the ETS 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 switch also energizes a throttle limit relay THL and provides a backup signal to energize FC3. THL 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. 3-5. 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.

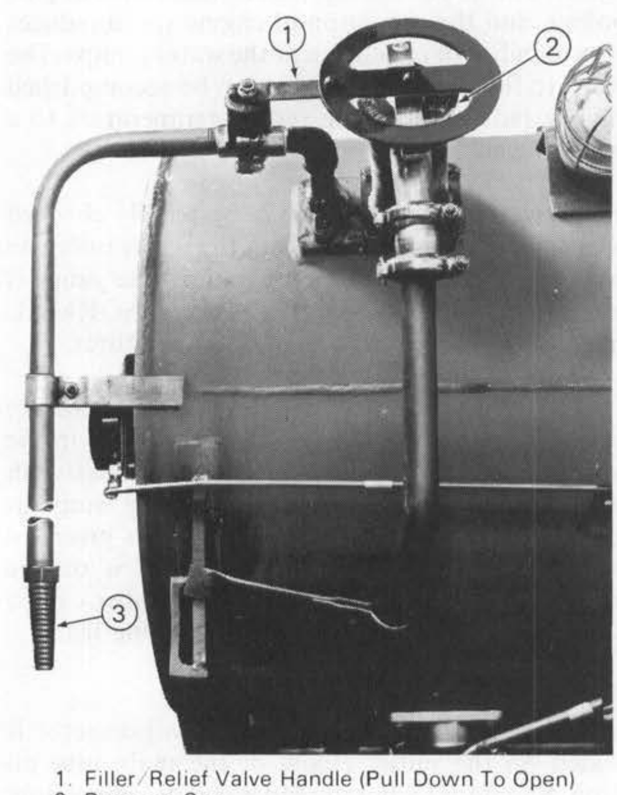
The thermostatic valve will reset automatically after the hot oil cools, but it is recommended that no attempt be made to start the engine after a hot oil shutdown until a thorough engine inspection is made by qualified personnel.

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. 3-6, 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.



1. Filler/Relief Valve Handle (Pull Down To Open)
2. Pressure Cap
3. Filler Pipe Connector

27509

Fig.3-6 – Cooling System Pressure Cap And Filler/Relief Arrangement

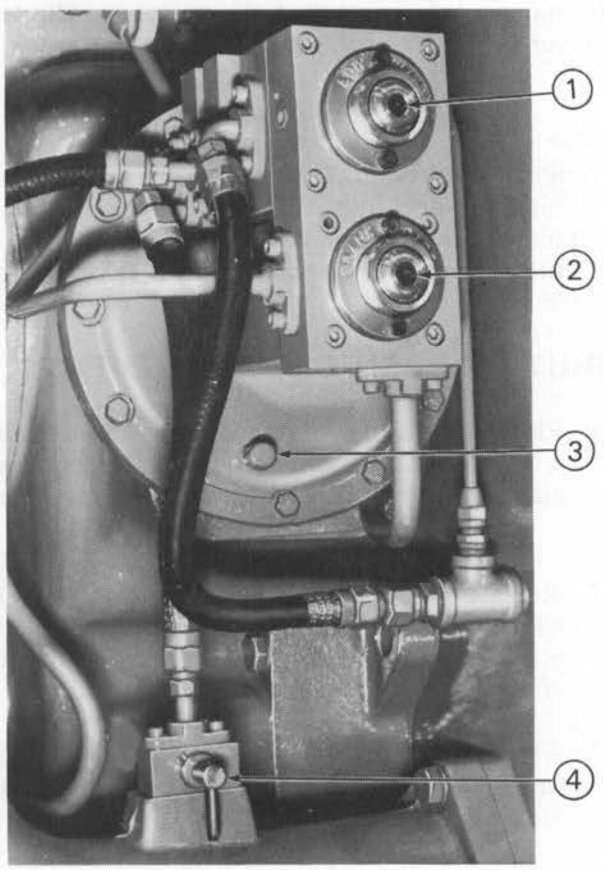
The pressure cap is equipped with a handle that facilitates application and removal, but more importantly it interlocks with the fill/relief valve handle. This ensures that system pressure is released through the fill/relief pipe before the cap can be loosened.

WARNING

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

LOW WATER SHUTDOWN

A low water detecting device, Fig. 3-7, balances water pump input and discharge differential pressure against air box pressure. When the differential pressure across the water pump becomes less than the air box pressure, the device dumps oil from the governor supply line, causing an engine shutdown. When a low water shutdown occurs, the low water reset button pops out, the low oil plunger on the governor protrudes, and the governor shutdown light on the engine control panel comes on.



1. Low Water Reset
2. Crankcase Pressure Reset
3. Vent And Test Fitting
4. Test Cock

27954

Fig.3-7 – Differential Low Water And Crankcase (Oil Pan) Pressure Detector

Since the detector compares pump differential with air box pressure, it cannot be tested on a non-operating engine. The engine must be running, and the cooling system vented in order to latch the low water reset button.

Depress the low water reset button during engine start allowing enough time for the water pumps to draw from the makeup tank and distribute to the radiators for proper circulation. Tripping at engine start is not an indication that the device is defective. Once water pump pressures have been established, it is merely necessary to reset the device within about 50 seconds after trip during starting. If the device is difficult to reset, operate the injector rack manual control lever momentarily to speed up the engine, and then press the reset button.

TESTING FOR LOW WATER SHUTDOWN

Operation of the low water shutdown device, Fig. 3-7, 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 vent and test opening of the detector and applying suction to trip the lower button.

CAUTION

Diaphragm can be damaged by applying a positive pressure or excessive suction at the vent tube.

AUTOMATIC COOLING WATER DRAIN SYSTEM (SPECIAL EXTRA)

The automatic cooling water drain system provides protection against cooling system freeze-up if an engine has shut down and has not been manually drained. This system consists of two major components, a solenoid operated automatic drain valve, and the external electrical control circuitry.

A bi-metallic sensor mounted in the drain valve body is designed to activate the automatic drain when descending coolant temperature reaches 7° C (45° F). A cold water fill switch is provided to electrically override the automatic drain valve (close it), for refilling a drained engine or to facilitate cold water filling. The system circuitry is automatically reset when the engine is cranked.

OPERATING WATER LEVEL

An operating water level instruction plate, Fig. 3-8, 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.

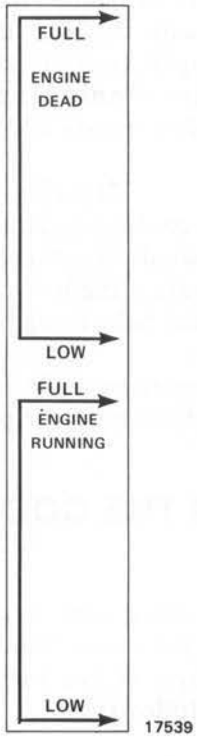


Fig.3-8 – Typical Water Level Instruction Plate

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 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 fill/relief valve handle until the air stops blowing. The pressure cap cannot be removed without hitting the fill/relief valve handle. When adding water to the system through the filler pipe connector, the fill/relief valve handle 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 fill/relief valve open, 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 properly positioned.

1. Cab heater supply and return valve in drain (handle vertical) position.
2. Engine and Air Compressor drain valve.

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

3. Preheater water supply open (located at equipment rack, if so equipped).
4. Preheater water return open (located at equipment rack, if so equipped).

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. Place cab heater supply and return valve in drain (handle vertical) position.
2. Engine and air compressor 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).

TESTING AUTOMATIC DRAIN VALVE AND SYSTEM OPERATION

To verify operation of the Auto-Drain Valve *only*, perform the following procedure:

1. Shut engine down (if running).
2. If necessary, close automatic cooling system drain circuit breaker and crank engine to reset system.
3. Manually operate test switch mounted on auto-drain valve.

NOTE

Auto-drain valve should immediately activate causing cooling water to rapidly drain out (if cooling system has water in it). If cooling system has been drained, a loud sound will signify proper operation of the auto-drain valve.

Releasing of the test switch should cause the auto-drain valve to immediately terminate draining (or generate a sound signifying closing action in the case of a drained unit). Observe the drain port, within a few seconds no water should be noted.

To verify operation of the Automatic Cooling Water Drain *System*, perform the following procedure:

1. Shut engine down (if running).
2. If necessary, close automatic cooling system drain circuit breaker and crank engine to reset system.
3. Remove retaining clip over auto-drain thermostat and swing thermostat out of well (do not disconnect electrically).
4. Place metal base of thermostat in a pan of water chilled to 4.4° C ± 1.1° C (40° F ± 2° F).
5. Within a few seconds, the auto-drain valve should activate and begin to drain the cooling system.
6. To terminate the draining of the cooling system, push the cold water fill switch mounted on the side of the A.C. cabinet.

NOTE

This step also checks the cold water fill circuit.

7. When the cold water fill switch is pressed, an alarm should sound in the cab and the WATER DRAIN DISABLED light should be energized.
8. To silence the alarm bell and reset the automatic cooling water drain system, restart the engine.
9. With the engine idling, push the cold water fill switch; the alarm and light should once again come on.
10. Attempt to throttle out the locomotive; it should remain in idle regardless of throttle position.
11. Shut engine down, reinstall thermostat in auto-drain valve, and re-energize starting motors (or start engine) to again re-arm the cooling water drain system.

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 TEMPERATURE SWITCHES

It is recommended that a routine check of temperature switch operation be made at the intervals specified in the Scheduled Maintenance Program.

Pickup and dropout of temperature switches, Fig. 3-9, can be checked on the locomotive. The operating temperatures of TA, TB, TC and ETS are given in the Service Data, and on the switch nameplate. The Service Data page also contains special information concerning selection of replacement temperature switches and their part numbers. To test switches use the following procedure:

1. At the temperature control manifold, Fig. 3-5, fill the thermometer well with oil or water. Water temperature will be taken at this point.
2. Set up engine loading apparatus capable of taking full rated load of the locomotive. Refer to the Load Testing section of this manual for instructions covering the load testing setup.

Fig.3-9 – Typical Temperature Switch

CAUTION

Many standard load boxes are not of sufficient capacity to fully load the locomotive.

3. Insert a thermometer into the well.

4. Disable fans by disconnecting the feed wires to the fan contactor coils.

CAUTION

Do not remove feed wires from ETS to THL coil.

5. Connect a test lamp to each pair of disconnected leads. Switch is closed when test lamp comes on.

6. Operate the engine and apply load. Do not operate above throttle position 3 until water temperature is above 54° C (130° F). Increase engine speed and load to throttle position 8.

7. Temperature switches should close in TA, TB, TC, and ETS sequence. When ETS picks up an alarm will sound and engine speed and load will be reduced. Record temperature at pickup of each switch.

8. After alarm sounds, reconnect feed wires to coil of fan contactor FC3. The shutters will open when FC3 picks up.

9. When fan No. 3 reaches full speed reconnect feed wires to coil of FC2. When fan No. 2 reaches full speed reconnect FC1.

When temperature comes down and ETS drops out, engine speed and load will increase. Record ETS dropout temperature, then reduce throttle to Run 4 and place the generator field switch in the OFF position to drop load. Record engine water temperature as each fan contactor drops out.

NOTE

Multi-stage temperature switches and electronic temperature probes may be checked in a similar manner, however, variations of the above procedure will be necessary.

INDICATIONS OF FAULTY SWITCH OPERATION

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

2. Low oil shutdown due to hot engine oil. A fault exists in the cooling system and the ETS switch did not operate properly. Also check the low water detector for proper operation.

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 companion 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 companion alternator.

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 connected to the fan contactors in the AC cabinet. The leads are indicated on Fig. 3-5. Reversal of AC leads at the alternator terminal board is not recommended because the inertial filter blower in the central air compartment will also be reversed.

CAUTION

When using fan test pushbuttons on the temperature switches, be careful not to accidentally release a button during the starting surge of current and be sure to allow the fan to reach full speed before pressing another button.

After the AC leads are reversed fan operation can be controlled by pressing the test pushbuttons on the temperature switches. One fan must be working to ensure automatic opening of the radiator shutters, or the manual shutter control valve can be manipulated to hold the shutters open.

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

PRESSURE CAP AND FILLER NECK

The pressure cap and filler neck should be inspected, tested, and 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 AND REPLACEMENT

1. If the pressure cap bell housing or other metal surfaces are bent, replace the entire cap with a new cap, Fig. 3-10. Seal cooling system after filling if required by railroad rules.

Fig.3-10 – Cooling System Pressure Cap

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.

3. If seals are hardened or damaged, replace the cap with a new cap.

NOTE

Rebuild of pressure caps is not recommended.

Perform pressure test to qualify pressure cap and filler neck.

COOLING SYSTEM PRESSURE TEST

Male 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. 3-11, 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 345 kPa (50 psi).

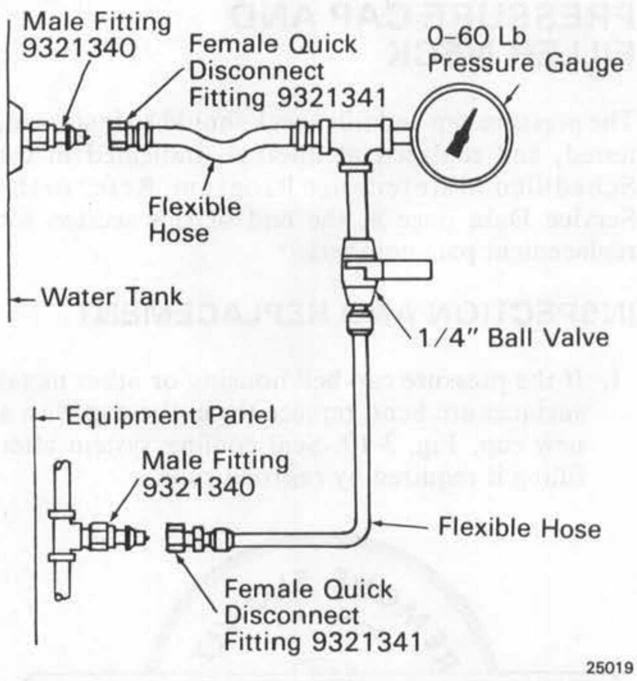


Fig.3-11 – Cooling System Pressure Test Apparatus

1. Using the testing apparatus, operate the ball valve to gradually pressurize the cooling system to about 83 kPa (12 psi). Tolerances for the 48 kPa (7 psi) pressure cap are as follows:

   Minimum Opening Pressure - 35 kPa (5 psi)

   Maximum Opening Pressure - 55 kPa (8 psi)

2. Close the ball valve and observe the pressure gauge. Pressure should drop slowly until the pressure cap closes. Pressure should then remain constant. Gauge pressure is the cap opening pressure.

3. If cap opening pressure is not within the allowable tolerance, replace the cap with a new cap and repeat the test.

4. If gauge pressure does not remain constant, the pressure falls below the allowable minimum, perform the following.

   a. At the discharge end of the water tank overflow pipe, place a container of water so that the water level is above the end of the pipe. Observe for air bubbles. The presence of air bubbles indicates a defective cap. Relieve system pressure, replace the cap with a new cap, and repeat the test.

   b. At intake end of the water fill pipe, place a container of water so that the water level is above the end of the pipe. Observe for air bubbles. The presence of air bubbles indicates a defective fill/relief valve. Relieve system pressure, replace the valve with a qualified valve, and repeat the test.

5. If Steps a and b above do not detect or eliminate leakage, as indicated by a continuing drop in gauge pressure, inspect the filler neck assembly and gasket, radiator, and cooling system piping connections.

SERVICE DATA
COOLING SYSTEM

REFERENCES

Temperature Control And Hot Engine Alarm Switches	M.I. 5511
Engine Water Treatment	M.I. 1748
Maintenance And Qualification Of Differential Low Water Detector	M.I. 260
Cooler, Lube Oil	M.I. 927
Water Cooling Radiators	M.I. 549
Locomotive Radiator Assembly And Installation	M.I. 550

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

	Part No.
Low Water Detector Qualification And Testing Apparatus	9339066
Temperature Switch-To-Manifold Gasket	8314926
Drain Cock 1/4″ NPT	8386667
Thermometer Well 1/4″ NPT	8268162
Water Tank Pressure Cap Assembly 48 kPa (7 psi) (Basic)	9323490
Filler Neck Assembly	9323491
Tank-To-Neck Gasket	8424925
Female Quick Disconnect Fitting	9321341

SPECIFICATIONS

Temperature Switch Settings

Switch	Pickup	Dropout	Part No. or	Part No.
TA	79° ± 0.8° C (174° ± 1-1/2° F)	71° ± 1° C (159° ± 2° F)	8424293	8424290
TB	83° ± 0.8° C (182° ± 1-1/2° F)	75° ± 1° C (167° ± 2° F)	8424294	8424291
TC	88° ± 0.8° C (190° ± 1-1/2° F)	79° ± 1° C (175° ± 2° F)	8424295	8424292
ETS	102° ± 0.8° C (215° ± 1-1/2° F)	96° ± 1° C (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 FAN CONTROL TEMPERATURE SWITCHES

Temperature switches are installed with a 4° C (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 1 829 m (6000 feet) or above, that 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 air system, the components of which are in or connected to a 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 drawn 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 inertial filter 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.

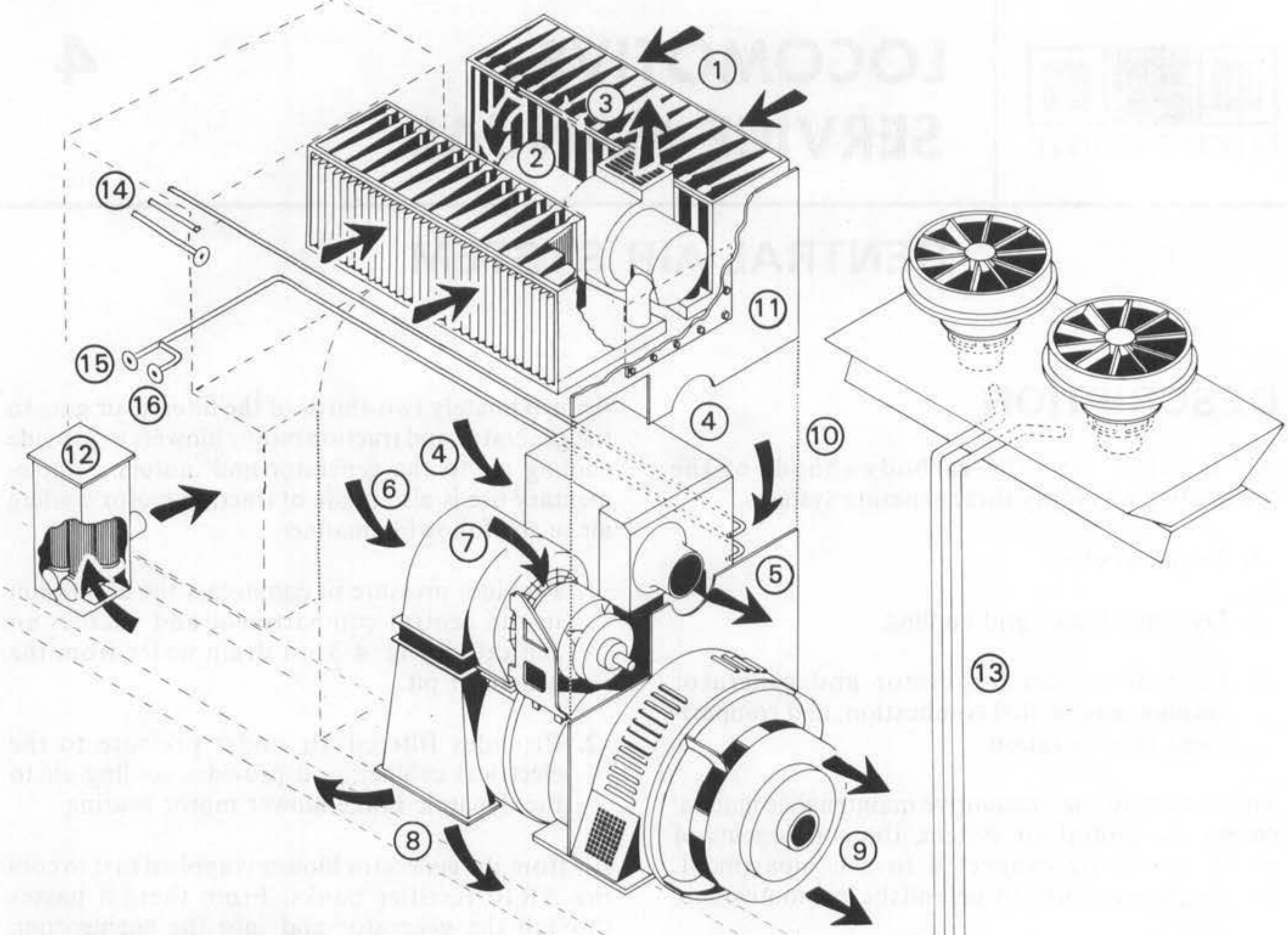
Air from the generator blower is applied first to cool the AR10 rectifier banks. From there it passes through the generator and into the engineroom. This creates a slight pressure which tends to keep dirt from entering the engineroom. This filtered air is used by the air compressor, reducing the load 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.
5. Generator pit aspirator not properly connected.



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 Bearings
14. Hose Stems For Manometer Connection
15. Filter Vacuum Switch FVS
16. Engine Filter Switch EFS

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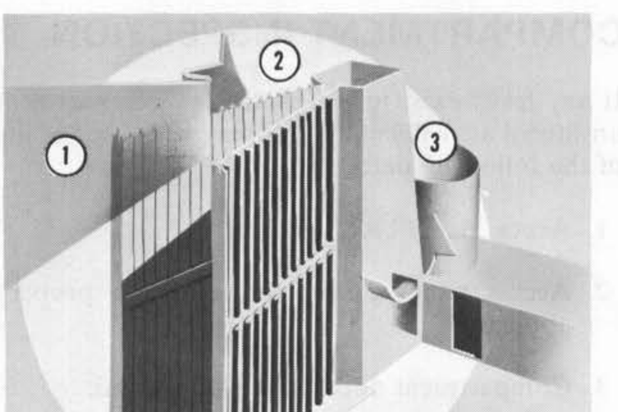
Fig.4-1 - Central Carbody Air System



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

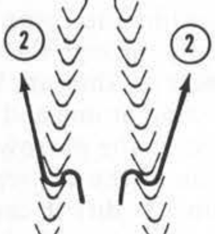

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Fig.4-2 - Inertial Air Filter Cell Diagram

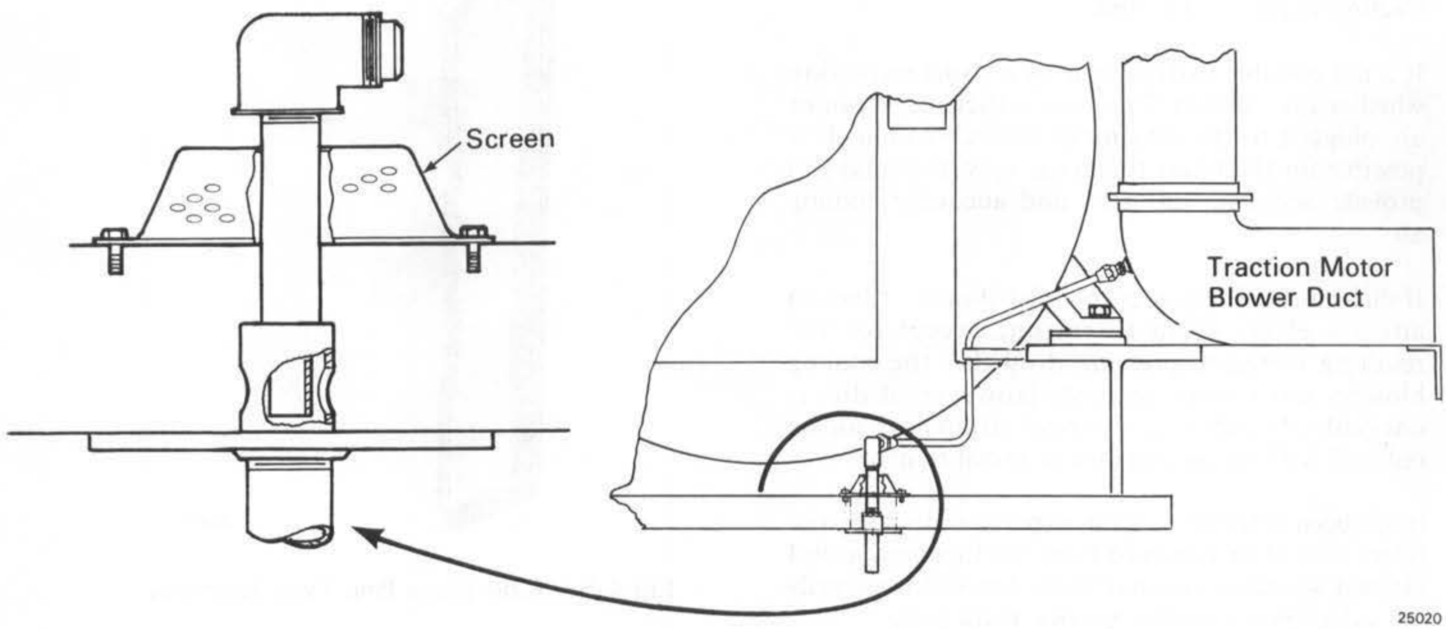

Fig.4-3 – Typical Generator Pit Aspirator

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.

INSPECTION OF INERTIAL FILTER BLOWER OPERATION

The efficiency of the inertial carbody air filters will be significantly reduced if the inertial filter blower is faulty. If the blower is not operating, unfiltered air will be drawn in through the 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 the engine filter may bring about the need for early filter maintenance.

Proper operation of the inertial filter 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 inertial filter 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 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.

When the pressure differential between ambient and the filter compartment reaches the maximum value stipulated on the Service Data page, cooling air flow is insufficient and damage to the main generator and traction motors is possible.

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 efficiency 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 INTAKE AIR FILTERS

Additional filtration is required for air used by the engine. Two types of engine intake filters are available. One uses disposable paper elements, Fig. 4-4, and one uses disposable bag type fiberglass elements, Fig. 4-5, Fiberglass and paper filter elements are not interchangeable due to differences in housing design. However, the housing for fiberglass elements is interchangeable with the housing for the paper filter elements and vice versa.

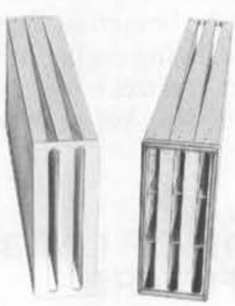

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Fig.4-4 - Pleated Paper Elements For Engine Air Filter

CHECKING DEPRESSION ACROSS INERTIAL PLUS ENGINE AIR FILTERS

Both types of engine air filter assemblies are equipped with safety pressure switches, Fig. 4-6, that sense the differential between ambient pressure 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.

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Fig.4-5 - Fiberglass Bag Type Element

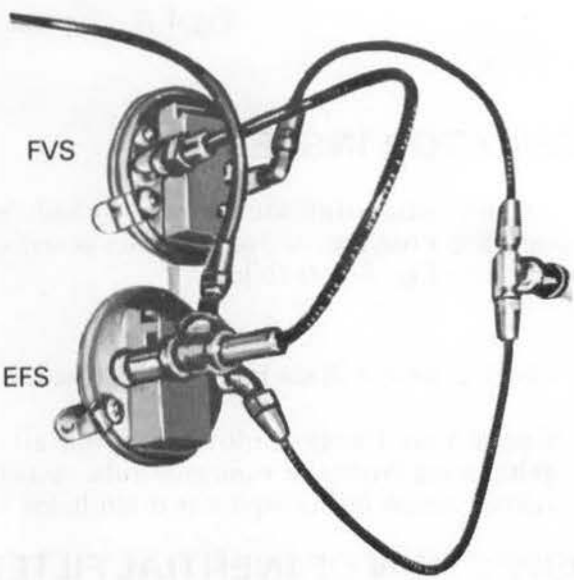

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Fig.4-6 - Typical Filter Safety Switches

As the filter elements become restricted, a depression is created within the filter housing. When the differential between the filter housing and ambient reaches 356 mm (14″ H_2O), the filter vacuum switch FVS will trip closed. FVS closing feeds a signal to the AN module. The ENGINE AIR FILTER light on the module will come on indicating excessive restriction of air to the engine. Filter elements should be checked at this time. Refer to Checking Filter Compartment Depression Section.

If the filter elements become so restricted that the differential reaches 610 mm (24″ H_2O) the engine filter switch EFS will trip closed. When EFS closes it energizes the filter latching relay EFL, located in the high voltage electrical cabinet. EFL relay contacts operate to limit engine speed and power. The GOVERNOR SHUTDOWN/6TH. THROT. light on the Engine Control Panel will come on and remain lit until latching relay is reset.

Hose stems located on the front of the electrical cabinet, Fig. 4-7, provide a convenient place to take manometer readings of pressure drops across the inertial air filters, the engine plus inertial air filters, and the electrical cabinet filter.

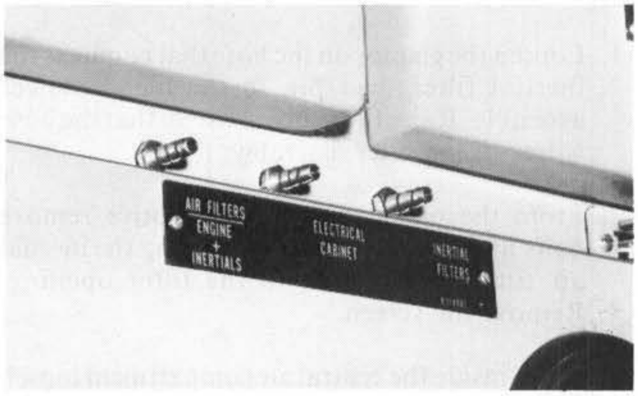

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Fig.4-7 - Hose Stems For Manometer Connections

FILTER ASSEMBLIES WITH PAPER ELEMENTS

When the ENGINE AIR FILTER light comes on, the filter depression should be measured and corrective action taken in accordance with the recommendation given on the Service Data page.

FILTER ASSEMBLIES WITH FIBERGLASS ELEMENTS

Fiberglass elements should be replaced every 90 days. These assemblies are equipped with a pressure switch arrangement only as a safety precaution.

CHECKING AIR FILTERS AND FILTER COMPARTMENT DEPRESSION - INERTIAL FILTERS

Filter compartment depression may be checked when operating conditions or the appearance of the filters seem to warrant such a check. Perform the following:

1. Connect a flexible tube to the INERTIAL FILTERS hose stem, Fig. 4-7. Connect the other end of the hose to the U-tube manometer. Vent other end of manometer to atmosphere.

2. Make necessary preparations to start engine. Start engine and allow it to idle until warm. 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, 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. When the filters are clean, the central air compartment depression should be near the value stipulated in the Service Data. Depression readings greater than the maximum stipulated are cause for immediate cleaning of the carbody inertial filters.

NOTE

If depression readings are taken on an annual basis, a reading of more than 89 mm (3.5″) H_2O 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 less than the minimum stipulated in the Service Data, and the inertial filter reading previously taken was satisfactory, the engine air filters should be checked for bypassing. Tears in the paper media, improper element seating, a loose connecting boot to the engine, and loose or broken pressure lines leading to the manometer hose stem or pressure switch are possible causes for such readings.

   If the reading is greater than the maximum stipulated in the Service Data, the engine air filters must be renewed.

NOTE

If, after a lengthy time of service, the pressure drop remains low, similar to new (clean) filters, or is decreasing rather than increasing, the air filters should be checked for bypassing.

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. If static pressure is less than the minimum stipulated in the Service Data page, renew all electrical cabinet filter elements.

CHECKING AFTERCOOLERS

The condition of each turbocharger aftercooler core can be checked by taking pressure differential readings across the aftercooler core. Use the following steps to check each aftercooler:

1. With engine shut down or at idle remove two aftercooler cover mounting bolts as shown in Fig. 4-8. Install two drilled bolts fitted with hose stems into the bolt holes.

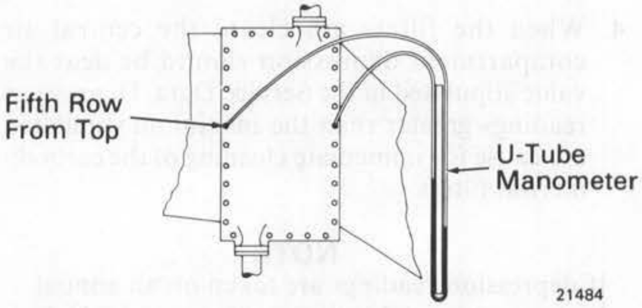


Fig.4-8 – Reading Differential Pressure On Aftercooler

WARNING

DO NOT remove hoses with engine at high speed. To prevent high pressure water discharge from manometer, DO NOT apply or remove hoses singly.

2. Connect a U-tube manometer with a hose attached to each end to the two hose stems previously applied.

3. Obtain a pressure differential reading with engine at full speed, with or without load. The maximum allowable pressure differential is listed in Service Data. If pressure differential is not within limits, refer to Engine Maintenance Manual for procedure to clean core.

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 causing unnecessary delay.

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

1. 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.

2. From the outside of the locomotive remove bolts and split lockwashers holding the inertial air filter inlet screen to the filter opening. Remove the screen.

3. 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.

4. 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.

5. Remove the bolts, Fig. 4-9, that hold the filter assembly and draw the assembly to the compartment opening.

6. Thread several lifting eyes into the filter assembly and attach a suitable lifting device to the filter assembly. Each filter assembly weighs approximately 272 kg (600 pounds).

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

8. 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.

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

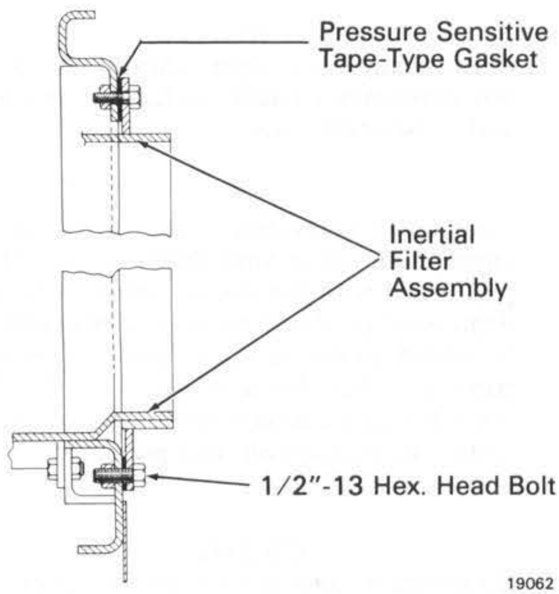


Fig.4-9 - Typical Inertial Filter Cross-Sectional View

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

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

12. 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.

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

CHECK AND ADJUSTMENT OF PRESSURE DIFFERENTIAL SWITCHES

Switches EFS and FVS sense pressure differential between two sources, therefore their calibration can be checked by either increasing the pressure at the "high" atmosphere port or by lowering the pressure at the "low" (engine air inlet) port.

SWITCH TRIP VALUES

Switch	Part No.	Pressure Differential At Trip Turbocharged Engine
FVS	8465021	356 ± 51 mm (14" ± 2") H_2O
EFS	8466230	610 ± 51 mm (24" ± 2") H_2O

1. Connect a voltmeter across the switch terminal; voltmeter positive at COMMON and negative at NORM. OPEN. With battery switch and local control circuit breaker closed, voltmeter should indicate 64 to 74 volts up scale.

NOTE

If voltmeter does not indicate up scale, recheck voltmeter connections to switch. Switch is defective if voltmeter does not indicate up scale in Step 1.

2. Connect a flexible tube to the atmospheric pressure reference port of the switch tested. "Tee" the tube to a U-tube manometer, Fig. 4-10.

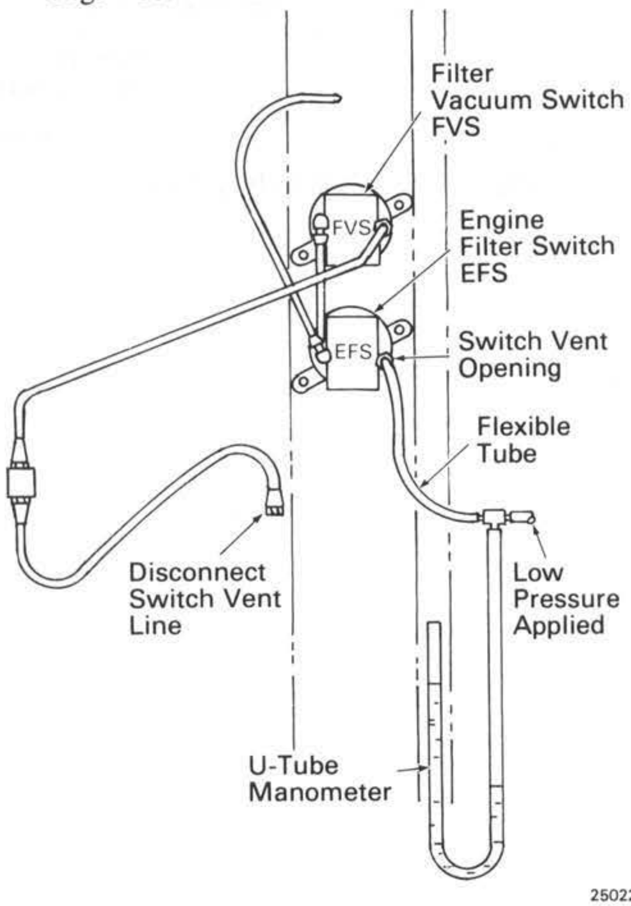


Fig.4-10 - Testing Filter Safety Switches

3. Apply low pressure air to the tube. This can be done by simply blowing into the tube.

4. Note manometer reading when voltmeter indication goes to zero (switch closes). If manometer reading is within limits shown in the Switch Trip Value chart, switch is satisfactory for continued use.

5. If the switch does not operate within the ± 51 mm (±2") H_2O limits, the switch should be

adjusted to within ±13 mm (±0.5″) H_2O. Turn the calibration screw, Fig. 4-11, clockwise to increase the trip value, or counterclockwise to decrease the trip value.

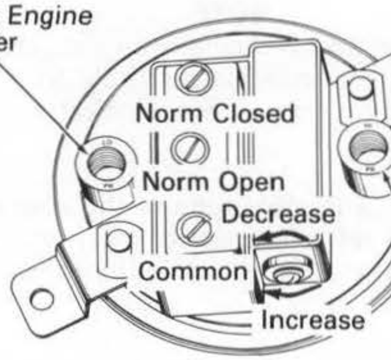


Fig.4-11 - Filter Safety Switch

NOTE

Occasionally a filter light indication is reported, but manometer checks indicate clean filters and satisfactory switches.

Tests on switches may be performed with the engine running or shut down. If the tests are performed with the engine running, the slight depression produced by the engine at idle must be added to the pressure found necessary to trip the switch. Refer to Checking Air Filter And Filter Compartment portion of this section to measure air inlet pressure to engine.

CAUTION

If a switch is removed from the locomotive and is to be calibrated at a bench, it is important to position the switch so that the diaphragm is in a vertical plane (which is the plane of mounting on a locomotive).

SERVICE DATA
CENTRAL AIR SYSTEM

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

	Part No.
Pressure Sensitive Backed Tape-Type Gasket	
1.6 mm x 19 mm (1/16″ x 3/4″) Rubber Cork	8135382
31 m (100 Ft) Length	8133198
1.6 mm 47.6 mm (1/16″ x 1-7/8″) Rubber Cork	8135383
31 m (100 Ft) Length	8133199
Rubber Weather Seal	8324100

SPECIFICATIONS

Engine Air Filter - Fiberglass Type	
Filter Element (4 Required)	8470903
Engine Air Filter - Pleated Paper Type (12 Required Per Assembly)	
Filter Element (Length 45″)	9093587
Electrical Cabinet Air Filter	
Pleated Cotton - Paper Elements (4 Per Housing)	8345482
(These elements also used as engine lube oil filters.)	
Inertial Filters (Central Air Compartment)	
Minimum Depression	51 mm (2″) H_2O
Maximum Depression	140 mm (5.5″) H_2O
Combination Engine Plus Inertial Filters	
Minimum Depression	102 mm (4″) H_2O
Maximum Depression	356 mm (14″) H_2O
High Voltage Electrical Cabinet Filter	
Minimum Static Pressure	38 mm (1.5″) H_2O
After Cooler Core	
Maximum Pressure Differential	254 mm (10″) H_2O
Filter Switches	
Filter Vacuum Switch - FVS	
356 ± 51 mm (14″ ± 2″) H_2O)	8465021
Engine Filter Switch - EFS	
610 ± 51 mm (24″ ± 2″) H_2O	8466230

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

COMPRESSED AIR SYSTEM

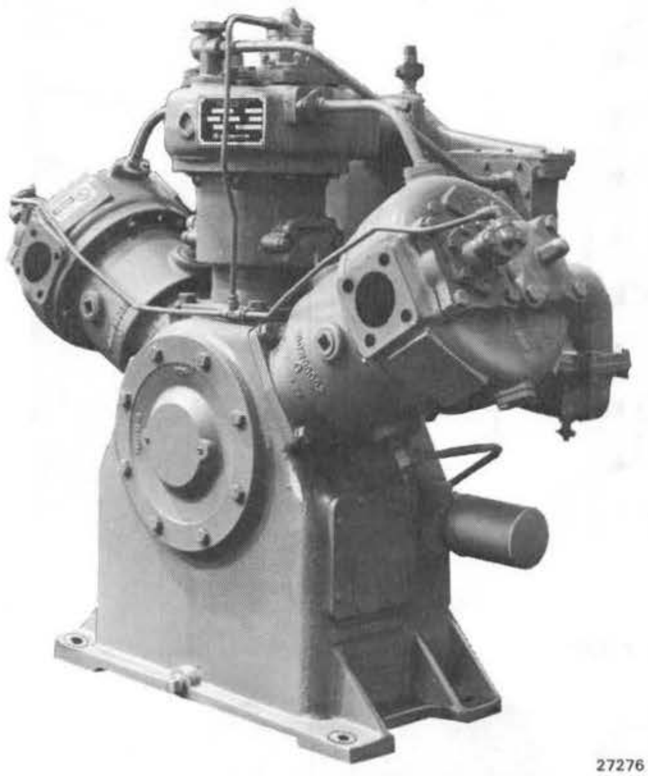
DESCRIPTION

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 COMPRESSOR

DESCRIPTION

Air is compressed by a deep sump 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.



27276

Fig.5-1 - Air Compressor

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, the oil pressure should be 124-172 kPa (18-25 psi). A plugged opening in the relief valve block is provided for an oil pressure gauge.

The basic 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.

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.

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.

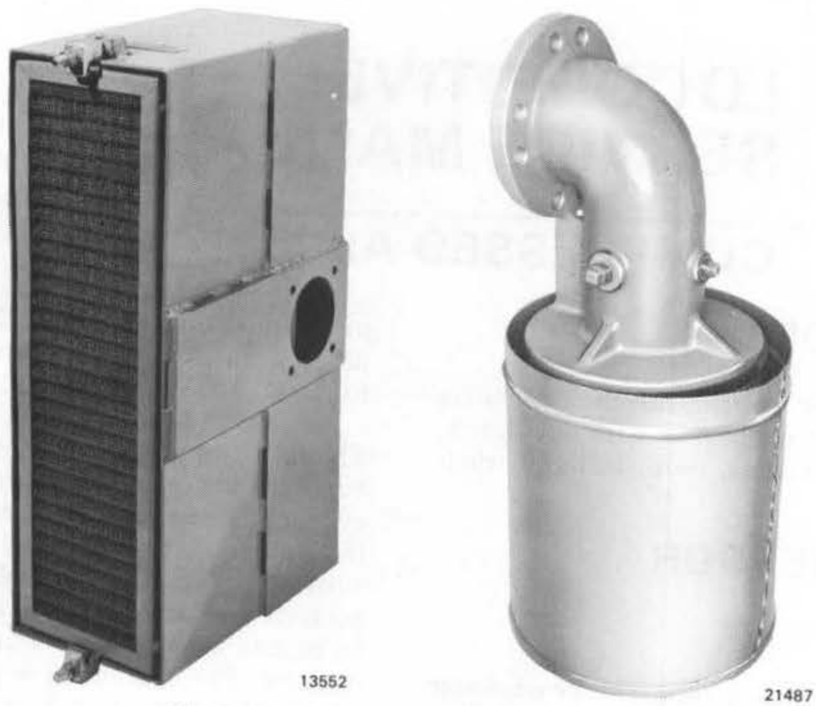
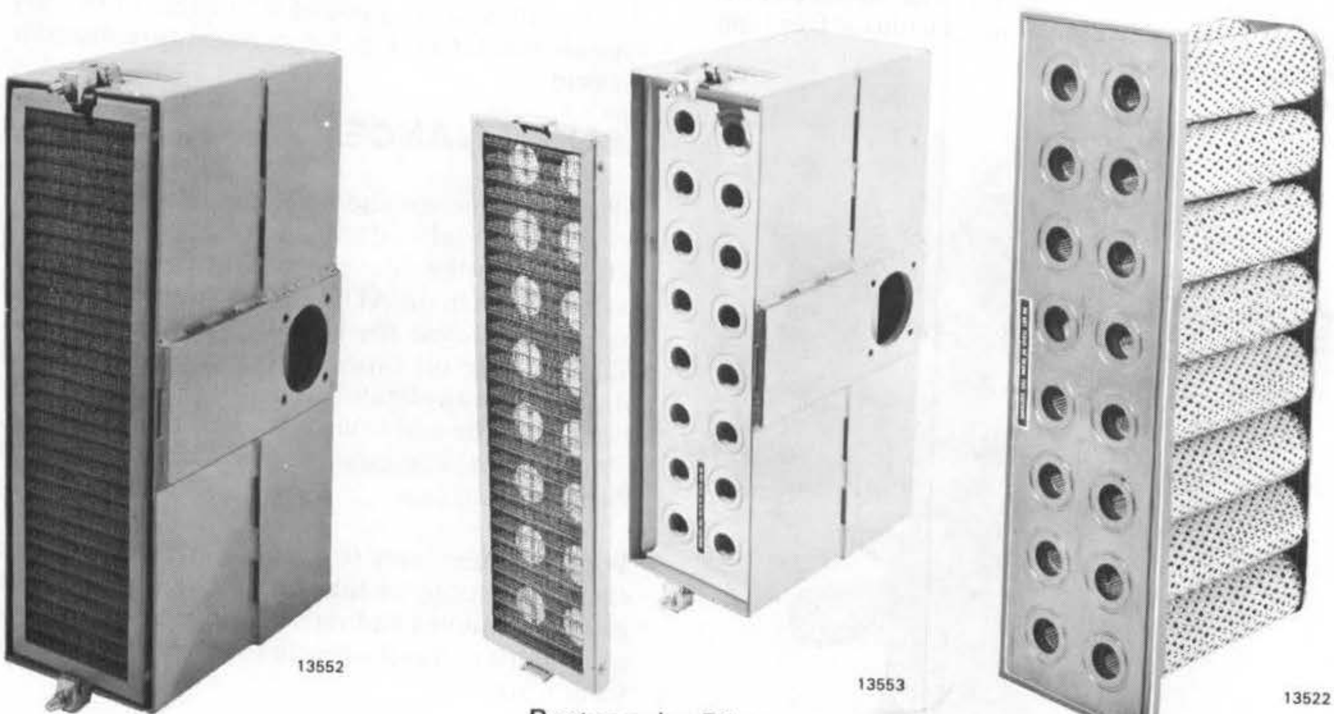


Fig.5-2 - Compressor Air Filters



Rectangular Filter

Cylindrical Filter

Fig.5-3 - Replacing Compressor Filter Element

To remove the element from the cylindrical shaped filter, remove bolt and sealing washer from top of filter housing. Remove housing and element. When reassembling, make certain that sealing washer is in good condition. Torque retaining bolt to 11 N·m (100 in. lbs.).

COMPRESSOR CONTROL SWITCH — CCS

DESCRIPTION

Since air compressor is directly connected to the engine, the compressor is in operation (although not always compressing air) whenever the engine is running. An unloader piston that cuts out the compressing action is provided in each high and low pressure cylinder head. The unloader pistons are actuated with main reservoir air pressure when the compressor control magnet valve MV-CC is energized, Fig. 5-4. MV-CC is energized by the compressor control switch CCS which senses main reservoir air pressure.

The unloader pistons cut out compressing action by blocking open the intake valves in the high and low pressure cylinders. When air pressure is removed, the unloader releases the intake valve and the compressor resumes pumping.

When the locomotive is equipped with 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 896 kPa (130 psi), Fig. 5-5. All units will continue to pump until main reservoir pressure in each and every unit reaches 965 kPa (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 1 000 kPa (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.

NOTE

Upon special customer request, pressure values controlled by CCS, may be slightly different than described. Consult specific locomotive wiring diagram if in doubt.

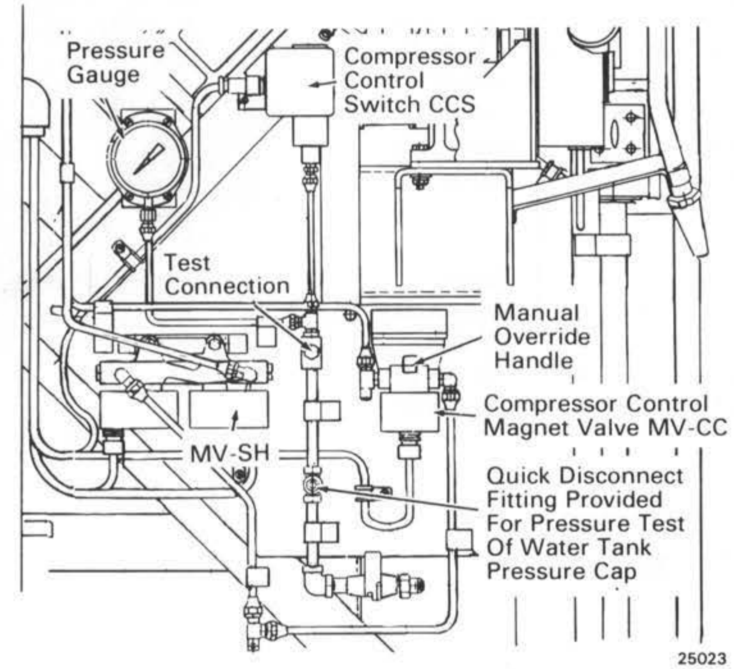


Fig.5-4 – Compressor Control Panel

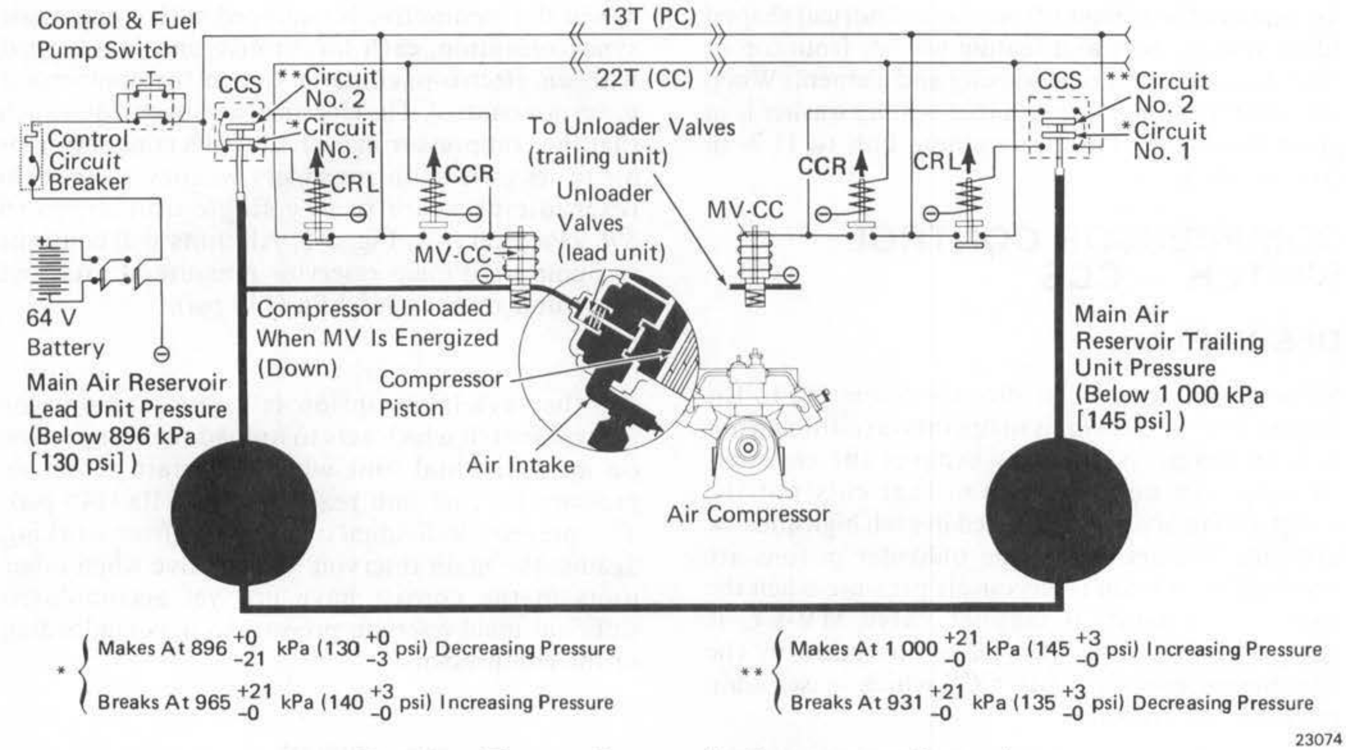
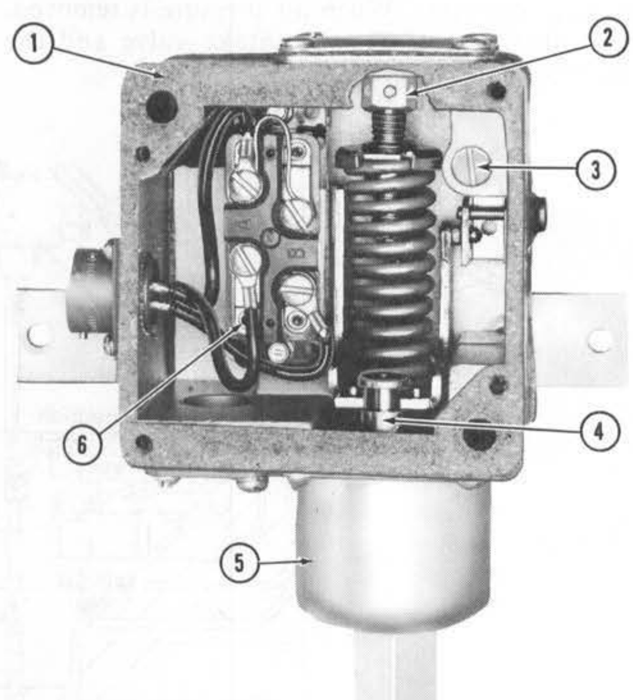


Fig.5-5 - Electro-Pneumatic Compressor Control

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.

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.



1. Gasket
2. Range Adjustment
3. Differential Adjusting Screw
4. Calibrating Nut
5. Bellows Assembly
6. Snap Switch

20556

Fig.5-6 - Compressor Control Switch, With Cover Removed

COMPRESSOR CONTROL MAGNET VALVE - MV-CC

DESCRIPTION

When the compressor control magnet valve, Fig. 5-5, 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 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.

COMPRESSED AIR GAUGE

DESCRIPTION

A pressure gauge, Fig. 5-4, is located on the compressor control panel. 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.

MAIN RESERVOIR AIR FILTERS

DESCRIPTION

The compressed air system has two centrifugal type filters, the main reservoir and auxiliary main reservoir filters, Fig. 5-7. 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 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 auxiliary 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.

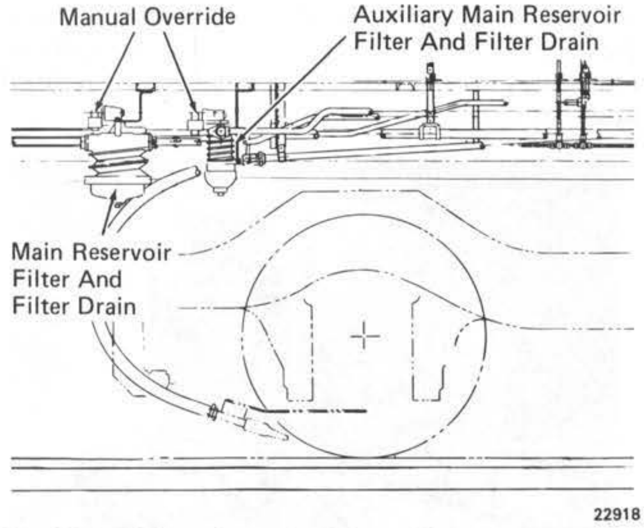


Fig.5-7 – Main And Auxiliary Main Reservoir Air Filters

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.

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

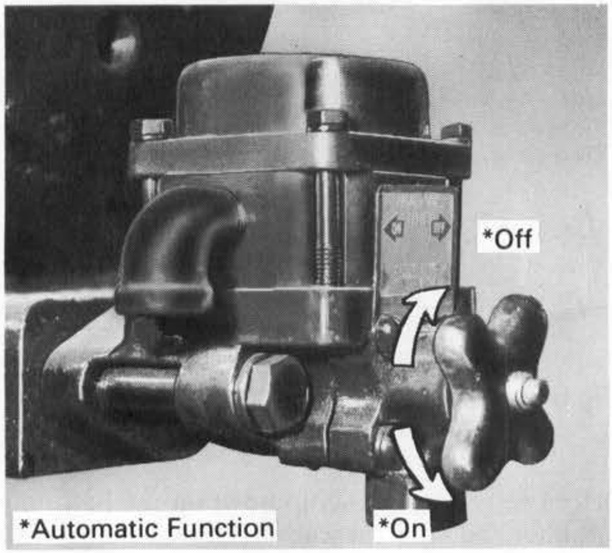
DESCRIPTION

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 Main Reservoir 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.



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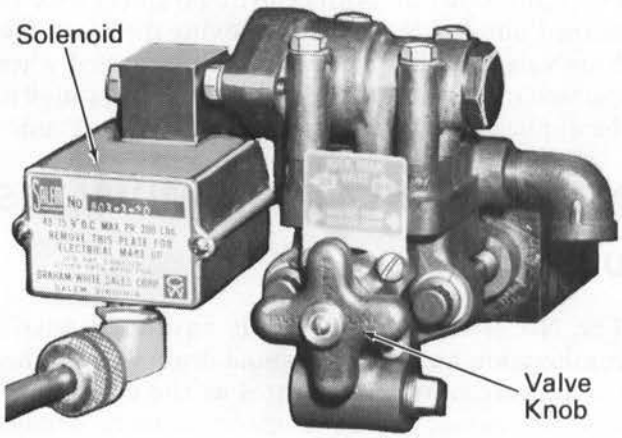
Automatic/Manual
Main Reservoir Drain Valve



21493

Solenoid Operated
Automatic Drain Valve

Fig.5-8 - Typical Main Reservoir Drains

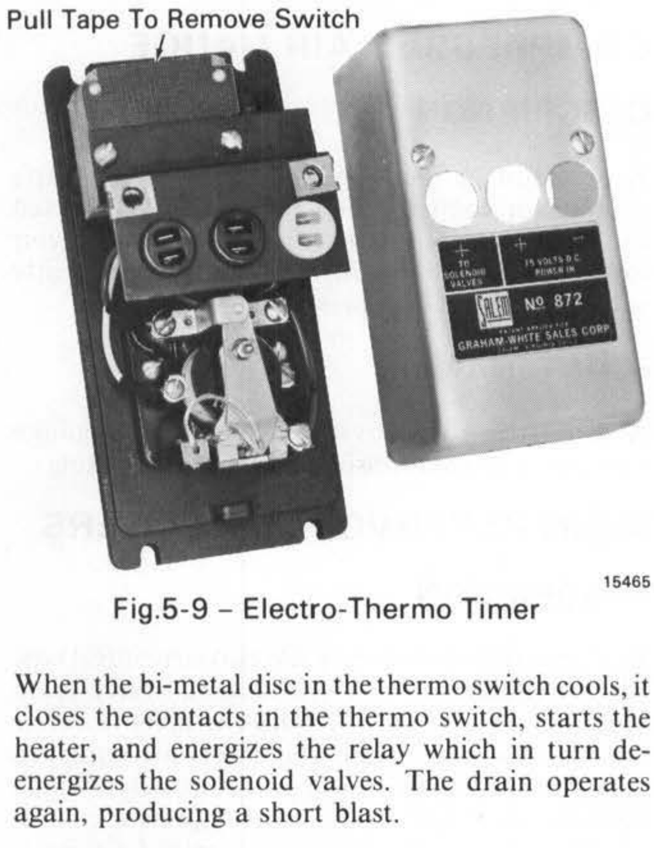
MAINTENANCE

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.



15465

Fig.5-9 - Electro-Thermo Timer

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 main reservoir air filters and main reservoir automatic drains should be operated manually at least once a day to ensure operation of the automatic feature. Refer to Fig. 5-10, for filter and drain location.

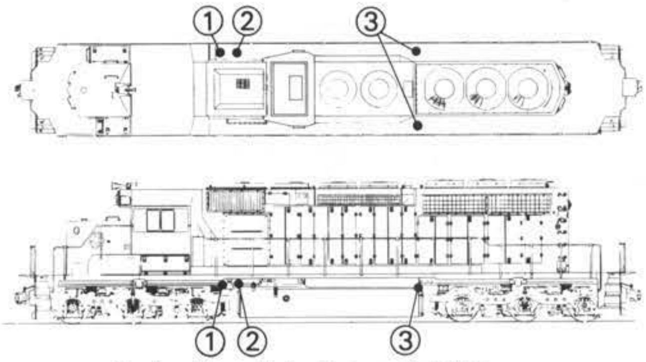


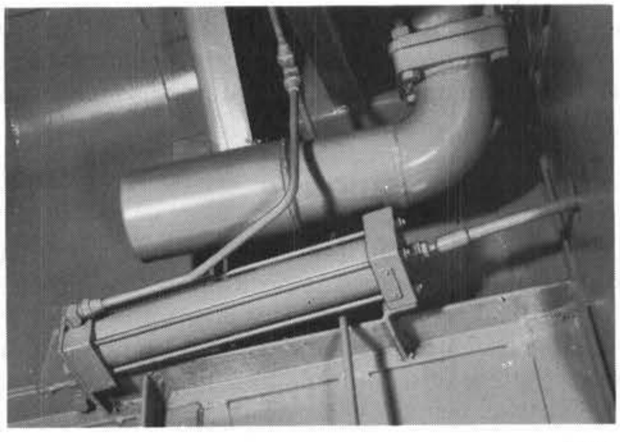
Fig.5-10 - Compressed Air System Drain Valve Locations

RADIATOR SHUTTER CONTROL

SHUTTER OPERATING CYLINDERS

DESCRIPTION

The radiator shutters are opened and closed by the action of four air operated cylinders, Fig. 5-11, which are mounted to the carbody structure at the front of the shutter assembly. The cylinders are actuated when the shutter control magnet valve, MV-SH, is energized.



23077

Fig.5-11 - Typical Shutter Operating Cylinder

MAINTENANCE

Open the shutters manually 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. Refer to Shutter Position Adjustment procedure in Section 3.

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 valve MV-SH, Fig. 5-4. This allows compressed air to be admitted to the shutter operating cylinders to force the spring loaded shutters closed. When the FC1 fan contactor is energized, the shutter magnet valve is de-energized, air pressure is released from the shutter operating cylinders 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 cylinders, exhausted through MV-SH, and the shutters will remain 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. Only EMD replacement parts should be used.

AIR BRAKE EQUIPMENT

DESCRIPTION

Basic locomotives are equipped with type 26L air brake equipment. This equipment is located to the left of the controller and as shown in Fig. 5-12 includes an automatic brake, independent brake, cut-off pilot valve, a trainline air pressure adjustment valve, and a multiple unit valve (when MU control is installed). A dead engine cutout cock and pressure regulator is also part of the 26L air brake equipment.

Fig.5-12 - Air Brake Equipment

AUTOMATIC BRAKE VALVE HANDLE

The automatic brake valve handle, Fig. 5-13, controls the application and release of both the locomotive and train brakes. The brake valve is of the "pressure maintaining type" which will hold brake pipe reductions constant against nominal brake pipe leakage. A brief description of the operating positions follows:

RELEASE POSITION

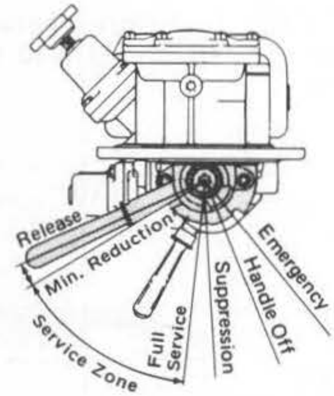
This position is for charging the equipment and releasing the locomotive and train brakes. It is located with the handle at the extreme left of the quadrant.

MINIMUM REDUCTION POSITION

This position is located with the handle against the first raised portion of the quadrant to the right of release position. With the handle moved to this position, minimum braking effort is obtained.

SERVICE ZONE

This position consists of a sector of handle movement to the right of release position. In moving the handle from left to right through the service zone, the degree of braking effort is increased until, with the handle at the extreme right of this sector, the handle is in full service position and full service braking effort is obtained.



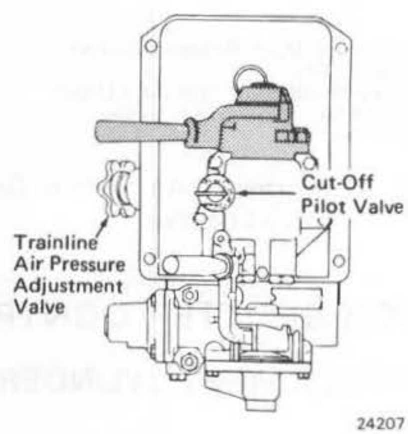


Fig.5-13 - Automatic Brake Handle Positions

SUPPRESSION POSITION

This position is located with the handle against the second raised portion of the quadrant to the right of release position. In addition to providing full service braking effort, as with the handle in full service position, suppression of overspeed control and safety control application, if equipped, is obtained.

HANDLE OFF POSITION

This position is located by the first quadrant notch to the right of suppression position. If so equipped, the handle is removable in this position. This is the position in which the handle should be placed on trailing units of a multiple-unit locomotive or on locomotives being towed "dead" in a train.

EMERGENCY POSITION

This position is located to the extreme right of the brake valve quadrant. It is the position that must be used for making brake valve emergency brake applications and for resetting after any emergency application.

INDEPENDENT BRAKE VALVE HANDLE

The independent brake valve handle, Fig. 5-14, is located directly below the automatic brake handle.

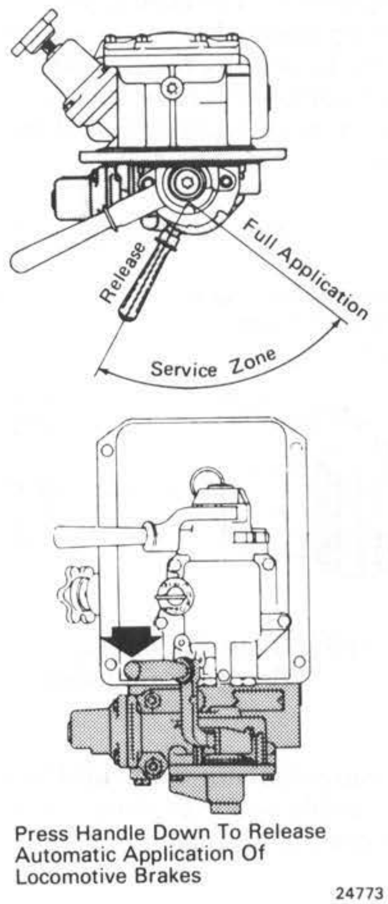


Fig.5-14 – Independent Brake Handle Positions

This handle provides independent control of the locomotive braking effort irrespective of train braking effort. The valve is self-lapping and will hold the brakes applied. A brief description of the operating positions follows.

RELEASE POSITION

This position is located with the handle at the extreme left of the quadrant. This position releases the locomotive brakes, provided the automatic brake handle is also in release position.

FULL APPLICATION POSITION

This position is located with the handle at the extreme right of the quadrant. In moving the handle from left to right through the service zone the degree of locomotive braking effort is increased until full application braking effort is obtained.

Depression of the independent brake handle whenever the handle is in release position will cause the release of any automatic brake application existing on the locomotive. Depression of the independent brake handle when in the service zone will release the automatic application of the locomotive brakes to the value corresponding to the position of the independent brake handle.

MULTIPLE UNIT VALVE

The multiple unit (MU-2A) valve is located on the lower left-hand side of the operator's control stand, Fig. 5-15. 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.

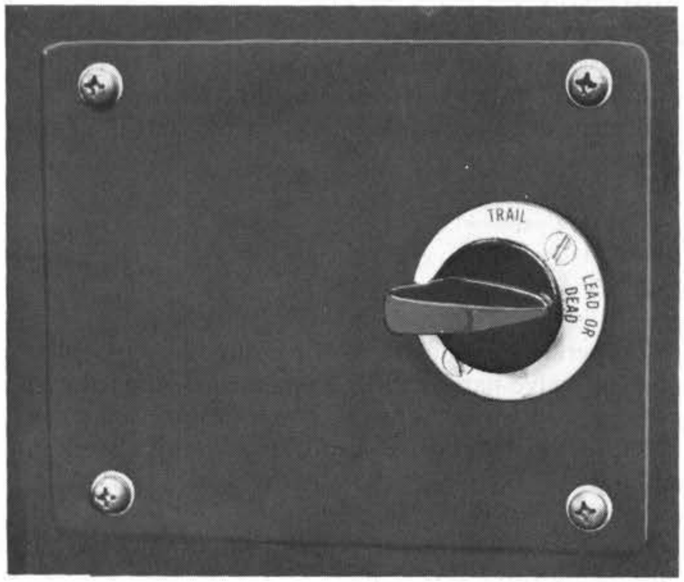


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Fig.5-15 – Typical MU-2A Valve Application

Three versions of multiple unit control are available. In each case the valve is positioned by pushing in and turning to the desired setting.

Basic MU-2A valve applications have the following two positions:

1. LEAD or DEAD
2. TRAIL 26 or 24

Locomotives equipped with three position MU-2A valve applications will utilize one of the following valve position configurations:

Black lettered escutcheon plate

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

*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.

Red lettered escutcheon plate

1. LEAD or DEAD

2. TRAIL 6

3. TRAIL 26 or 24

CUT-OFF PILOT VALVE

The cut-off pilot valve, Fig. 5-12, is located on the automatic brake valve housing directly beneath the automatic brake handle. The valve has the following two positions:

1. OUT

2. IN

To operate locomotive as the controlling unit, the cut-off valve handle must be pushed in and rotated to the IN position. The OUT position is used when hauling the locomotive "dead" or as a trailing unit in a consist.

On special order the cut-off pilot valve may have the following three positions:

1. OUT

2. FRT (freight)

3. PASS (passenger)

In this case the valve is pushed in and placed in the position desired, depending on make-up of train.

TRAINLINE AIR PRESSURE ADJUSTMENT VALVE

The trainline air pressure adjustment valve, Fig. 5-12, is located to the left of the automatic brake valve. With the automatic brake valve handle in release position, it is used to obtain the brake pipe pressure desired. The automatic brake valve will maintain the selected pressure against overcharge or leakage.

DEAD ENGINE CUTOUT COCK AND PRESSURE REGULATOR

A dead engine feature is also part of the 26L air brake equipment. The dead engine cutout cock and pressure regulator, Fig. 5-16, are accessible from outside the locomotive through side doors provided. When a locomotive is to be shipped dead in a train the cutout cock handle should be in the open position.

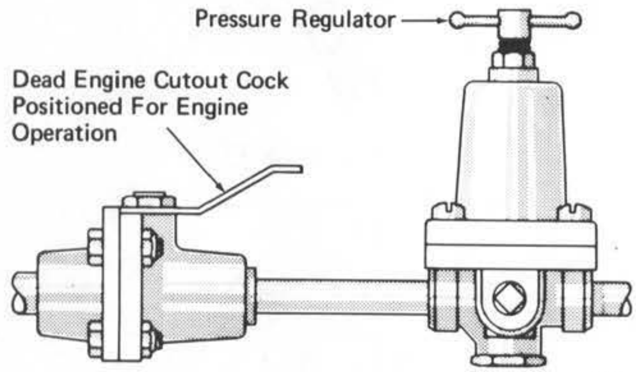


Fig.5-16 - Dead Engine Cutout Cock And Pressure Regulator

The pressure regulator is provided to regulate the air pressure available for braking a locomotive being shipped dead in a train.

The pressure regulator is pre-set at the value given in the Service Data. 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.

26L AIR BRAKE EQUIPMENT OPERATING POSITIONS

In the absence of specific instructions, usually issued by each railroad to cover its own recommended practices, refer to Fig. 5-17, for brake equipment operating positions most often encountered while the locomotive is in service.

Type Of Service	Automatic Brake Valve	Independent Brake Valve	Cutoff Valve	Dead Engine Cutout Cock	26D Control Valve	26F Control Valve	Multiple Unit Valve: MU2A Valve	Multiple Unit Valve: Dual Ported Cutout Cock	Overspeed Cutout Cock	Deadman Cutout Cock
SINGLE LOCOMOTIVE EQUIPMENT										
Lead	Release	Release	*In	Closed		Graduated Direct	Lead	Open	Open	Open
Shipping Dead In Train	Handle Off Position	Release	Out	Open	Relief Valve At Control Reservoir 73±2 Lbs.	Direct	Dead	Closed	Closed	Closed
Radio Control Lead Unit	Release	Release	*In	Closed		Direct	Lead	Open	Open	Open
Radio Control Remote Unit	Release	Release	*In	Closed		Direct	Lead	Open	Closed	Closed
MULTIPLE LOCOMOTIVE EQUIPMENT AND EXTRAS										
Lead	Release	Release	*In	Closed		Graduated Direct	Lead	Open	Open	Open
Trail	Handle Off Position	Release	Out	Closed		Graduated Direct	†Trail 6 or 26 Trail 24	Open	Open	Open
Shipping Dead In Train	Handle Off Position	Release	Out	Open	Relief Valve At Control Reservoir 73±2 Lbs.	Direct Release	Dead	Closed	Closed	Closed
Dual Control:										
Operative Station	Release	Release	*In	Closed		Graduated Direct	Lead	Open	Open	Open
Non-Operative Station	Handle Off Position	Release	Out							

*On Units equipped with a three position cut-off valve, position valve to either FRT or PASS, depending on make-up of train.

†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 inadvertent loss of air brakes due to possible pressure buildup in the actuating line.

NOTE

By AAR standard, all cocks in the brake system except brake pipe end cocks have handles perpendicular to pipe when open.

29221

Fig.5-17 – Typical 26L Air Brake Equipment Positions

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. 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 is 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-

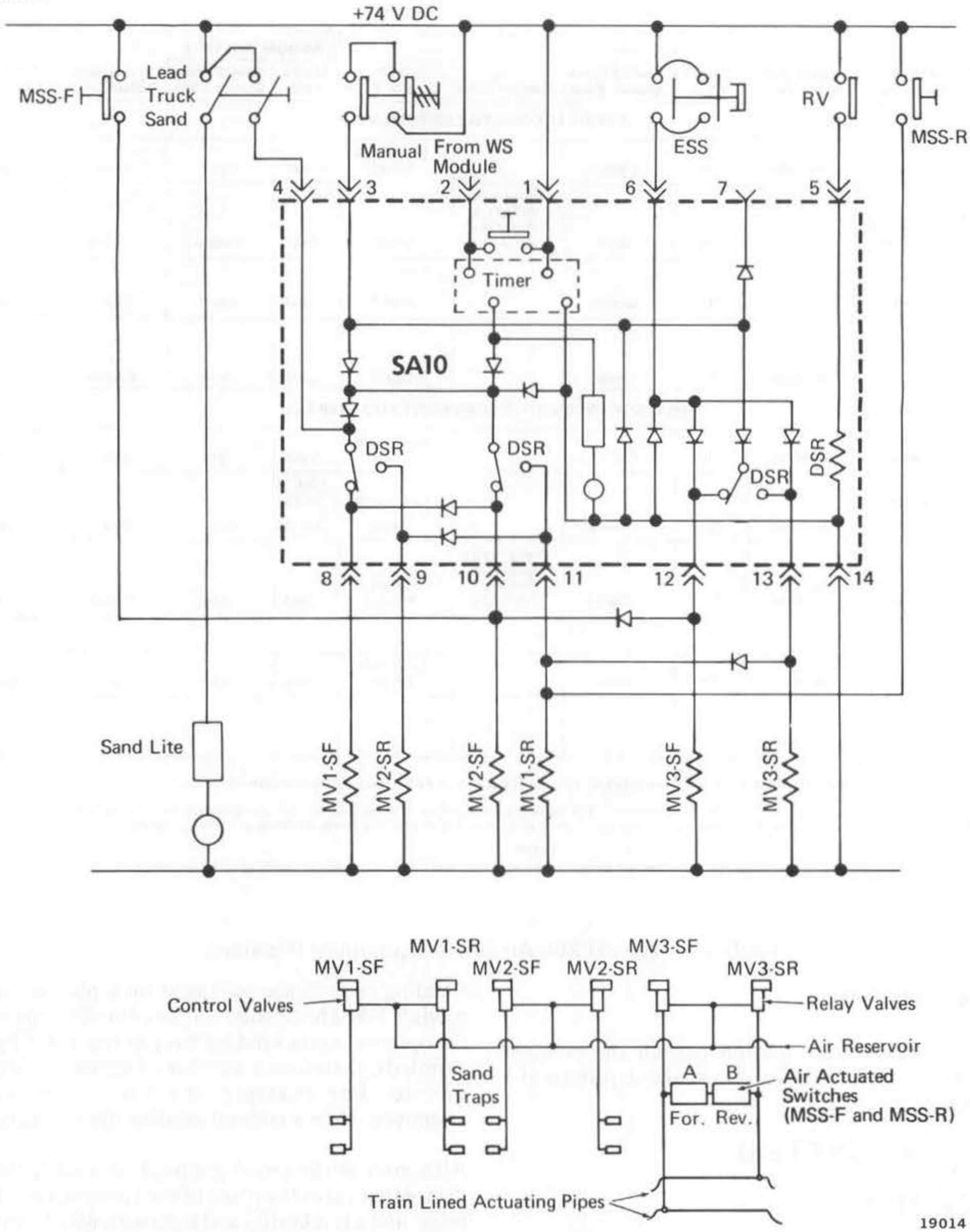


Fig.5-18 – Sanding Circuit And Air Schematic Including Pneumatic Sanding Option

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 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. 5-19, 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.

17566

Fig.5-19 - Sanding Control Valves

MAINTENANCE

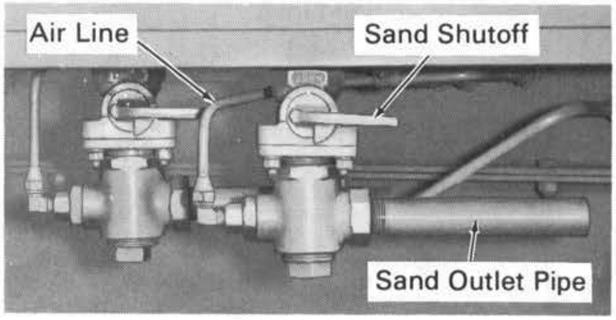
If faulty operation is suspected, inspect the electrical connections for tightness and inspect the air connections for leaks. The control valve is equipped with automatic clean-out jets to clean out the orifice. To operate the clean-out jets push in the plungers on each side of the valve, Fig. 5-19. The plunger will automatically reset at the beginning of the next sanding cycle from the high pressure clean-out blast of air.

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. 5-20, 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 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.



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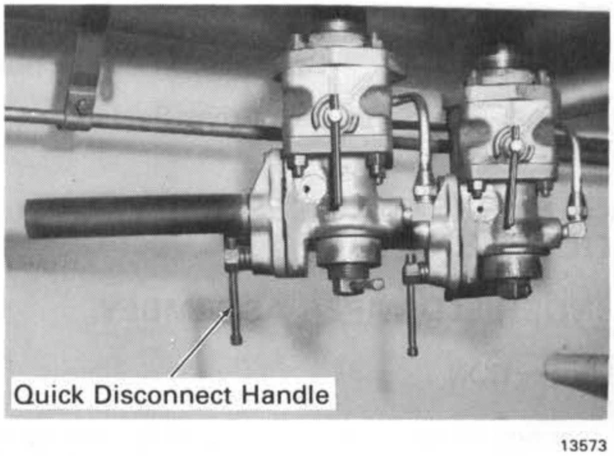

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Fig.5-20 - Sand Trap

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 567g to 680g (20 to 24 oz.) of sand per minute. To change the rate of delivery, screw the adjusting nut, Fig. 5-21, 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.

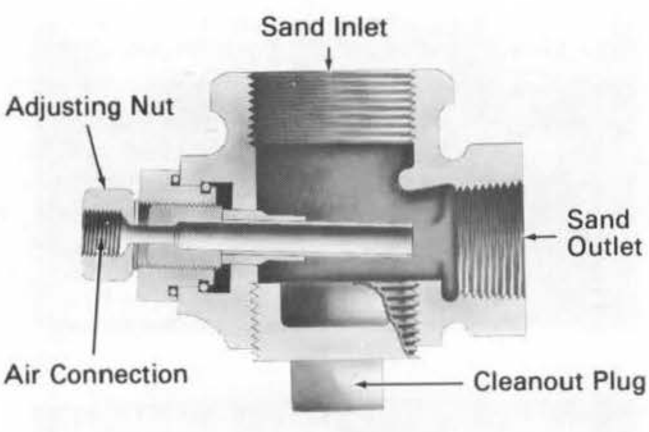


Fig.5-21 - Sand Trap, Cross-Section

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. 5-22, used for the center windshield is identical to the other motors but is set for a longer degree of sweep.

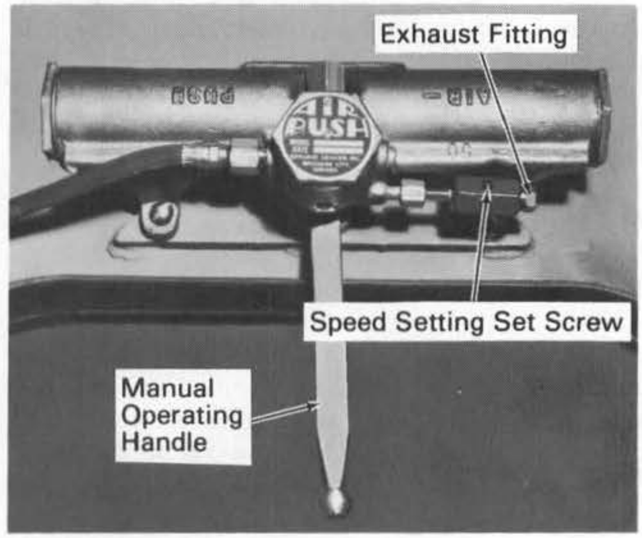


Fig.5-22 - Windshield Wiper Air Motor (Shown Without Protective Cover/Gasket)

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 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. 5-22, 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. 5-22, 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 896 to 965 kPa (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

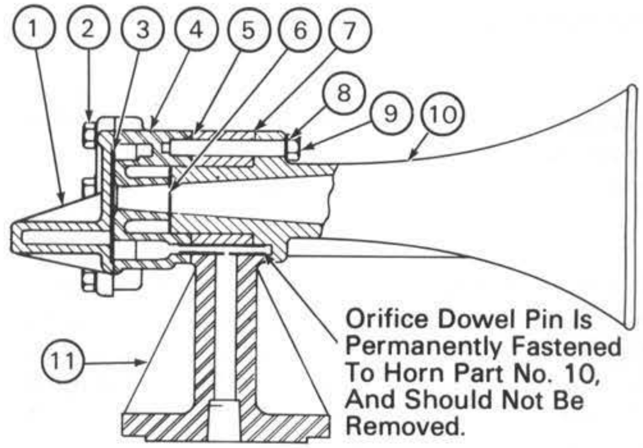
DESCRIPTION

The basic air horn is a three chime, low profile type, Fig. 5-23. 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.

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

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.



1. Back Cover
2. Taptight Screw
3. Diaphragm
4. Diaphragm Housing
5. Gasket 8211999
6. Gasket
7. Gasket 8211999
8. Lockwasher
9. Cap Screw
10. Horn Bell
11. Base

24290

Fig.5-23 - Air Horn

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. 5-24, 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.

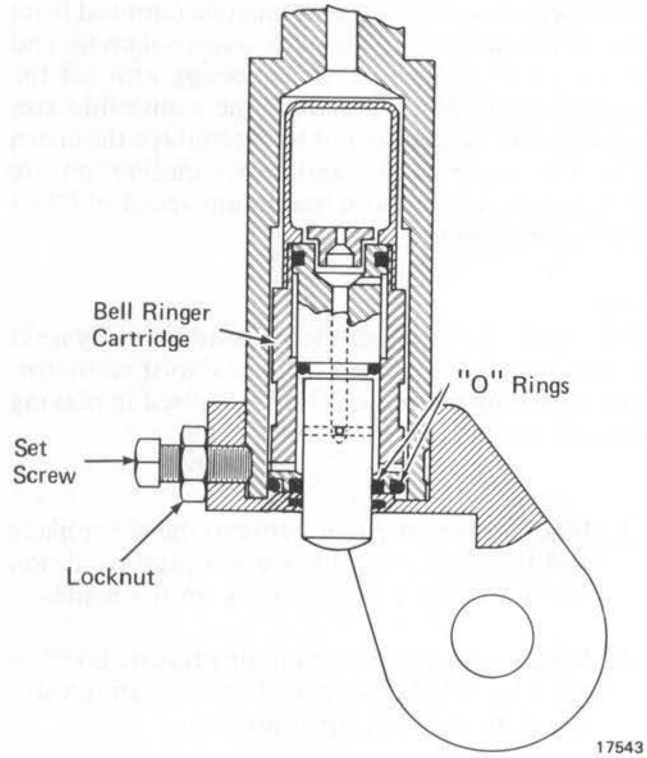


Fig.5-24 – Bell Ringer, Cross-Section

SERVICE DATA
COMPRESSED AIR SYSTEM

REFERENCES

Air Compressor Models WBO and WBG	M.I. 1144
Solenoid (Magnet) Valves	M.I. 4707
Pressure Control Switch - Type 9012	M.I. 5512

ROUTINE MAINTENANCE PARTS AND EQUIPMENT

FILTERS

Inlet Compressor Air Filter Element	
(Rectangular Filter)	8347199
(Cylindrical Filter)	9093553, 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	Two Stage
Number Of Cylinders (Basic)	3
Number Of Cylinders (Optional)	6
Displacement At 900 RPM (3 cylinder)	7 198 liters (254 cu. ft.)/Min.
Displacement At 900 RPM (6 cylinder)	11 364 liters (401 cu. ft.)/Min.
Lube Oil Capacity (3 cylinder)	39.8 liters (10-1/2 Gal.)
Lube Oil Capacity (6 cylinder)	68 liters (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)	
@ 38° C (100° F) seconds	130 to 180
@ 99° C (210° F) seconds	42 to 45
Pour Point (ASTM D97 Degrees — Minimum)	-18° C (0° F)
Rust-Distilled Water (ASTM D665)	No Rust

DEAD ENGINE PRESSURE REGULATOR SETTING

SD — Single Brake (Composition Shoe)	172 ± 10 kPa (25 ± 1-1/2 psi)
SD — Clasp Brake (Iron Shoe)	172 ± 10 kPa (25 ± 1-1/2 psi)
SD — Clasp Brake (Composition Shoe)	90 ± 10 kPa (13 ± 1-1/2 psi)

ELECTRO-MOTIVE

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

The main generator, Fig. 6-1, 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.

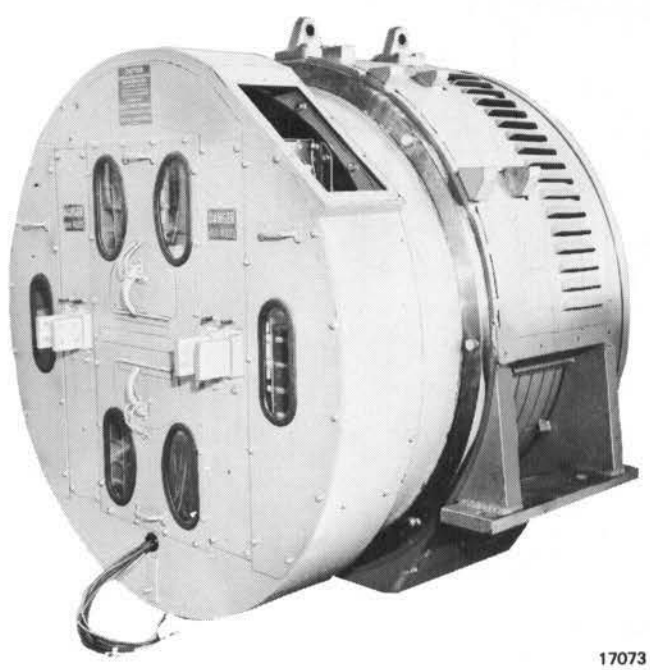


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Fig.6-1 – AR10 Main Generator

COMPANION ALTERNATOR

The companion alternator, Fig. 6-2, is physically connected to but electrically independent of the traction alternator. The rotor (field) is excited by low voltage current which it receives from the DC auxiliary generator through a pair of collector rings adjacent to the collector rings for the main generator.

19065

Fig.6-2 – Companion Alternator

There are no controls in the 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. Nominal output is 215 volts at 120 cycles per second with the engine running at full speed of 900 RPM.

TRACTION MOTORS

Electrical power from the main generator is distributed to traction motors, Fig. 6-3, 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.

CAUTION

The maximum continuous current rating of the traction motors and the value given on the traction motor short time rating plate is applicable only when operating at throttle No. 8 engine speed. These values decrease as engine speed and cooling air are decreased.

AUXILIARY GENERATOR

All low voltage direct current electricity required during locomotive operation comes from the auxiliary generator, Fig. 6-4. This current is used for battery charging and for excitation of the com-

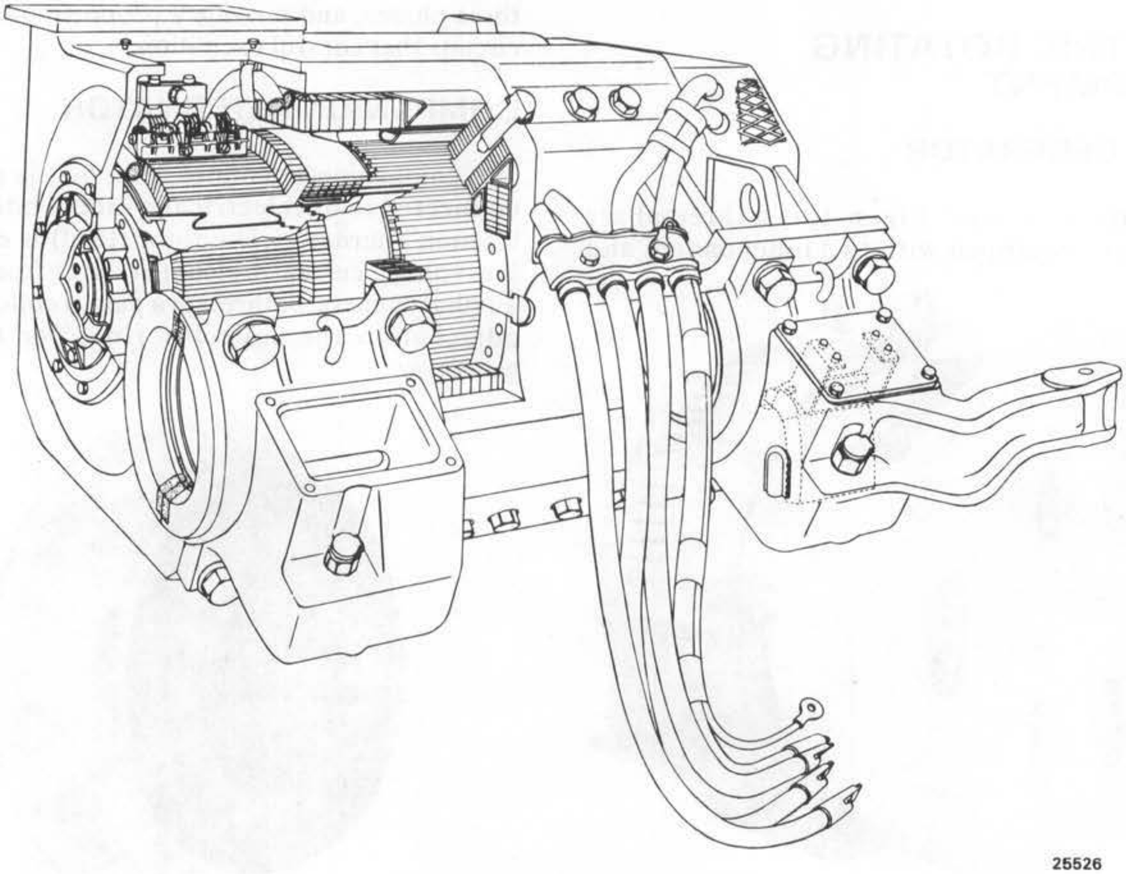
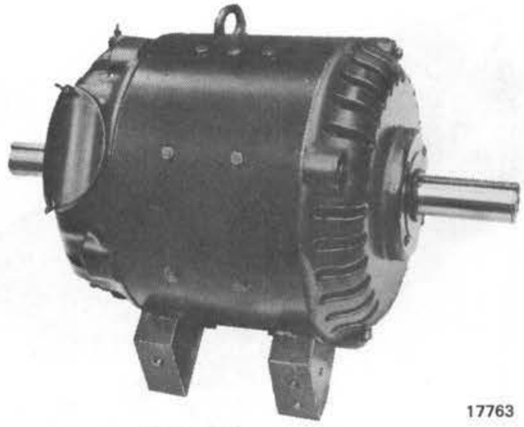


Fig.6-3 – Traction Motor



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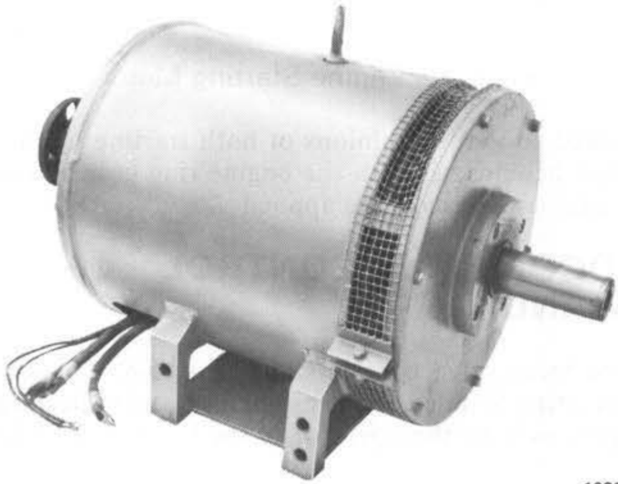
10 kW Generator



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18 kW Generator

Fig.6-4 – Auxiliary Generator

panion alternator as well as for energizing control circuits and 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.

RADIATOR COOLING FAN MOTORS

These motors, Fig. 6-5, 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.

28896

Fig.6-5 – Cooling Fan Assembly

Motor and fan rotating speed are directly proportional to the AC frequency of the D14 alternator which in turn is dependent upon engine speed.

DYNAMIC BRAKE GRID BLOWER ASSEMBLY

The dynamic brake grid cooling blower assembly, Fig. 6-6, 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 resistors 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.

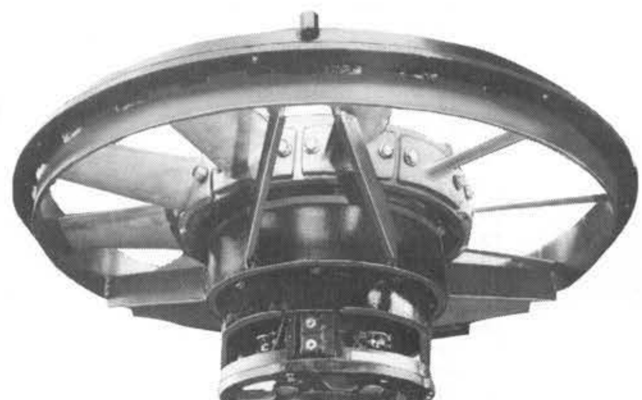

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Fig.6-6 – Dynamic Brake Grid Blower Assembly

TURBO LUBE PUMP MOTOR

This is a 3/4 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

The starting motor solenoid, Fig. 6-7, 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.

The diesel engine is equipped with dual motors for cranking. Power circuits to the motors are inter-

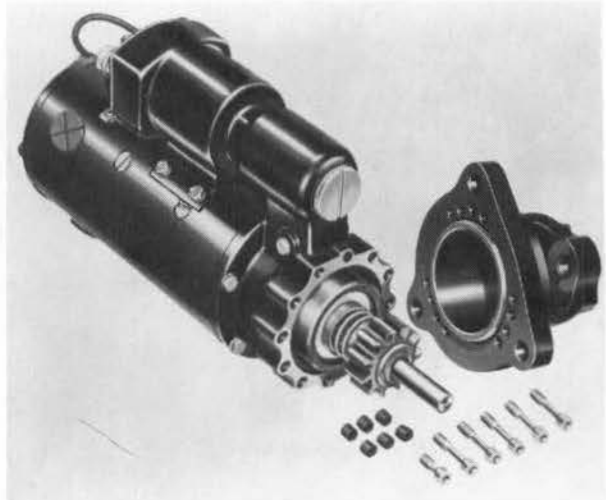

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Fig.6-7 – Engine Starting Motor

locked so that the pinions of both starting motors must be engaged with the engine ring gear before cranking power can be applied.

LOCOMOTIVE CONTROL STAND

The locomotive control stand, Fig. 6-8, contains operating handles, switches, gauges, and indicating lights used by the operator of the locomotive. The

1. Multiple Unit Valve (MU-2A Or Dual Ported Cutout Cock)
2. Independent Brake Valve
3. Cut-Off Valve
4. Trainline Air Pressure Adjustment Valve
5. Automatic Brake Valve
6. Air Horn Valve
7. Air Gauges
8. Load Current Indicating Meter
9. Control And Operating Switches
10. Light Dimmer
11. Dynamic Brake Circuit Breaker
12. Headlight Switch-Front
13. Throttle Handle
14. Reverser Handle
15. Ground Reset Button
16. Attendant Call Button
17. Headlight Switch-Rear
18. Bell Ringer Valve
19. Manual Sand Lever Switch
20. Lead Truck Sand Switch
21. Indicator Light Panel
22. Dynamic Brake Handle
23. Ground And Light Switches

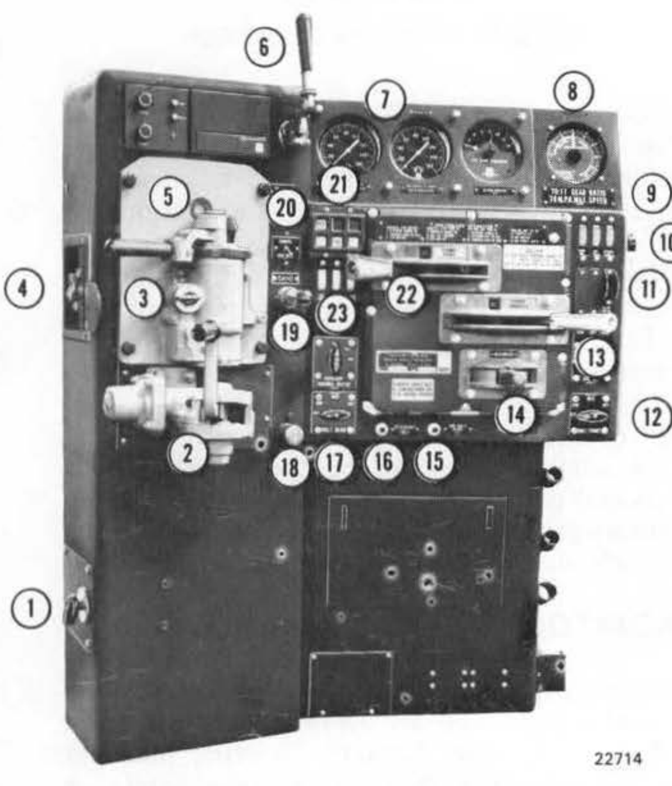

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Fig.6-8 – Locomotive Control Stand

air brake valves and handles are at the left side of the stand, with the controller assembly to the right. Various gauges and indicating lights are located above the controller, and various operating switches are adjacent to it or below.

CONTROLLER ASSEMBLY

The controller, Fig. 6-9, contains the three main operating handles; throttle, reverser, and dynamic brake. Nameplates identify each handle, and the positions of the throttle and dynamic brake handles are indicated in illuminated windows located directly above those handles. The controller assembly is hinged to the control stand, and can be swung down for maintenance and troubleshooting.

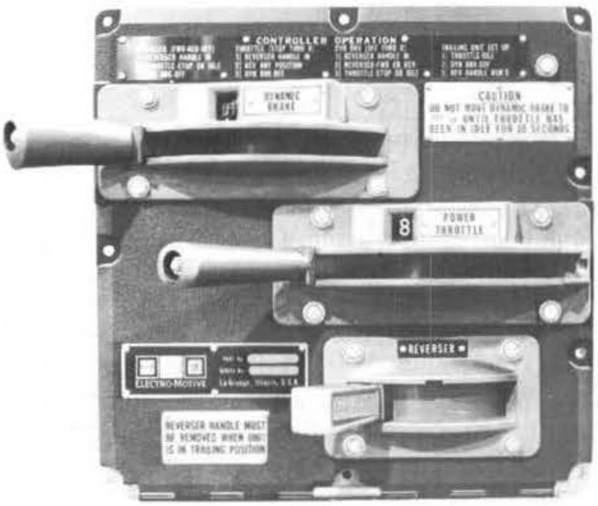

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Fig.6-9 – Locomotive Controller

DYNAMIC BRAKE HANDLE

A separate handle is provided for control of dynamic brakes. It is uppermost on the controller panel and is moved from left to right to increase braking effort. The handle grip is somewhat out of round with the flattened surfaces vertical to distinguish it from the throttle handle, which has its flattened surfaces horizontal. The brake handle has two detent positions; OFF and SET UP, and an operating range through which the handle moves freely without notching. The handle is in the OFF notch when positioned fully left. The SET UP position is one notch to the right of OFF. When the handle is moved to the right out of the SET UP notch, it can then be moved without notching to positions 1 through FULL 8 to increase the signal from the dynamic brake rheostat, which is part of the controller assembly. Mechanical interlocking prevents the dynamic brake handle from being moved out of the OFF positions unless the throttle is at IDLE and the reverser handle is positioned for either forward or reverse operation.

CAUTION

During transfer from power operation to dynamic braking, the throttle must be held in IDLE for 10 seconds before moving the dynamic brake handle to the SET UP position. This is to allow time for decay of magnetic flux and preclude a sudden surge of braking effort with possible train run-in or motor flashover.

THROTTLE HANDLE

The throttle is the middle handle on the controller panel. It is moved from right to left to increase engine speed and power. The handle grip is somewhat out of round, with the flattened surfaces horizontal to distinguish it from the dynamic brake handle, which has its flattened surfaces vertical. The throttle has nine detent positions; IDLE, and 1 through 8 plus a STOP position which is obtained by pulling the handle outward and moving it to the right beyond IDLE to stop all engines in a locomotive consist. Mechanical interlocking prevents the throttle handle from being moved out of IDLE when the dynamic brake handle is advanced to SET UP or beyond, or when the reverser handle is centered and removed from the controller.

CAUTION

Damage to the traction motors may occur if the reverser is moved from forward to reverse position or from reverse to forward position while the locomotive is in motion. The reverser position should be changed only when the locomotive is completely stopped.

REVERSER HANDLE

The reverser handle is the lowest handle on the controller panel. It has three detent 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, mechanical interlocking prevents movement of the dynamic brake handle, but the throttle handle can be moved to increase engine speed. In such case power will not be applied to the traction motors, but a load test may be made if the proper circuit setup is made.

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

NOTE

Engine speed will be reduced to low idle when the reverser is centered.

LOAD CURRENT INDICATING METER

This meter, Fig. 6-10, 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 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.

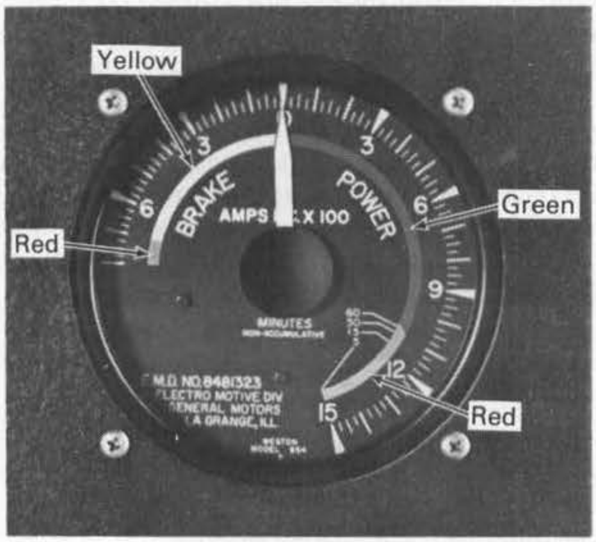

Fig.6-10 - Load Current Indicating Meter

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 PANEL

Indicating lights alert the locomotive operator of various operating conditions. The panel assembly, Fig. 6-11, is located adjacent to the upper left corner of the controller. It has provision for six press-to-test lights (three basic, and from one to three additional as required by the use of special equipment on the locomotive).

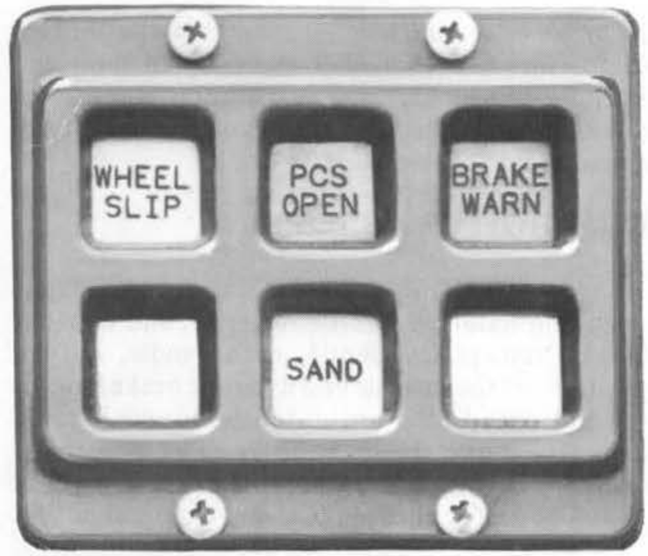

Fig.6-11 - Indicating Lights Panel

The indicating light assembly consists of a rectangular aluminum plate with six 1/2" drilled holes to accept holders for grooved-base sub-miniature lamps. Limiting resistors of high wattage are also affixed to the plate. The lamp holders form the front part of the press-to-test assemblies, and a printed circuit board equipped with Faston tabs is connected to the backs of the switches. The tabs are wired to appropriate locomotive circuits.

Translucent phenolic lens caps, either white or colored, and identified by black block letters, fit over the lamps and into the switch assemblies. When finger pressure is applied to the lens caps, the switches close to test the lamps. A fiberglass guard formed to accept and retain the lens caps is bolted to the aluminum plate to complete the indicating light assembly.

NOTE

A delay of about one second occurs between pressing the indicating lens cap and illumination of the indicator.

WHEEL SLIP light indicates moderate to severe wheel slip, locked sliding wheels, or circuit difficulty. Depending upon conditions, the light will flash intermittently or come on and go off at regular intervals.

NOTE

On locomotives equipped with locked wheel detecting equipment and an LW module, a locked wheel will cause the WHEEL SLIP light to light and remain lit and the alarm bell to sound. In addition, LOCK WHEEL indications independent of the wheel slip protective circuits are provided.

PCS OPEN light indicates a safety control or emergency air brake application.

SAND light indicates that the SANDING LEAD TRUCK switch on the control stand is closed to provide continuous sanding at the leading wheels of the locomotive. On special order, the light can be connected to indicate operation of the manual or emergency sanding switches.

BRAKE WARN light indicates excessive dynamic braking current.

Various other lights may also be provided.

OPERATING SWITCHES

The ENGINE RUN, GEN. FIELD, and CONTROL & FUEL P. 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.

DYNAMIC BRAKE CONTROL CIRCUIT BREAKER

On locomotives equipped for dynamic braking, this circuit breaker is provided to protect against a faulty operating or test setup. The circuit breaker should be in the on (up) position for normal operation. A tripped circuit breaker generally indicates that at some time during makeup of a locomotive consist more than one dynamic brake handle was out of OFF position at one time.

HEADLIGHT SWITCHES

Two four-position rotary snap switches are provided for independent control of the front and rear headlights. Each switch has OFF, DIM, MED., and BRT. positions. All positions of each switch are operative, but in a multiple unit consist, the headlight control switches on the engine control panels of each unit in a consist must be properly positioned, and only the lead unit controls the headlights.

GROUND RESET AND ATTENDANT CALL PUSHBUTTONS

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

SANDING LEAD TRUCK SWITCH

The switch provides continuous sanding at only the leading truck of the locomotive.

SAND LEVER SWITCH

The switch provides directional sanding on the locomotive and, if so equipped, on all units in a locomotive consist.

BRAKE HANDLE VALVES

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

ELECTRICAL CABINETS

HIGH VOLTAGE CABINET, Figs. 6-12 and 6-13

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

The basic engine control panel, Fig. 6-14, 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.

On special order, an indicator light panel, Fig. 6-15, may be substituted for the six basic indicator lights. When required, a second indicator light panel may be used to contain up to six additional indicator lights.

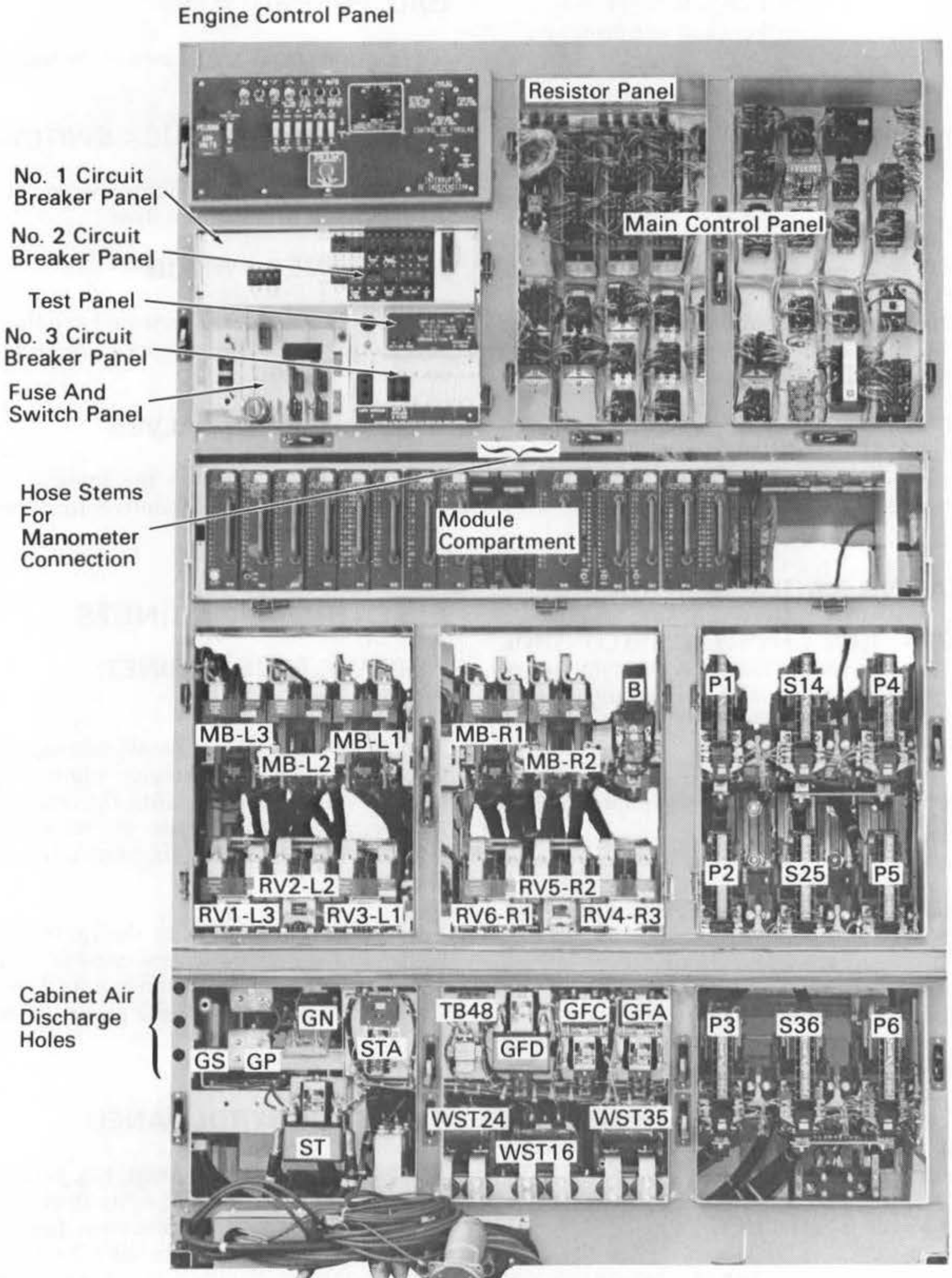

Fig.6-12 – Electrical Cabinet, Front

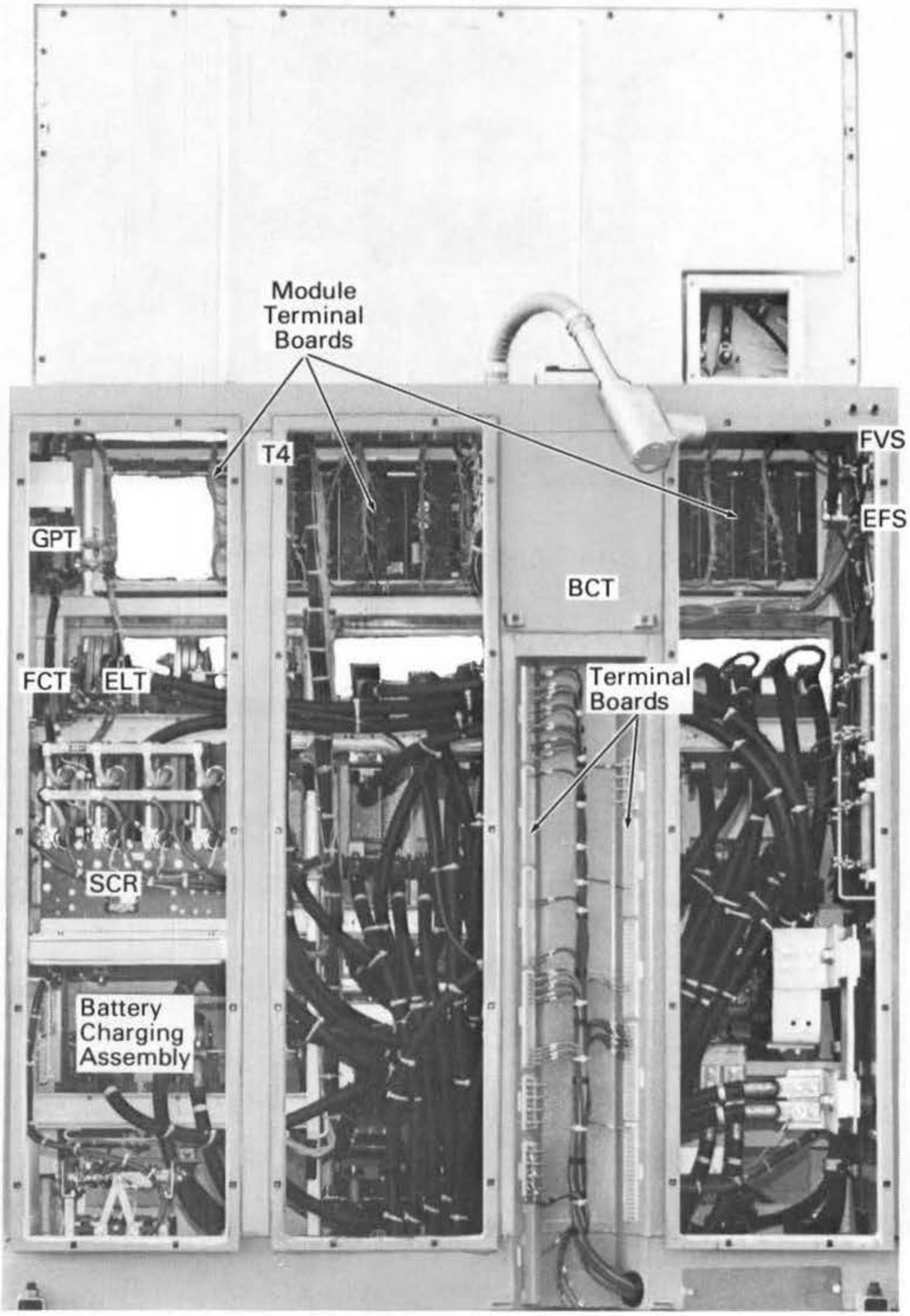

Fig.6-13 – Electrical Cabinet, Rear

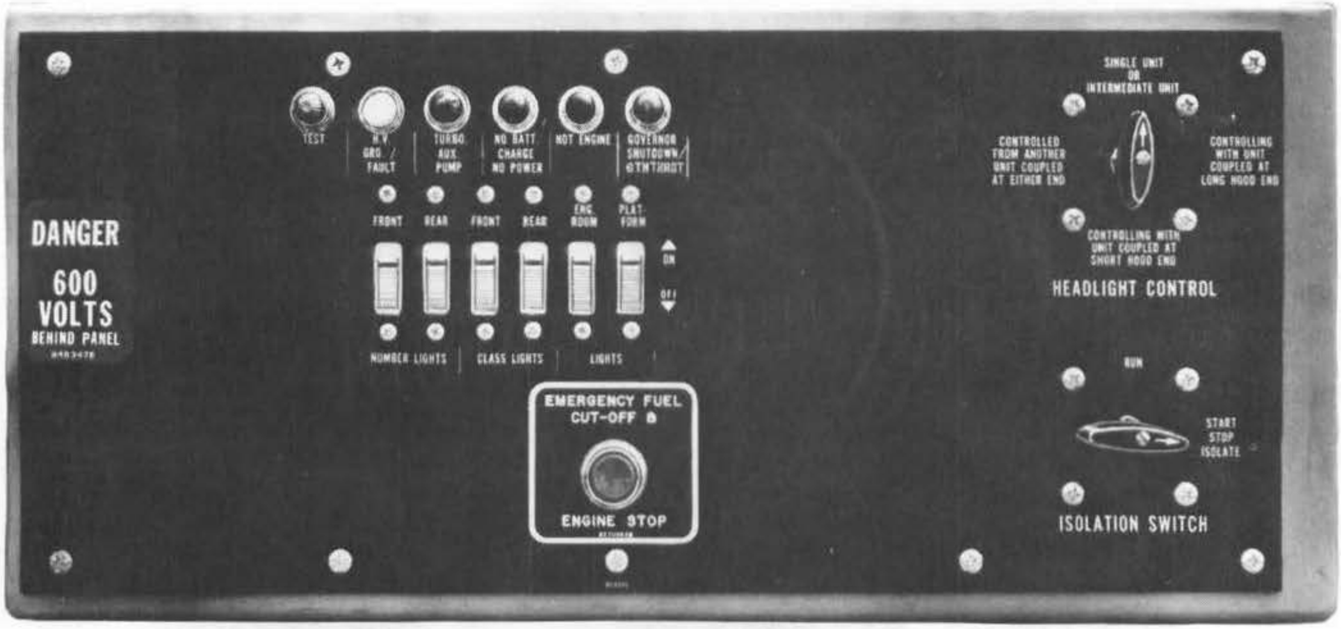

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Fig.6-14 – Basic Engine Control Panel

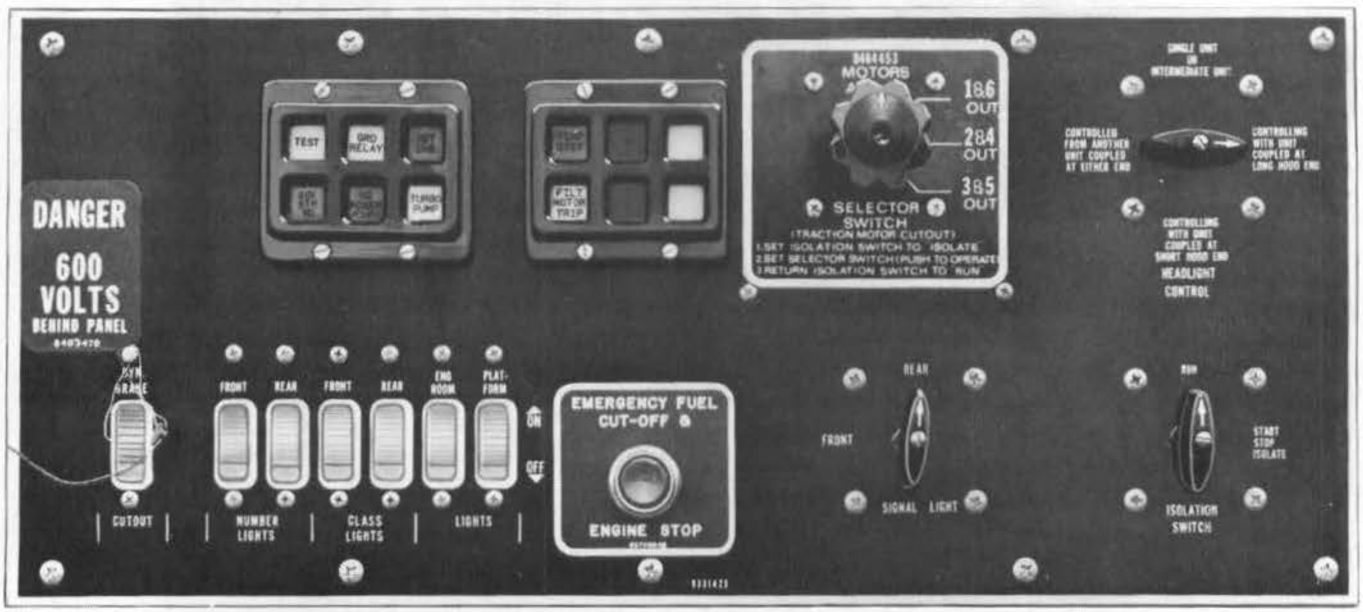

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Fig.6-15 – Engine Control Panel With Typical Extras

NOTE

Indicator light panels are equipped with push-to-test lights. This feature allows testing of the lamp circuit alone isolated from its operation in the power control system. When the lens cap is depressed, voltage is supplied to the lamp circuit. After a one second delay the light should go on.

BASIC LIGHTS

TEST Light

This light comes on when circuits are set up for circuit check or load testing. On locomotive 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 snap switch located on a test panel in the module compartment is properly positioned. If the unit is not equipped for automatic self loading, a loading resistor grid must be connected to perform the load test.

WARNING

On units not equipped for automatic self loading, the main generator will be open circuit during a load test setup unless an external loading resistor grid is connected.

During CIRCUIT CHECK position of the test switch, the generator field circuit breaker unit must be in off position to prevent excitation of the main generator.

Do not return the test switch to NORMAL position until the throttle is in IDLE position.

HV GRD/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

This light will come on as soon as the main battery switch and turbo lube pump circuit breaker are closed. It indicates that the turbocharger auxiliary lube oil pump is supplying lube oil to the turbocharger. It will remain on for approximately 35 minutes after the main battery switch is closed. When the fuel prime engine start switch is operated after the 35 minute period, the time cycle is again re-established and the light remains on for another 35 minutes.

The light will also come on and remain on for approximately 35 minutes after the engine is stopped. It provides an indication that the auxiliary lube oil pump is supplying oil to cool the turbocharger bearings.

If the power supply to the turbo lube pump motor is open, the engine will not start and the light will fail to come on when a starting attempt is made.

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.

GOVERNOR SHUTDOWN/6TH. THROT. Light

This light comes on when the engine governor has gone to a throttle six speed and power limit due to a plugged air filter condition or has shut the engine down 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.

   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.

TRACTION MOTOR CUTOUT SWITCH (If Provided)

The traction motor cutout switch operates to electrically isolate a defective traction motor along with an electrically related motor. This permits operation with the remaining good motors. The power control system automatically limits power to prevent overloading the operative motors. The isolated motors will continue to rotate as the train moves, therefore the locked wheel detection system remains fully effective.

To operate the motor cutout switch it is first necessary to place the isolation switch on the engine control panel in ISOLATE position. The switch is then pressed in and turned to cut out the desired pair of motors.

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 (if equipped, the unit will run at low idle speed). 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.

LIGHT SWITCHES

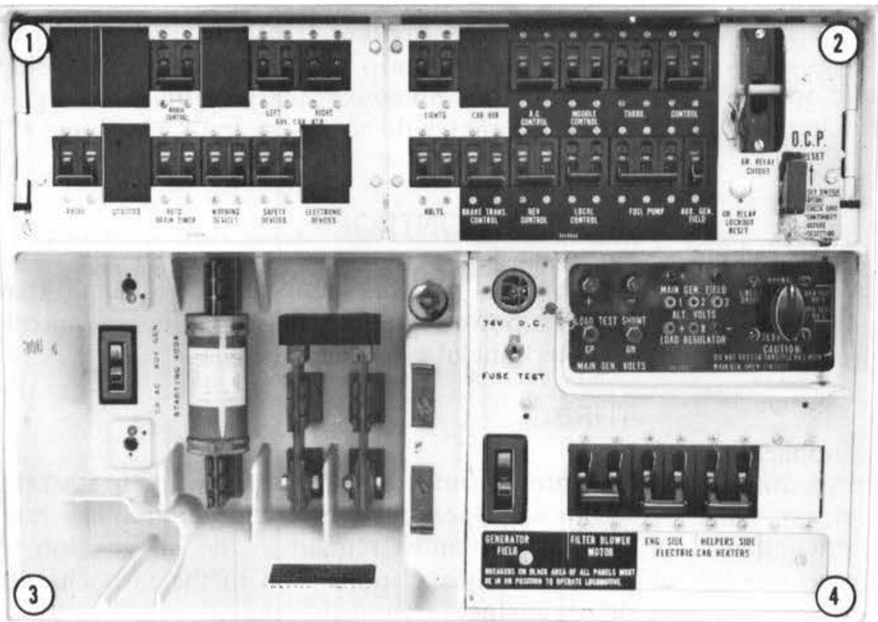
Switches are provided for various lights employed on the locomotive.

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.

CIRCUIT BREAKER PANELS

The three circuit breaker panels, Fig. 6-16, contain circuit breakers and controls used to protect engine, control systems, lights, and miscellaneous devices that are used as conditions require. These circuit breakers can be operated as switches, but will trip open when an overload occurs.



1. No. 1 Circuit Breaker Panel
2. No. 2 Circuit Breaker Panel
3. Fuse And Switch Panel
4. No. 3 Circuit Breaker Panel

NOTE

A 150 ampere fuse may be used instead of an AUX GEN circuit breaker on the fuse and switch panel.

25028

Fig.6-16 – Fuse And Switch Panel And Circuit Breaker Panels

NO. 1 CIRCUIT BREAKER PANEL

This panel contains circuit breakers used to protect requested extra equipment. The No. 1 circuit breaker panel, Fig. 6-17, has provisions for twelve circuit breakers. The following paragraphs contain a brief description of typical circuit systems protected by breakers on this panel.

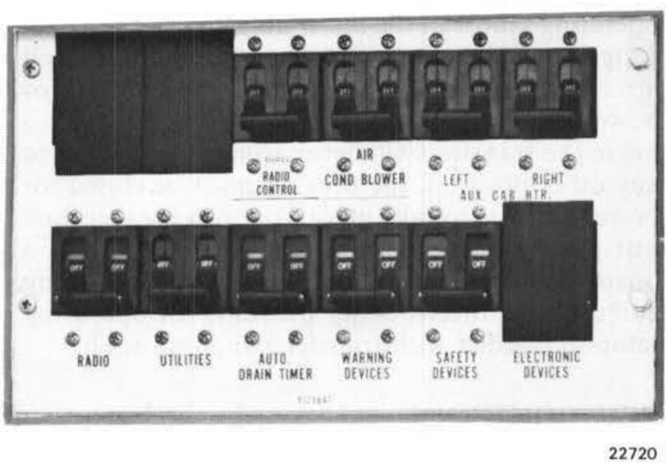


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Fig.6-17 – Typical No. 1 Circuit Breaker Panel

WATER COOLER

When an electric water cooler is provided, this circuit breaker protects the circuit.

TRAIN CONTROL

When automatic train control is applied, this circuit breaker protects the circuits.

AUTO WATER DRAIN

On special order the cooling system will drain automatically when coolant temperature in the automatic drain valve approaches freezing and the engine is shut down. This two-pole breaker protects the circuits.

RADIO CONTROL

When equipped for remote radio control, this breaker protects radio control circuits.

AIR COND. BLOWER

When equipped with air conditioning this breaker protects the blower fan motor circuits. A separate breaker for the air conditioner compressor is located on No. 3 circuit breaker panel.

AUX. CAB HTR.

These breakers protect the left and right auxiliary cab heaters. Heat control is provided by switches located on the control stand and on the cab front wall.

RADIO

Protects circuits that supply the radio, when equipped.

UTILITIES

When equipped, this breaker protects the toilet immersion heater, or similar devices.

AUTO. DRAIN TIMER

Protects circuits that control automatic operation of drain valves in the compressed air system.

WARNING DEVICES

This breaker protects signal light circuits, when equipped. This breaker may also be used to protect similar devices.

SAFETY DEVICES

Train overspeed brings about a penalty application of the brakes and operation of the pneumatic control switch to drop locomotive power. This breaker protects the overspeed magnet valve circuit. This breaker may also be used to protect similar devices.

ELECTRONIC DEVICES

Provision is made for application of circuit breaker to protect special warning or electronic devices.

NO. 2 CIRCUIT BREAKER PANEL

The No. 2 circuit breaker panel, Fig. 6-18, contains circuit breakers and switches that protect basic locomotive equipment and control systems. The panel is divided into three sections. The shaded middle section indicates breakers required on for locomotive operation. Breakers and switches in the unshaded sections are used as conditions require.

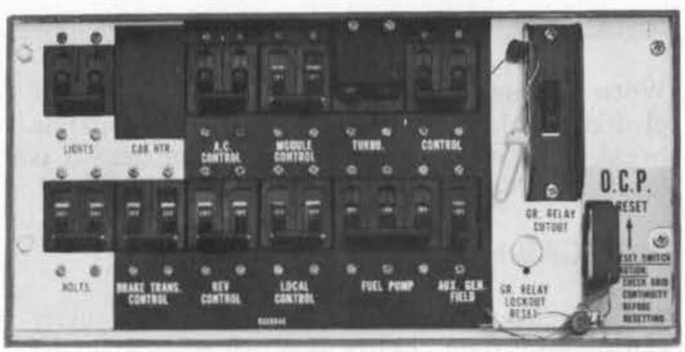

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Fig.6-18 - Typical No. 2 Circuit Breaker Panel

Breakers Required On For Locomotive Operation

A. C. CONTROL

This breaker protects the portion of the sensor module receiving A. C. power from the D14 alternator. The sensor module controls main generator field excitation current level. The no A. C. voltage relay (NVR) is also connected in this circuit. If the breaker trips during locomotive operation, the main generator will not develop power and the no power/charge light on the engine control panel will come on indicating no D14 output.

MODULE CONTROL

This breaker protects the local control circuit that supplies power to the circuit modules and miscellaneous control system devices.

TURBO

This breaker must be in the on position to start the engine and operate the turbocharger auxiliary lube oil pump. It must remain in the on position to provide auxiliary lubrication to the turbocharger before engine start and after the engine is shut down.

CONTROL

This breaker sets up the fuel pump and control circuits for engine starting. Once the engine is running, power is supplied through this breaker from the auxiliary generator to maintain operating control.

BRAKE TRANS. CONTROL

This double pole breaker is located in the feed to the operating motor of the multi-pole, motor operated, ganged switches that control the motor field and armature connections for either dynamic braking or power operation. Since control power is required to move the transfer switchgear from any position to any other position, the breaker must be closed for power transfer to take place. An open breaker does not prevent switchgear from already being in position to properly conduct motor or braking current, but interlocking prevents an operating setup in conflict with transfer switch position.

REV. CONTROL

This breaker is located in the feed to the operating motor of the multi-pole, motor operated, ganged switches that control the direction of current flow through the traction motor fields and thus control the direction of locomotive travel. Since control power is required to move the RV transfer switchgear from any position to any other position, this breaker must be closed for power transfer to take place. An open breaker does not prevent switchgear from already being in position to properly conduct traction motor current, but interlocking prevents an operating setup in conflict with transfer switch position.

LOCAL CONTROL

This two-pole circuit breaker establishes "local" power from the auxiliary generator to operate heavy duty switchgear and various control devices.

FUEL PUMP

This three-pole breaker protects the fuel pump motor circuit. A fuel filter bypass valve is provided to prevent overloading the fuel pump motor if the fuel filter becomes clogged.

AUX. GEN. FIELD

The field excitation circuit of the auxiliary generator is protected by this single-pole breaker. In the event that this breaker trips, it stops auxiliary generator output to the low voltage system and also stops fuel pump operation. An alternator failure (no power no battery charge) alarm occurs. The engine will stop from lack of fuel.

Miscellaneous Circuit Breakers

LIGHTS

This two-pole breaker must be on to supply power to switches that control miscellaneous locomotive lights.

CAB HTR.

These breakers provide protection for electrical cab heaters, when applied.

HDLTS.

This two-pole breaker must be on to provide current to the front headlight circuit and through the trainline to the light at the rear of the consist.

GROUND RELAY CUTOUT SWITCH

The purpose of the ground relay cutout switch is to eliminate the ground protective relay from the locomotive circuits during certain shop maintenance inspections. It must always be kept closed in normal operation. When this switch is open it prevents excitation of the main generator in addition to cutting out the ground protective relay.

OPEN GRID CIRCUIT RESET

This switch is used to reset the open grid circuit protective OCP system on units equipped with extended range dynamic braking. If an open circuit occurs in the dynamic braking grids or cabling, the OCP relay will pickup to actuate the OCL relay which latches in to lockout dynamic braking.

CAUTION

Do not reset the OCP switch. The OCP switch should only be reset by maintenance personnel following a thorough inspection of the dynamic brake grids and cabling.

NO. 3 CIRCUIT BREAKER PANEL

The No. 3 circuit breaker panel, Fig. 6-19, has provisions for five circuit breakers. The panel also contains a sealed section. This section contains a test panel intended for use by maintenance personnel during maintenance and testing procedures. A 74 volt receptacle and fuse test switch are also part of this panel.

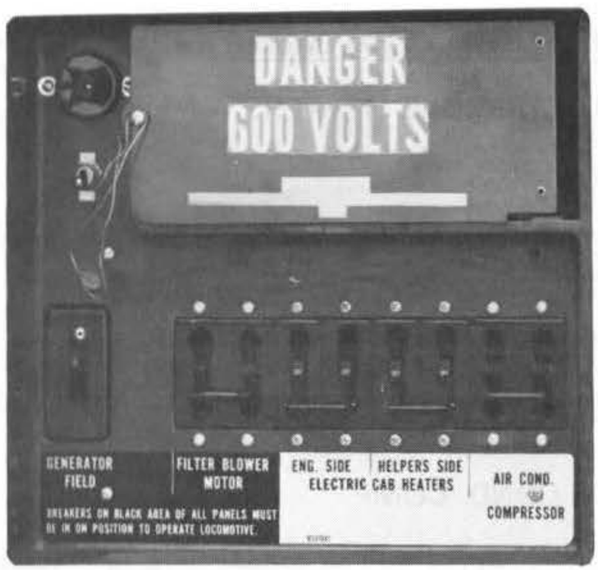

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Fig.6-19 – Typical No. 3 Circuit Breaker Panel

The circuit breaker portion of the panel is divided into two sections. Breakers in the shaded section are required on for locomotive operation. Breakers in the unshaded section are to be used as conditions require.

Breakers Required On For Locomotive Operation

GENERATOR FIELD

The main generator receives excitation current through a controlled rectifier from the D14 companion alternator. This breaker is provided to protect the controlled rectifier and both generators as well as associated circuitry.

NOTE

Unlike other breakers on the panel that trip to the full off position, the generator field circuit breaker will trip to the center position. After a period for cooling, the breaker must be placed in the full off position before resetting to the on position.

FILTER BLOWER MOTOR

This breaker protects the inertial filter blower motor circuit. The blower is used to evacuate dirt loaded air from the central air compartment inertial filters.

The FILT. MOTOR TRIP light on the engine control panel will come on if this breaker trips open or is inadvertantly left in the off position. If tripped open, operation may continue to the nearest maintenance point.

Miscellaneous Circuit Breakers

ELECTRIC CAB HEATERS

Eng. Side

Protects circuits to the cab heater at the engineer's station.

Helper Side

Protects circuits to the cab heater at the helper's side of the cab.

AIR COND. COMP.

When equipped with air conditioning, this breaker protects the air conditioner compressor motor circuits. A separate breaker for the air conditioner blower fan motor is located on the No. 1 circuit breaker panel.

FUSE TEST SWITCH

Refer to Fuse Test Equipment paragraph under Fuse And Switch Panel section.

74 VOLT RECEPTACLE

This receptacle makes 74 volts D.C. available for maintenance or testing purposes. Power is supplied to the receptacle when the main battery switch and the LIGHTS circuit breaker are closed.

FUSE AND SWITCH PANEL

The fuse and switch panel, Fig. 6-20, contains the equipment described in the following paragraphs.

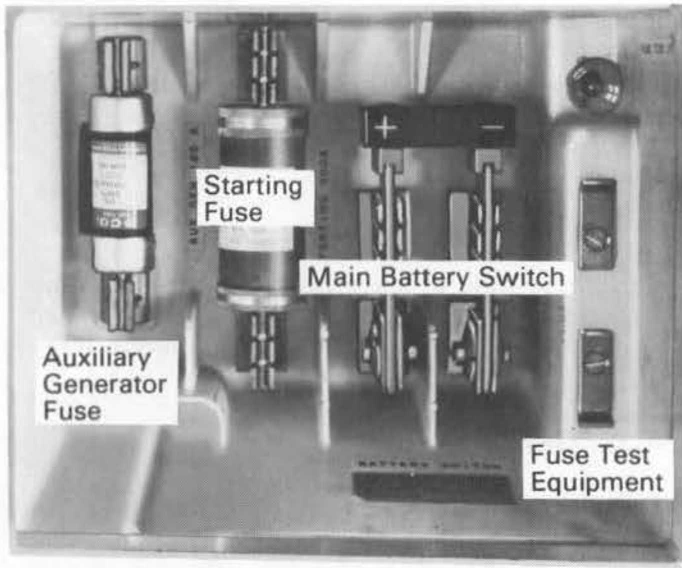

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Fig.6-20 – Fuse And Switch Panel

NOTE

There is no D14 alternator field fuse. The D14 field is connected directly across the output of the DC auxiliary generator to minimize any voltage drop in cabling, thereby maintaining full D14 excitation to ensure rapid fan motor starting. If a short occurs in this circuit, the machine, being self-excited, will not support the short. Voltage will come down and the machine will not be harmed. A NO BATT CHARGE/NO POWER alarm will be given, and engine speed and power will reduce to idle conditions.

AUXILIARY GENERATOR FUSE

This 150 ampere fuse connects the auxiliary generator to the low voltage system. It protects against excessive current demands. In the event that the fuse is burned out, it stops auxiliary generator output to the low voltage system and also stops fuel pump operation. An alternator failure (no power) alarm would then occur. The engine will go to idle speed and then stop from lack of fuel.

Auxiliary generator power to the cab heaters is taken from the generator side of the fuse. Therefore, current to the cab heaters does not flow through the fuse.

AUXILIARY GENERATOR CIRCUIT BREAKER

This breaker performs the same function as fuse (above). However, unlike the breakers on the panel that trip to the full off position, this breaker will trip to the center position. After a period for cooling, this breaker must be placed in the full off position before resetting to the on position.

STARTING FUSE

The starting fuse is in use only during the period that the diesel engine is actually being started. At this time, battery current flows through the fuse and starting contactor to the starting motors.

Although this fuse should be in good condition and always left in place, it has no effect on locomotive operation other than for engine starting. A defective fuse can be detected when attempting to start the engine, since at that time (even though the starting contactors close) the starting circuit is open.

CAUTION

This model may be equipped with either a 400 or 800 ampere starting fuse depending on starting motor connection. The two fuses are of the same physical size. Observe marking on panel. Do not use an incorrectly rated fuse.

MAIN BATTERY KNIFE SWITCH

This switch is used to connect the batteries to the locomotive low voltage electrical system and should be kept closed at all times during operation.

CAUTION

Do not open battery switch at engine shutdown following load operation. The turbocharger lube oil pump will come on and continue to run for approximately 35 minutes following engine shutdown, then shut off automatically. The 35 minutes allows turbocharger bearings to cool using engine lube oil.

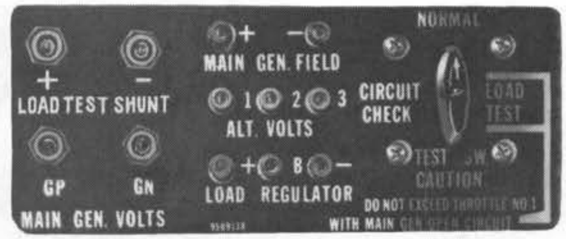
FUSE TEST EQUIPMENT

To facilitate testing of fuses, a pair of fuse test blocks and a test light are installed on the fuse and switch panel. A test light toggle switch is located on the No. 3 circuit breaker panel. Fuses may be readily tested as follows. Move test light switch to the on position to make sure the fuse test light is not burned out. Move test light switch to the off position to turn light off. Place fuse to be tested across the test blocks so that the metal ends of the fuse are in firm contact with the blocks. If the fuse is good the light will come on.

It is always advisable to test fuses before installation. Always isolate the circuits in question before changing or replacing fuses.

TEST PANEL

The test panel, Fig. 6-21, located on the No. 3 circuit breaker panel contains terminals and receptacles



23906

Fig.6-21 - Test Panel

that provide an easy place to read significant test voltages during operation or test. The test selector switch has the following positions.

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.

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.

CIRCUIT MODULE, Fig. 6-22

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.

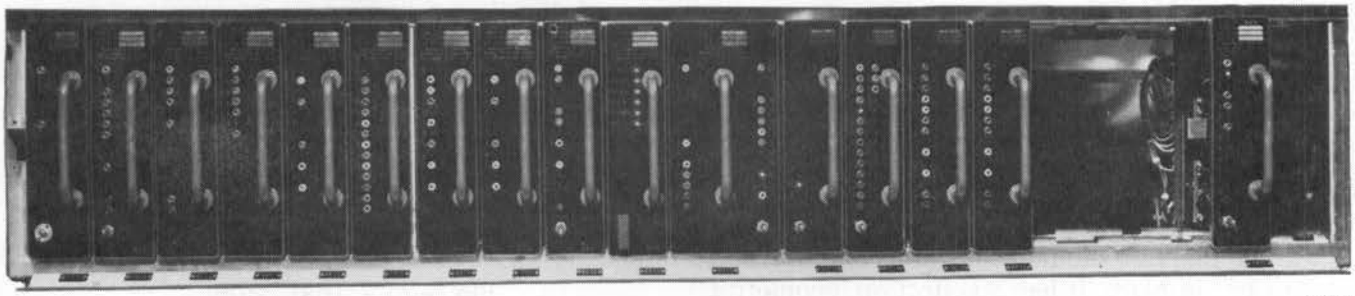


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Fig.6-22 - Module Compartment And Typical Circuit Modules

AN CIRCUIT MODULE - FAULT ANNUNCIATOR, Fig. 6-23

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.

19365

Fig.6-23 - Typical Annunciator Module

The basic annunciator provides the following indications.

1. Hot Engine.

2. Engine Air Filter Restriction.

3. Ground Relay Operated.

4. Excitation Limit Operated.

Units with dynamic brakes provide additional indications.

5. Grid Overcurrent.

6. Motor Overexcitation.

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

On special order the following indications may be applied.

8. Grid Blower Failure.

9. Locked Wheel.

10. Dynamic Brake Ground.

11. Filt. Blower Circuit Open.

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 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 protection module. A signal proportional to grid current I_G and a signal proportional to the voltage across the parallel combination of the grid blower motor and a portion of one braking grid E_G is applied to the DG module. The ratio of E_G to I_G increases as grid temperature increases. The DG module operates to lock out the dynamic braking system if this ratio increases above a predetermined value.

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.

EP CIRCUIT MODULE -
ENGINE PURGE

The engine purge system avoids the possibility of engine damage due to hydraulic lock by limiting engine cranking speed at startup. The EP module monitors cranking speed by sensing the starting motor current to voltage ratio - Engine cranking speed while starting is maintained between 25 and 30 RPM by inserting a limiting resistor RE EPC in the starter circuit for the first 6 seconds.

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.

LW CIRCUIT MODULE
LOCKED WHEEL DETECTION

When a locked wheel is detected by the locked wheel (LW) module, Fig. 6-23, the module causes the alarm to sound and turns on the LOCK WHEEL light on the engine control panel, the LOCKOUT light on the face of the module, and the LOCKED WHEEL light on the annunciator panel. When a locked wheel indication is observed, the locomotive should be stopped and a ground inspection made for the locked wheel with the locomotive moving slowly. If a wheel slides, the unit must be cut out of the train. If all wheels roll and the indicating light on the engine control panel and the alarm go off automatically, normal operation may continue.

The LW module, Fig. 6-24, receives signals from detectors at the traction motor armature shafts. The detectors used to sense wheel rotation are magnetic pickup devices that generate electrical pulses as metal teeth move past the pickup tips. The teeth are cut into the rotating bearing retainer plates. Since each tooth produces one pulse, the frequency at which the pulses occur is therefore proportional to motor speed. Circuits in the LW module convert the frequency-varying signals to DC voltage signals at levels related to motor rotating speed. Other LW circuits differentiate between low level signals (slowly rotating or locked wheels) and high level signals (freely rotating wheels). One or more low signal received along with one or more high signal brings about a locked wheel indication. The duration of the motor speed signals must exceed a delay period designed to prevent false locked wheel indications due to transient operating conditions. If a temporary locked wheel condition occurs (such as unequal air brake release), the locked wheel circuitry will automatically reset when all wheels rotate freely, but the annunciator module will retain the locked wheel indication. Whenever a locked wheel indication is observed on the annunciator module, the wheels should be inspected for flat spots.

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.

19158

Fig.6-24 - Locked Wheel Module

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

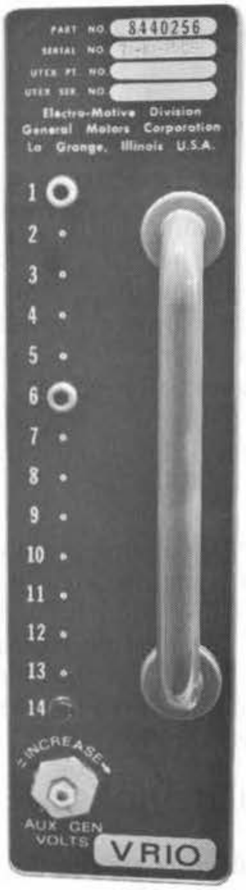
Transition is required in order to stay within current limitations of the main generator at low track speeds and within voltage limitations at high track speed. This is accomplished by using 3 parallel motor paths each with two motors in series at low speeds and 6 parallel single motor paths at high 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 relays. FTR pickup at a higher value than BTR pickup initiates forward transistion. BTR droput 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 module, Fig. 6-25, is used in the auxiliary generator field excitation circuit and



20529

Fig.6-25 - Voltage Regulator Module

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 VDC. 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

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.

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.

BC; BATTERY CHARGING ASSEMBLY

The battery charging assembly, Fig. 6-26, consists of a pair of heat sink mounted silicon diodes, in parallel with a selenium suppression rectifier, and a limiting resistor. The rectifier protects the diodes from high voltage spikes and prevents battery current from flowing in the windings of the auxiliary generator and D14 alternator when the diesel engine is stopped. The 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.

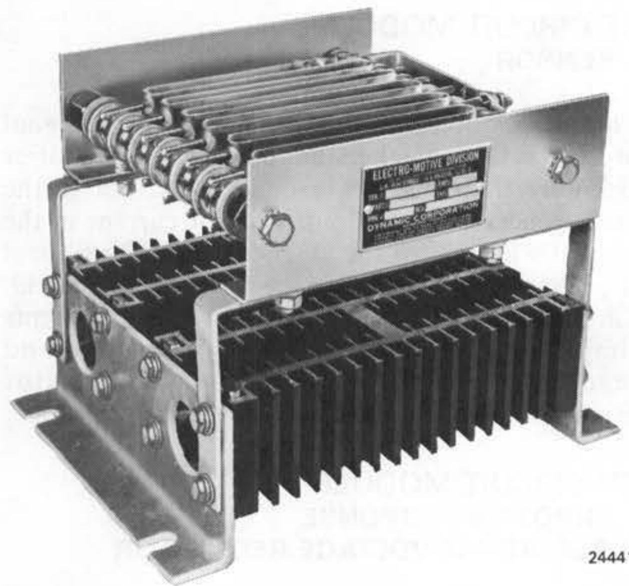


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Fig.6-26 - Battery Charging Rectifier

B; BRAKING POWER CONTACTOR, Fig. 6-27

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.

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.


17648

Fig.6-27 - Braking Power Contactor

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, BR3; 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. BR contacts are located in control circuits that carry small amounts of current and are made of gold alloy material.

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.

CA35

Connected in series with a resistor around operating coil of auxiliary pilot relay DP1A to maintain pickup of relay coil during opening and closing cycles of grid shorting contactors on units equipped with extended range dynamic brakes.

CA37

Acts to suppress a transient generated upon GFC contactor dropout.

CA42

Connected in series with a resistor around operating coil of equipment protective relay EQP to delay relay dropout due to transient circuit interruptions.

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 de-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 a traction motor cut out. This involves disabling a "P" power contactor and certain wheel slip control circuits, changing the slope and position of power control lines, and provides circuits around the interlocks that are not positioned because the related motor is cut out.

CR; RECTIFIERS

CR1 THRU CR4

Connected in a single-phase, full wave rectifier configuration at the ground relay GR operating coil to change AC signals to DC for rapid relay operation.

CR26 THRU CR29

Perform blocking functions in the dynamic brake regulator circuits on units equipped with basic dynamic brakes.

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 circuits 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 feed to RAA and RAB to prevent sanding during simultaneous wheel overspeed.

CR41

Blocks rate control capacitor discharge through the TH module.

CR42 THRU CR44

Perform blocking functions in low idle circuit.

CR45

Blocks backfeed from ORS circuit.

CR46

Blocks regenerative feedback from brake current transductor BCT through DE module circuits to RC module circuits.

CR47

Performs blocking function in reverse grid current protection circuit on units equipped with basic or extended range dynamic brakes.

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.

CR61 THRU CR64

Perform blocking functions in the dynamic brake regulator circuits on units equipped with extended range dynamic brakes.

CR66 AND CR67

Performs blocking function in reverse grid current protection circuits on units equipped with two speed extended range dynamic brakes.

CR76

Prevents false trainlined throttle response signals.

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; DYNAMIC BRAKE GRID SHORTING CONTACTORS

On locomotives equipped with extended range dynamic brakes, the DC power contactors, Fig. 6-28, close or open in sequence to short out approximately one-fourth dynamic braking grid resistance in each sequence. This reduction of braking grid resistance allows current flow through the remaining grids to continue at a high level as locomotive speed decreases.

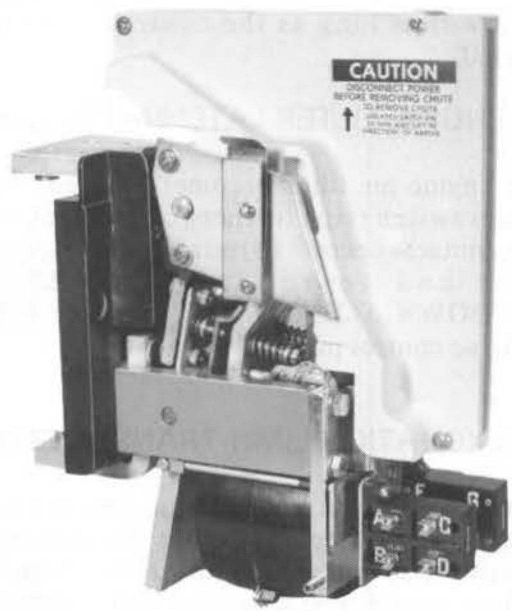

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Fig.6-28 – Dynamic Brake Grid Shorting Contactor

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 an intermittent duty blowout coil. This arrangement desensitizes the contactor to current direction (polarity) when properly installed. 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.

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 and 2.

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 circutis 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 turn on GOVERNOR SHUTDOWN/6TH. THROT. indicator light on the engine control panel.

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 (low idle speed, if equipped).

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 THL 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 winding. A test winding is 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

The cooling fan contactors on the AC cabinet 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

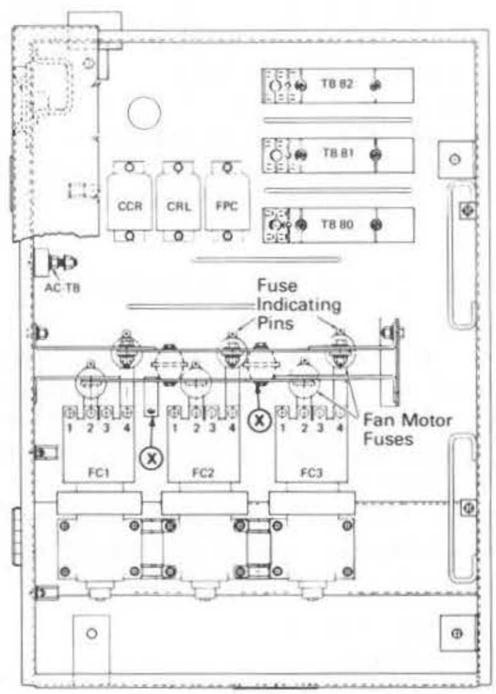
The control and fuel pump switch must always remain in the ON position while the engine is running. If an engine shuts down from lack of fuel, damage to the engine injectors is possible.

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

These 200 ampere bolted lug-type fuses located in AC cabinet, Fig. 6-29, protect against the following.



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

Ⓧ indicates AC cable terminals to be reversed for reverse fan operation.

19782

Fig.6-29 - AC Cabinet

1. Locked motor rotor due to bearing seizure or ice-bound fan blades.

2. Single phase motor windings.

3. Faulty fan contactors.
4. Faulty electrical plugs or cables.

The fuse 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 de-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.

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, the performance control module PF, and the 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 GRD RELAY 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 afer 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

The load regulator, Fig. 6-30, is a rheostat driven by a hydraulically operated vane motor. A pilot valve in the engine governor controls a flow of engine oil

27265

Fig.6-30 - Load Regulator

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 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

When the test panel switch is rotated to the LOAD TEST position, these switches, Fig. 6-31, 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.

MB; MOTOR BRAKE TRANSFER SWITCH

This switchgear, Fig. 6-32, 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

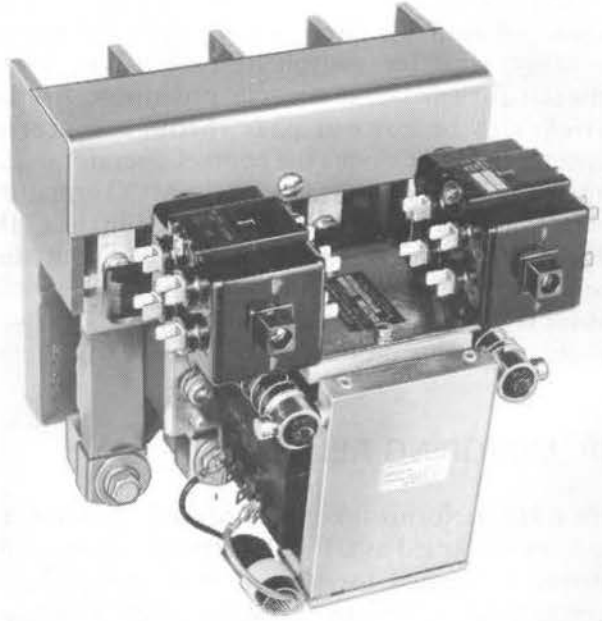


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Fig.6-31 - Load Test Transfer Switch

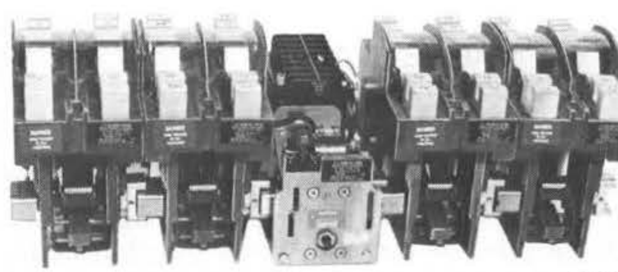

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Fig.6-32 - Typical Motor Operated Transfer Switch

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.

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 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

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, Fig. 6-33. 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

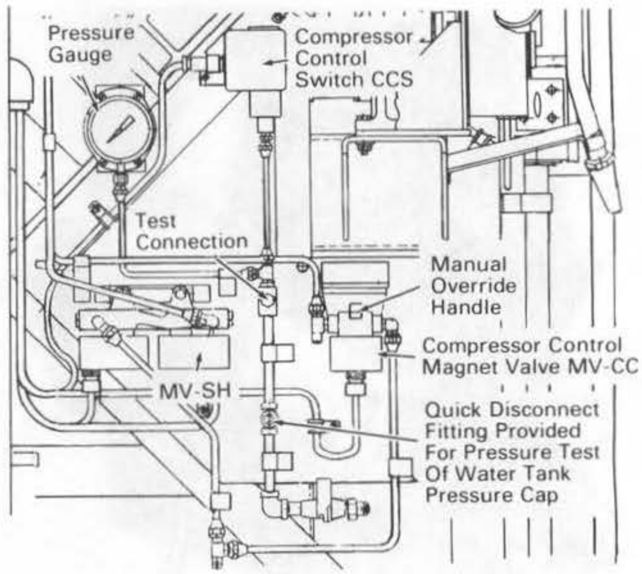

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Fig.6-33 - Air Equipment Mounting Panel

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. 6-34.

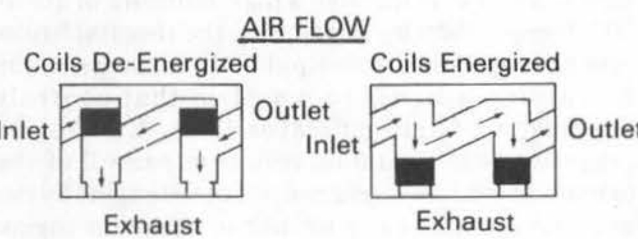

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Fig.6-34 - Shutter Magnet Valve Air Flow

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 about every three minutes.

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.

NIR; NORMAL IDLE RELAY

Engine speed will remain at normal idle when this relay is energized. When de-energized, NIR relay contacts close to energize the "A" and "D" governor solenoid valves resulting in low idle engine speed.

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.

OCL; OPEN CIRCUIT LOCKOUT

The OCL relay works in conjunction with the pickup of OCP relay which provides open circuit protection on units with extended range dynamic brakes. When an open circuit is detected in the dynamic brake resistor grids or cables, the contacts of this relay operate to disable the dynamic brake system, and actuate the Grid Open Circuit fault light on the annunciator module AN. One set of OCL contacts provides a feed to the OCL relay to maintain relay pickup until the OCP reset pushbutton is pressed.

OCP; OPEN CIRCUIT PROTECTIVE RELAY

On units equipped with extended range dynamic brakes, this relay is bridge connected between motor armatures and dynamic braking reistor grids during dynamic braking. If an open occurs in the grids or cables, the relay picks up to actuate the OCL relay which 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; PENUMATIC 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—; SP—; POWER CONTACTORS

Power contactors, Fig. 6-35, 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.

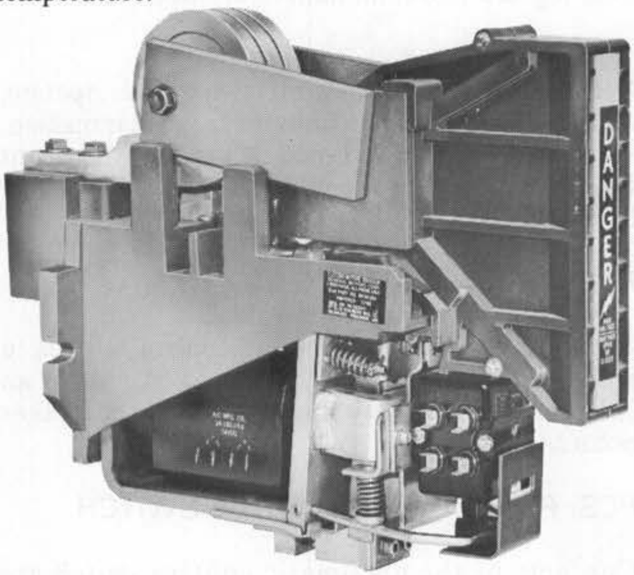

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Fig.6-35 - Power Contactor

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

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

RE1A-B

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 - C

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.

RE11; RE12

These resistors are connected across starting solenoids SM1 and SM2 to increase current through the starting motors during engagement. This increase in current is sufficient for positive engagement of pinion gear with ring gear.

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.

RE36; RE37

Provide limiting resistance in circuits for the open grid protection system on units equipped with basic dynamic brakes.

RE39

Used to modify SE operating characteristics during dynamic braking.

RE40

Provides limiting resistance in reverse grid current protection circuits.

RE41

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

RE42

With CA42 acts to suppress transient circuit interruptions of equipment protective relay EQP.

RE43

Provides the load for the OCP relay during an open grid circuit.

RE44

Controls the rate control capacitor discharge rate through grid current control circuits on units equipped for trainlined grid current control or with extended range dynamic brakes.

RE45

Used with CA34 in a circuit which senses increases in dynamic braking effort and "anticipates" overshoot. The anticipation circuit calls for discharge of rate control capacitors through the DR circuits and ensures slow buildup of braking effort. On special order, extra capacitors can be used with CA34.

RE46

With CA35 establishes circuit to maintain pickup of DP1A relay during cycling of dynamic brake grid shorting contactors.

RE50

Provides limiting resistance for engine control panel indicator lights.

RE53, RE59-1A - B THROUGH RE59-3A - B

These resistors, in conjunction with RH51, provide proper voltage for various gauge lights.

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 braking handle. It consists of a plate type potted assembly. Its resistance is used in combination with RE-DB.

RH51

This rheostat provides feed to various gauge light circuits.

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.

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 votlage 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 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 turns on the GOVERNOR SHUTDOWN/6TH. THROT. indicator light on the engine control panel.

FVS; FILTER VACUUM SWITCH

This switch senses the pressure drop across the inertial plus the 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 outlet 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.

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

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 companion alternator to the field of the AR10 main generator.
4. Use of throttle control 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 companion alternator. When the diesel engine is running, the companion field excitation is maintained at a nominally constant level.

Three phase alternating current is taken from the companion 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.

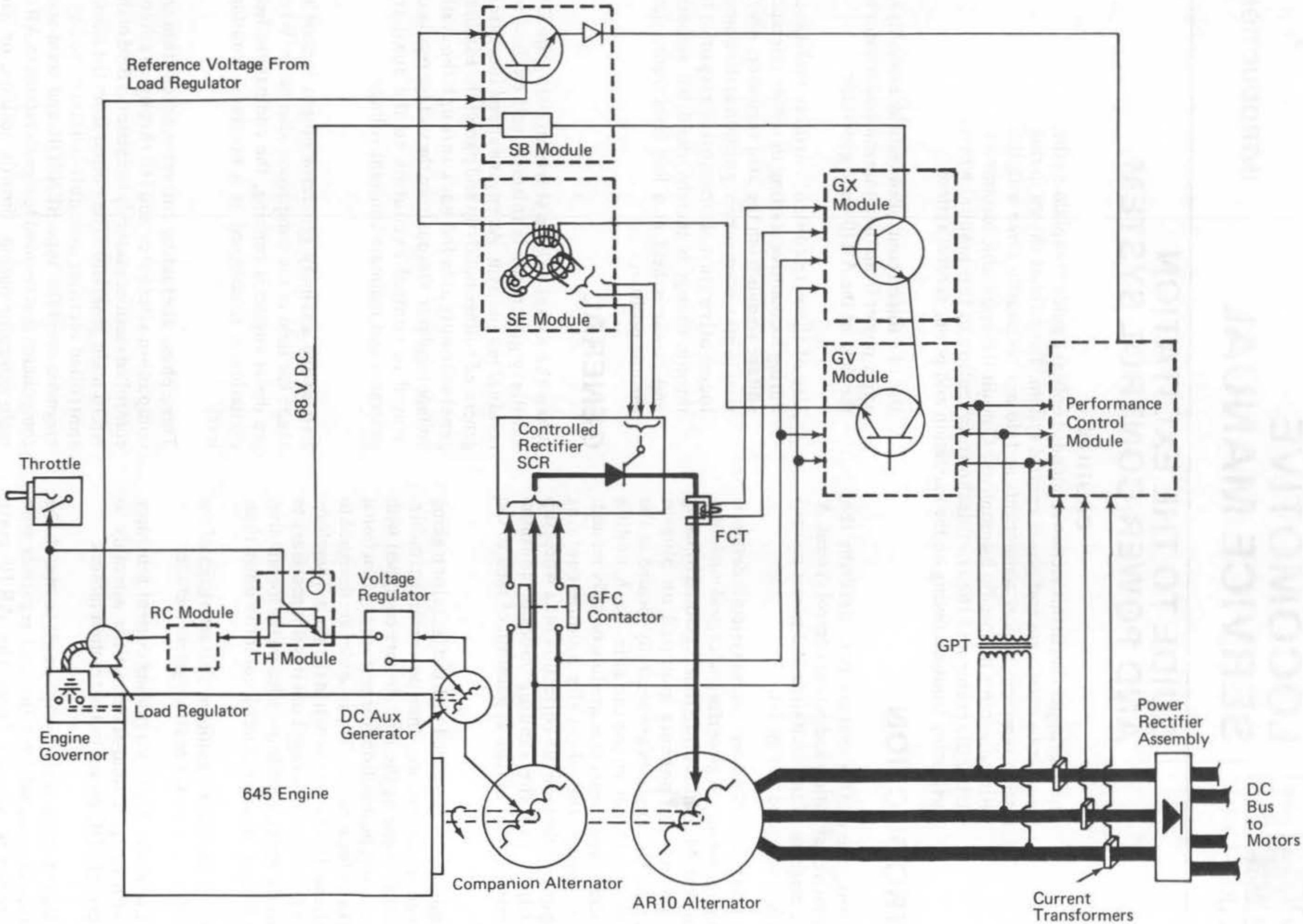

Fig.7-1 – Excitation System Block Diagram

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. ACAG - AC Auxiliary Generator (Special Order)
3. AR10 - AR10 Main Generator And Ground Relay Protection System
4. Companion Alternator
5. VR - Voltage Regulator Module, VR10
6. VR - Voltage Regulator Module, VR11 (Special Order)

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(s)
6. RC - Rate Control Module
7. SB - Sensor Bypass Module
8. SCR - Silicon Controlled Rectifier Assembly
9. SE - Sensor Module
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. WS - Wheel Slip Module
3. WSBC - Wheel Slip Bridge Circuit
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 Modules

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.

PART F - MISCELLANEOUS CONTROL CIRCUITS AND DEVICES

Description of various types of automatic ground relay reset circuits and hot engine and engine filter power reduction system.

The contents of Section 7 Part F are presented in the following order:

1. AGR - Automatic Ground Relay Reset Assemby 8488371
2. AGRL - Automatic Ground Relay Reset Limiter 8408360
3. EP - Engine Purge System 8498709 - EP11
4. PR - Hot Engine And Engine Filter Power Reduction
5. RS - Radar Speed Module - RS15

GENERATORS AND VOLTAGE REGULATOR

Part A of Section 7 provides a general description of the auxiliary generator, auxiliary generator voltage regulator, companion alternator, and AR10 main generator assembly.

The auxiliary generator provides a nominal output voltage of 74 volts for excitation of the companion 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 companion 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:

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

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 or 24 kW 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 companion 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.

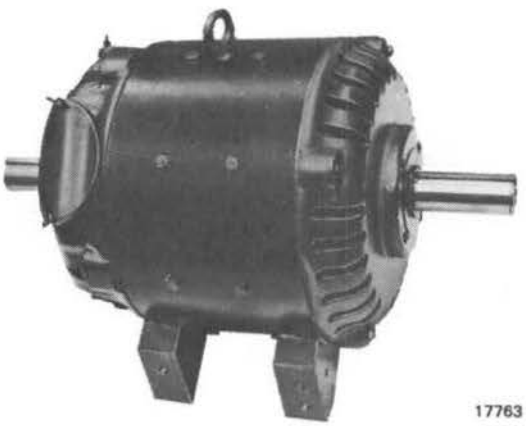
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Fig.AG-1 - 10 kW Auxiliary Generator

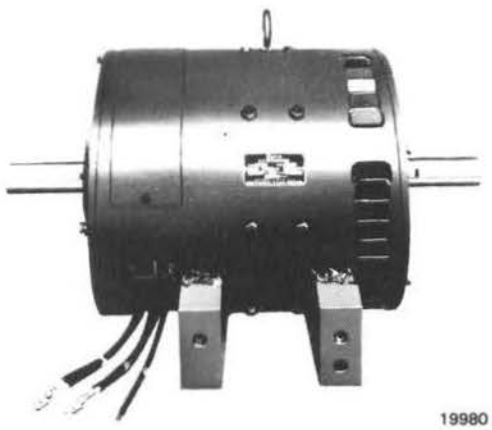
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Fig.AG-2 - 18 or 24 kW Auxiliary Generator

LOCOMOTIVE SERVICE MANUAL

AC AUXILIARY GENERATOR

The AC auxiliary generator, Fig. ACAG-1, consists of a three-phase pilot exciter assembly and a three-phase AC auxiliary generator field and armature assembly. The nominal output rating of the AC auxiliary generator is 18 kW at 55 VAC. The three-phase 55 VAC output is applied to a full-wave three-phase rectifier assembly to obtain 74 VDC output for battery charging, companion alternator excitation, and low voltage DC control power.

The three-phase pilot exciter assembly consists of a stationary field, a rotating armature, and a rotating rectifier assembly. The AC auxiliary generator has a rotating field and a stationary armature. The pilot exciter rotating armature and rotating rectifier assembly and the AC auxiliary generator rotating field are installed on a common shaft.

During start up, residual magnetism of the pilot exciter stationary field induces a voltage into the pilot exciter rotating armature. This AC voltage is rectified by the pilot exciter rotating rectifier assembly and applied to the AC auxiliary generator rotating field. This rotating field induces a voltage into the AC auxiliary generator stationary armature. Output voltage of the AC auxiliary generator armature is applied to an external three-phase full-wave rectifier and fed back to the pilot exciter stationary field through a voltage regulator assembly. This positive feedback results in fast voltage buildup. Description of the voltage regulator assembly is provided in Section 7 Part A-VR.

Fig. ACAG-1 – AC Auxiliary Generator

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

MAIN GENERATOR AND GROUND RELAY PROTECTION SYSTEM

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 operation of electrical generators is such that alternating current is produced. Because 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 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 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 companion alternator and the AR10 main generator. The companion alternator is described in Part A – Companion Alternator 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

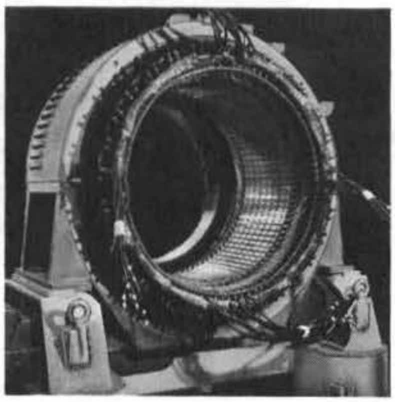

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Fig.AR10-2 – AR10 Stator Assembly

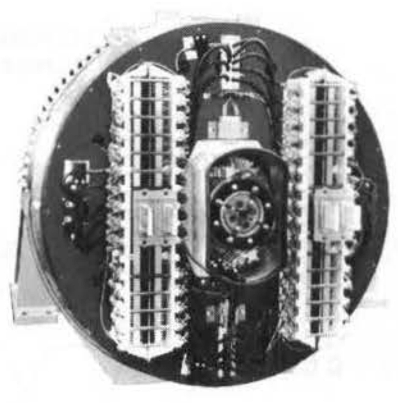

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Fig.AR10-3 – AR10 Rectifier Bank Assembly

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 collector 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.

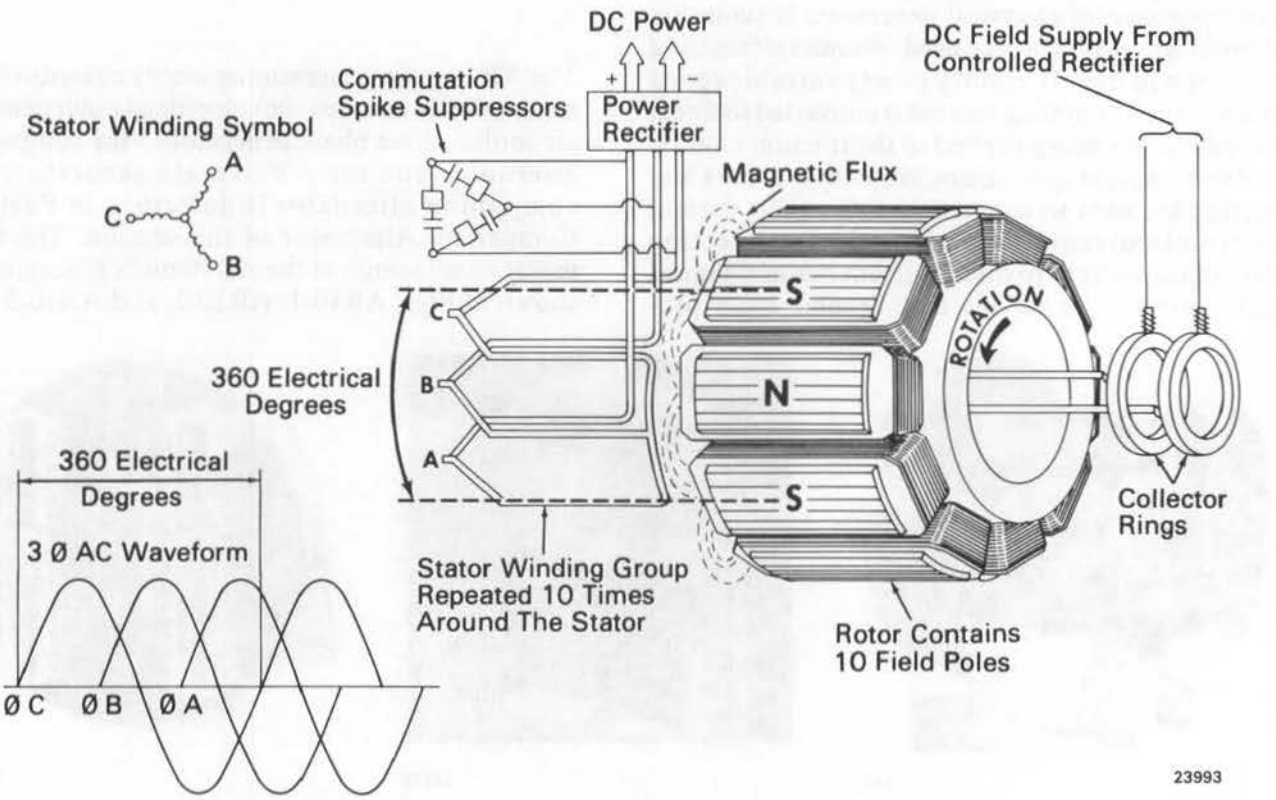

Fig.AR10-4 – Main Generator Pictorial Diagram

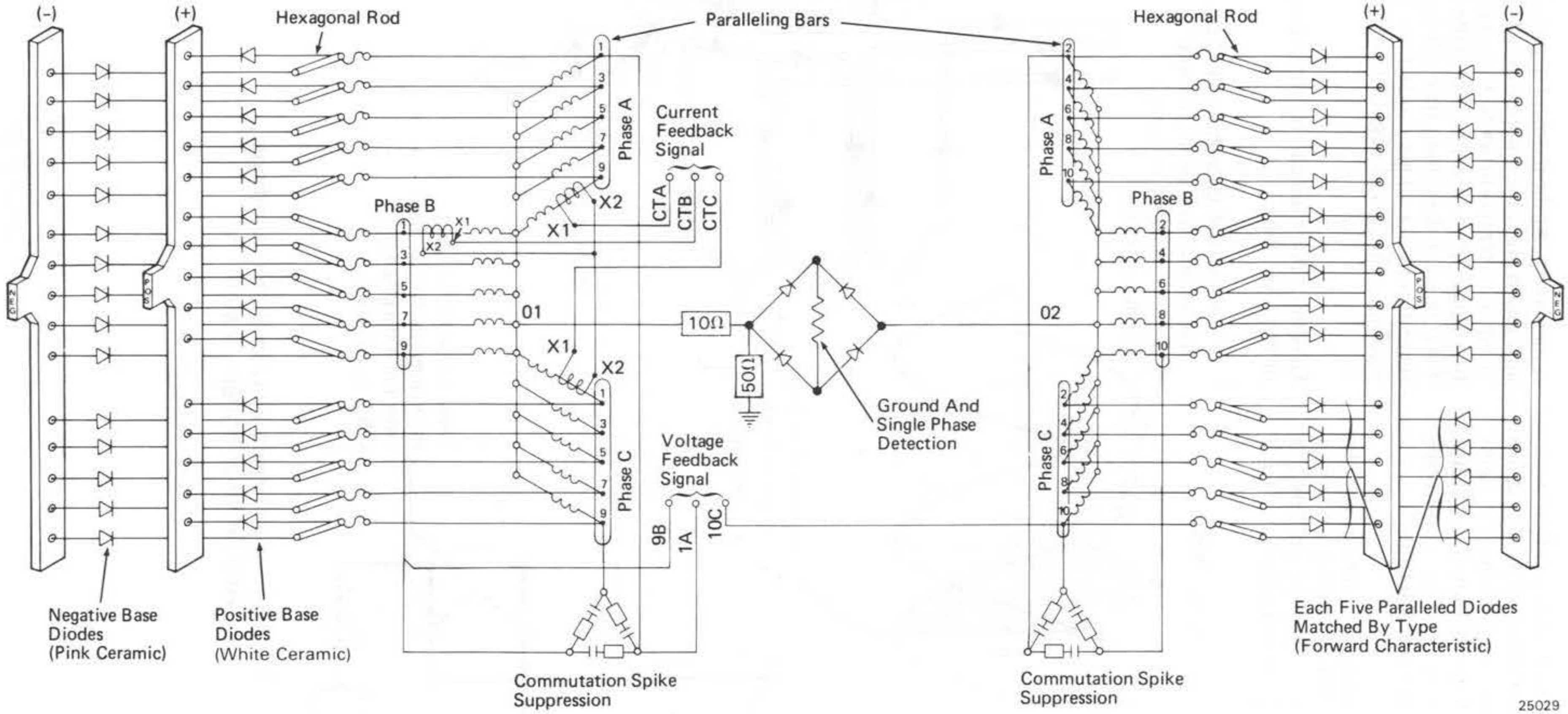

Fig.AR10-5 – AR10 Wiring Diagram

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.

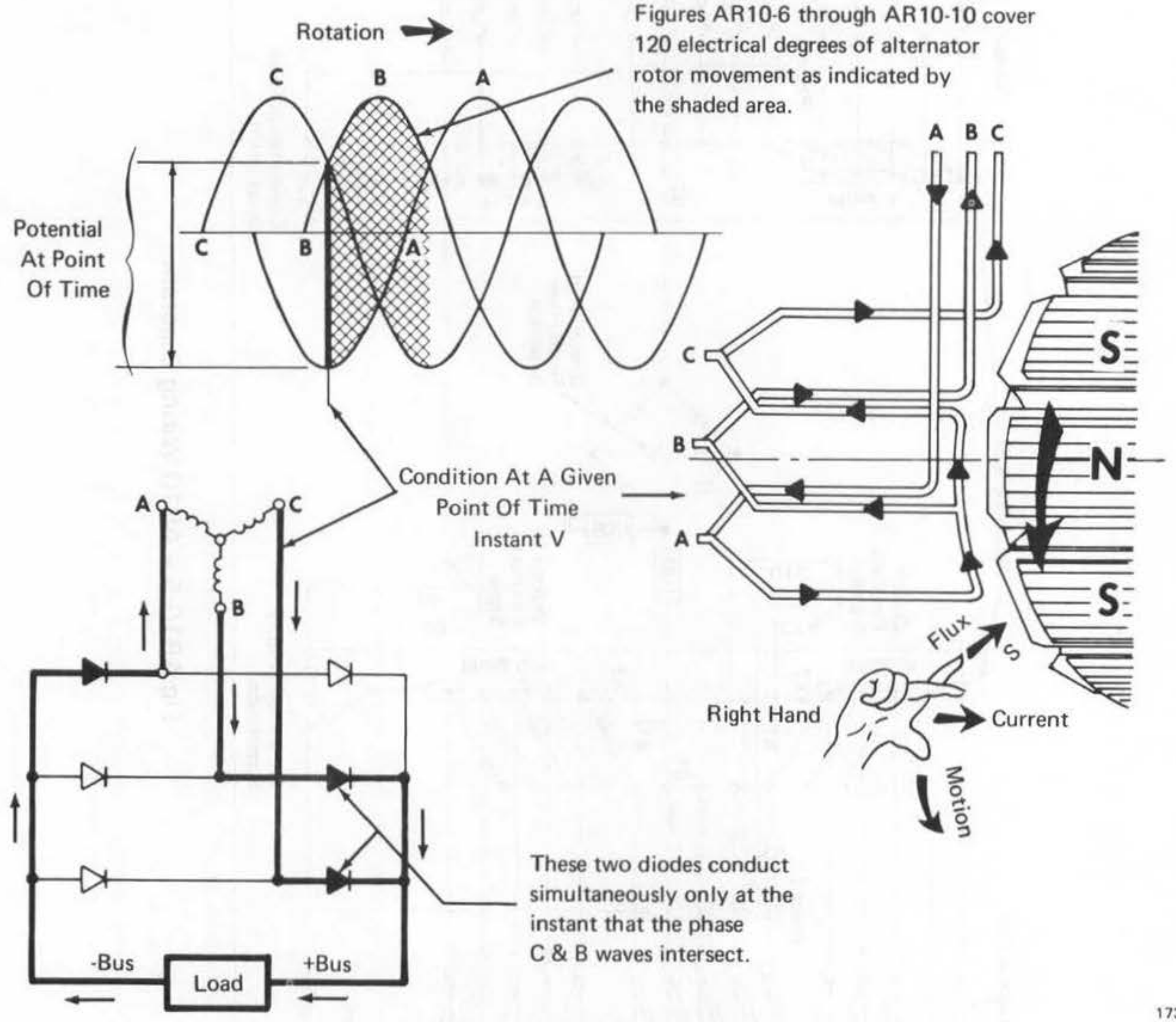

Fig.AR10-6 – Current Flow In Stator Windings And Rectifier Bridge - Instant "V"

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.

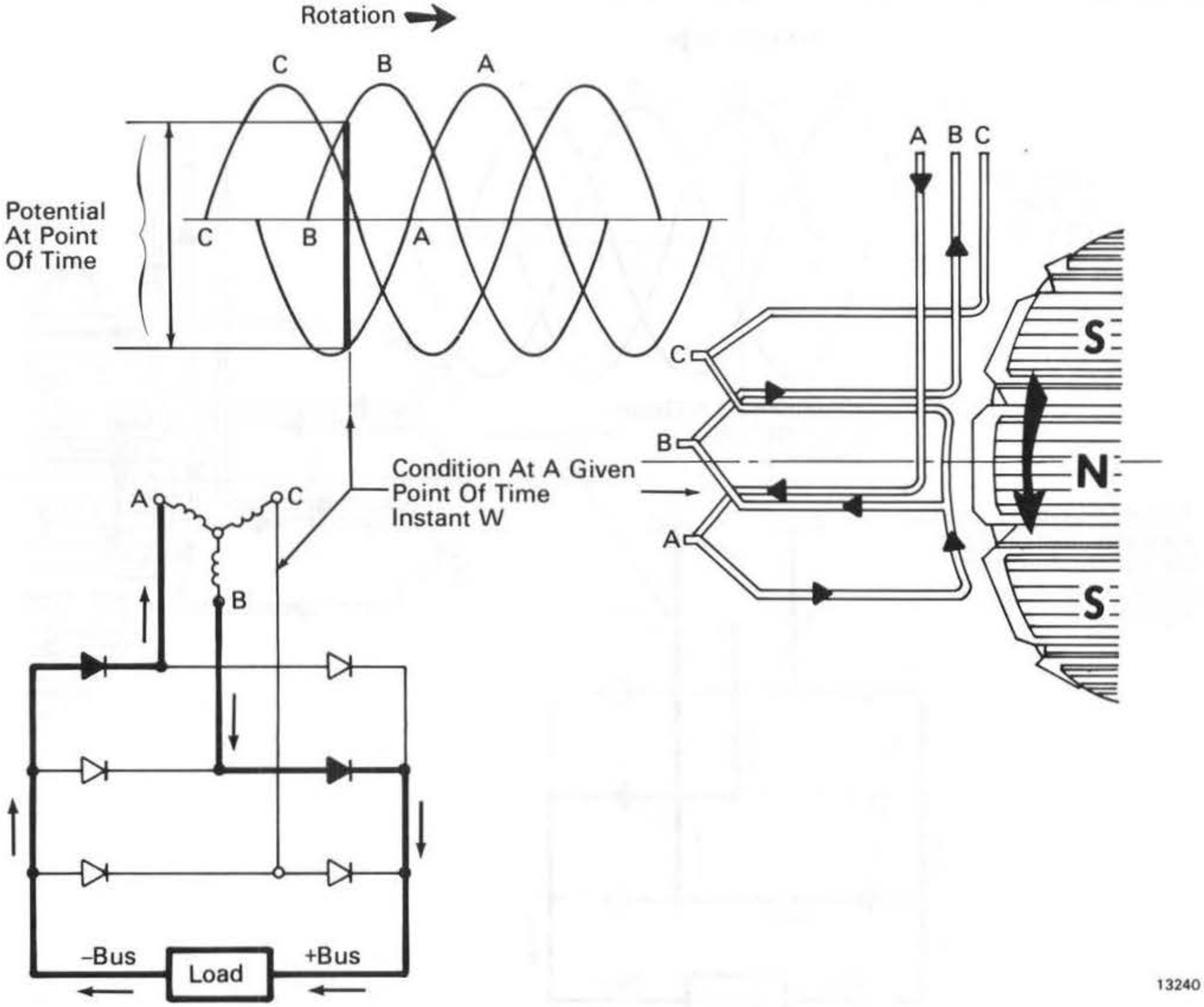

Fig.AR10-7 - Current Flow In Stator Windings And Rectifier Bridge - Instant "W"

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.

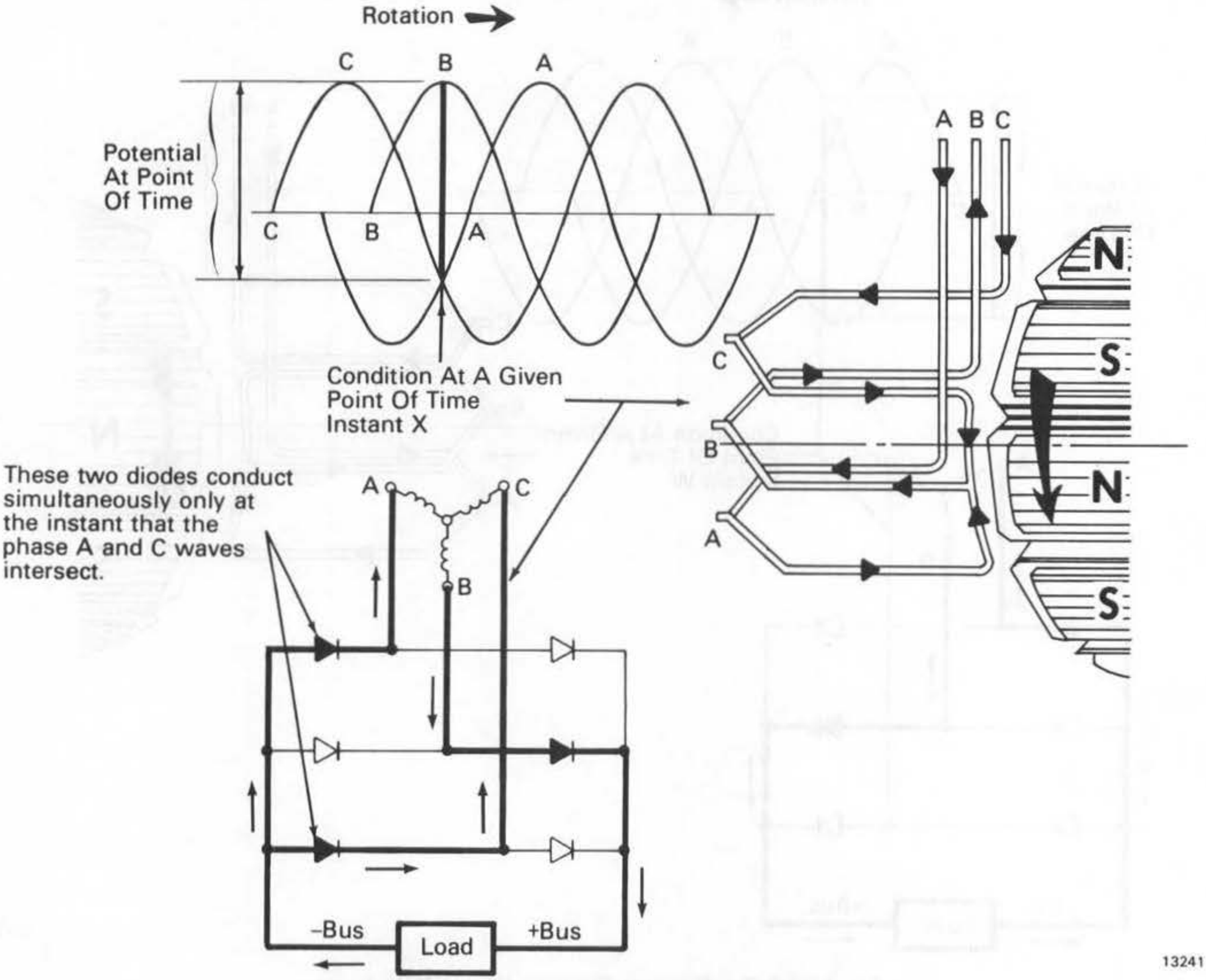

Fig.AR10-8 – Current Flow In Stator Windings And Rectifier Bridge - Instant "X"

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.

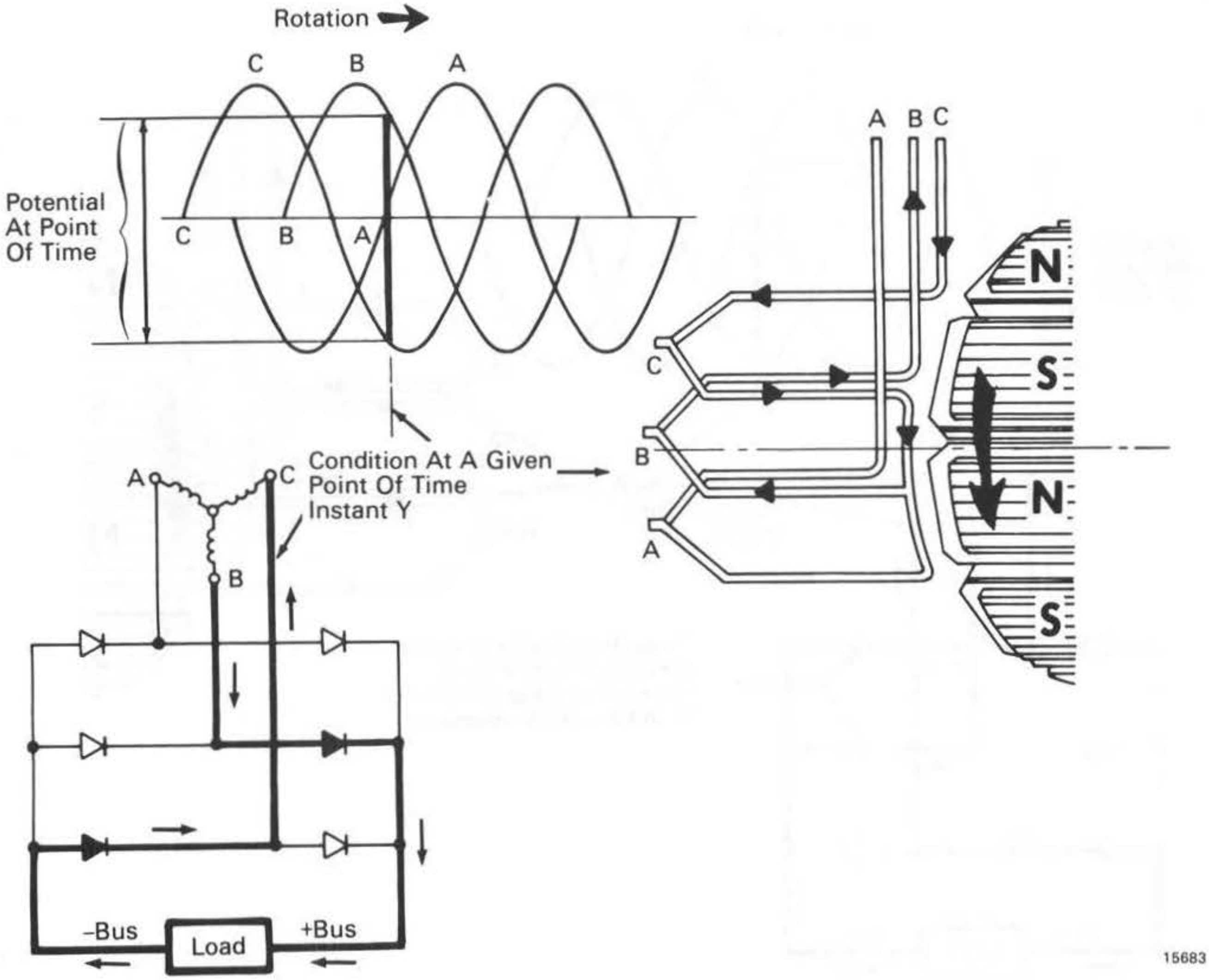

Fig.AR10-9 – Current Flow In Stator Windings And Rectifier Bridge - Instant "Y"

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.

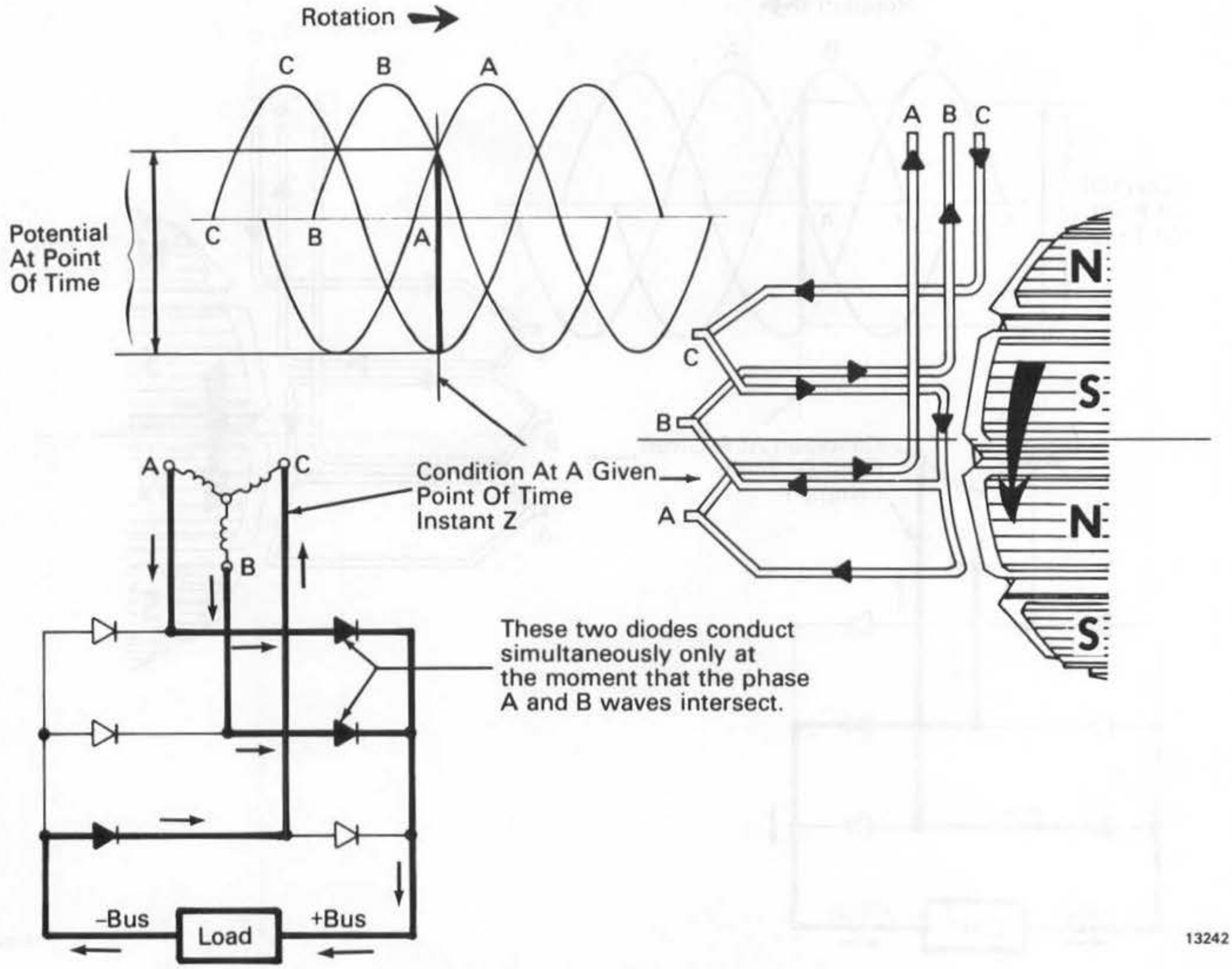

Fig.AR10-10 - Current Flow In Stator Windings And Rectifier Bridge - Instant "Z"

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.

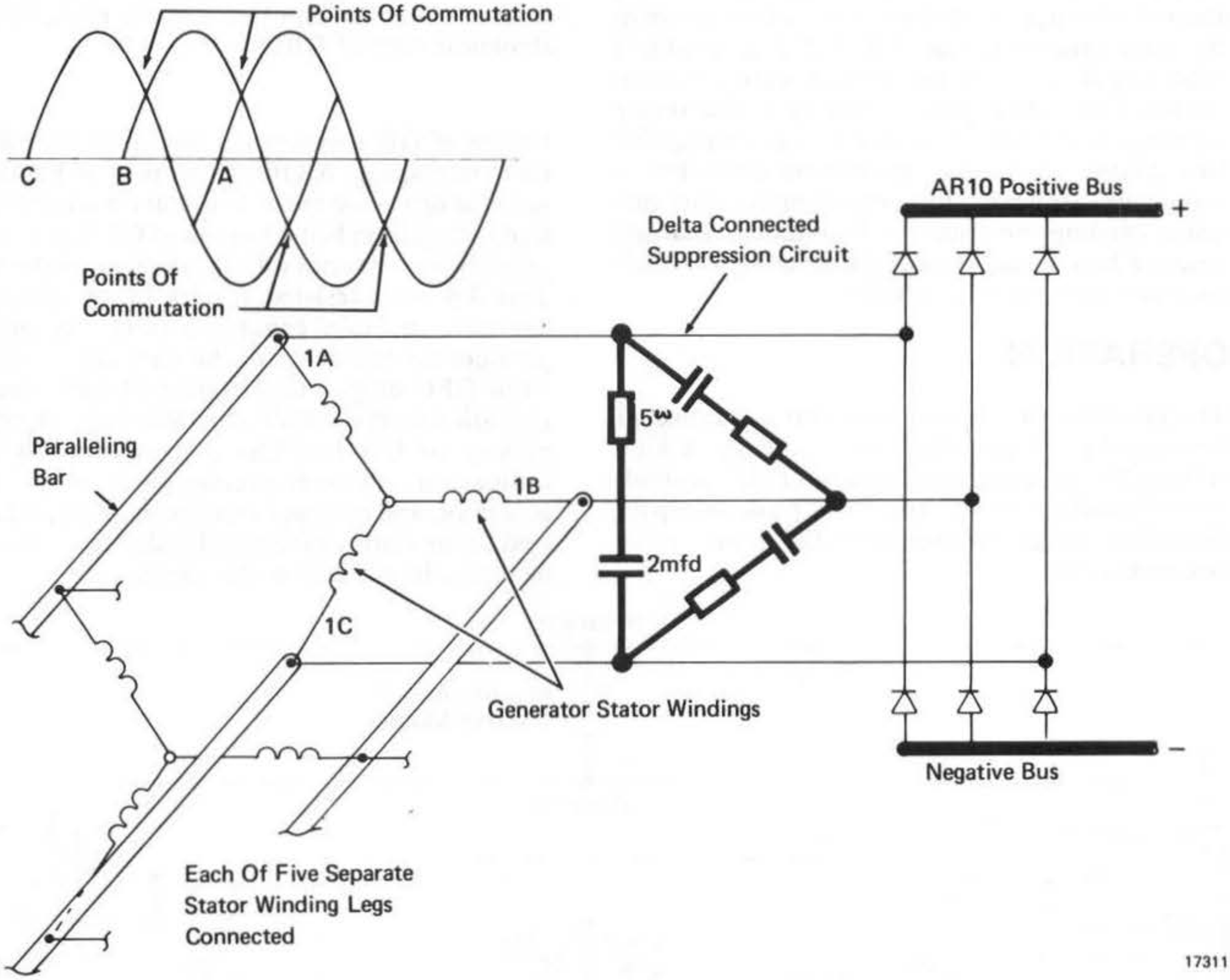

Fig.AR10-11 – Delta Connected Suppression Circuit - Simplified Diagram

GROUND RELAY PROTECTION SYSTEM

INTRODUCTION

The purpose of the ground relay protection system is to protect the main generator, traction motors, and high voltage wiring, and to reduce the possibility of electrical fires by removing excitation from the main generator field when a ground or certain faults occur in the high voltage system.

The ground relay protection system detects high voltage DC grounds, main generator AC grounds, shorted windings, or the loss of one phase group in the main generator. Fig. AR10-12 is a simplified schematic diagram of the ground relay detection circuit. Each phase group consists of five stator windings, five positive base diodes, and five negative base diodes. Three phase groups are connected to each bank. However, for simplification, only one stator winding, one positive base diode, and one negative base diode of each phase group for each bank are shown in Fig. AR10-12.

OPERATION

The ground relay detection circuit is connected between the left and right bank neutral. A high voltage DC ground, main generator AC ground, shorted windings, or the loss of one phase group on either bank results in energizing the ground relay GR pickup coil.

Pickup of GR provides a feed to the ground relay light on the AN module, to the ground/fault light on the engine control panel, and also sets up the circuit between the GR reset coil and the ground/fault reset switch. On basic order locomotives, pick up of GR operates a mechanical latch so that GR contacts remain in the operated position, opposite to the position shown in Fig. AR10-13, until the ground/fault reset switch, located on the locomotive control stand is closed. Closing the ground/fault reset switch energizes the GR reset coil which releases the mechanical latch and allows the GR contacts to move to their normal position, provided a ground or fault has been cleared. Upon special order from the customer, the locomotive may be equipped for automatic reset of GR.

Pickup of GR removes the feed from the ER and GFD relays, Fig. AR10-13. Dropout of ER results in reducing engine speed to idle and also provides a feed to the alarm bell. Dropout of GFD places a 4.8 ohm resistor in series with the main generator field. This 4.8 ohm resistor results in an immediate decrease in main generator field current and provides for fast decay of the main generator field when GFC drops out. Dropout of GFC removes excitation from the main generator field. Therefore, pickup of GR provides a ground/fault light indication, removes excitation from the main generator, and provides a feed to the alarm bell. The feed to the alarm bell is trainlined so that the alarm bell rings in all units of the consist.

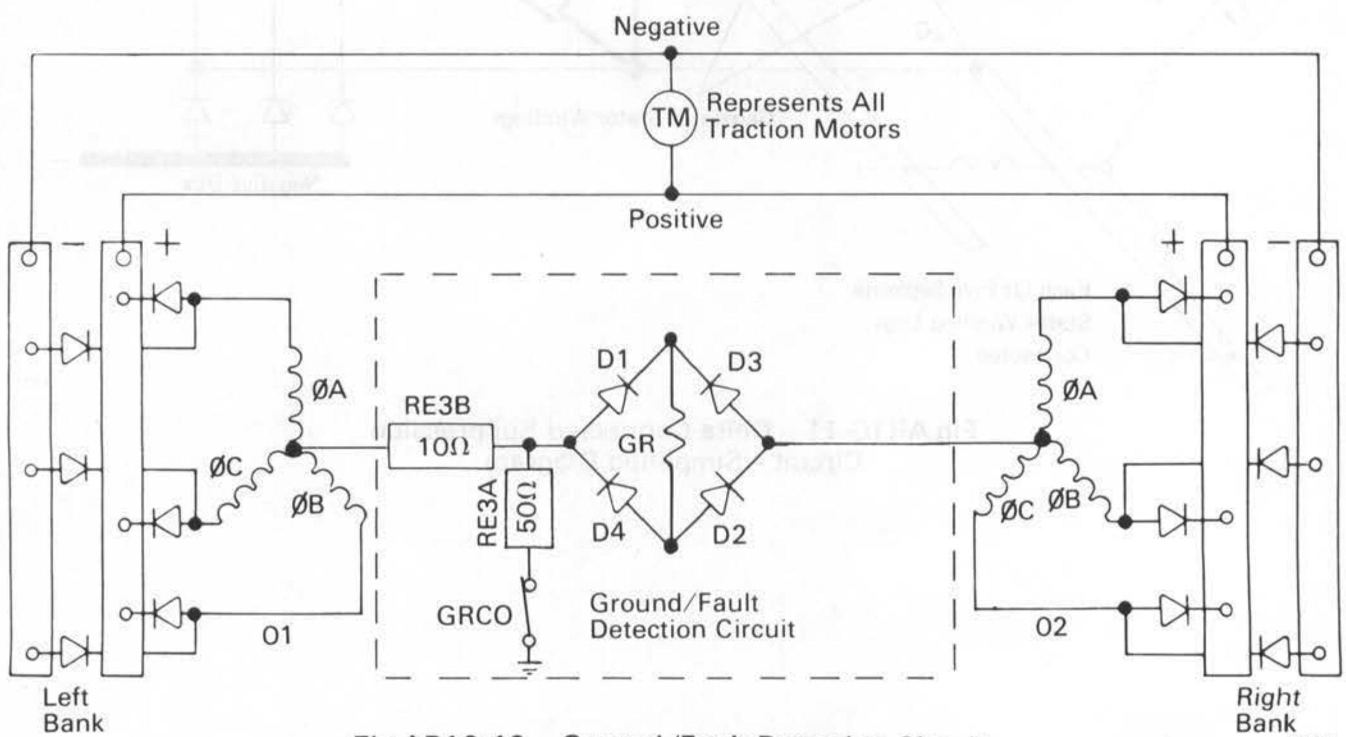

Fig.AR10-12 – Ground/Fault Detection Circuit, Simplified Schematic Diagram

After pickup, GR may be reset after a 10 second waiting period. To reset GR, press the ground/fault reset pushbutton located on the locomotive control stand. It is not necessary to isolate the unit nor is it necessary to place the throttle in IDLE position before pressing the reset pushbutton, unless the locomotive is at a standstill.

Repeated resetting of the ground relay is possible, but instructions as issued by the railroad regarding repeated resetting must be followed. However, in the absence of definite instructions to the contrary, isolate a unit when the ground/fault light comes on for the third time after resetting.

CAUTION

Always report ground/fault light indications to proper maintenance personnel.

A ground relay cutout switch GRCO is provided to eliminate the ground protective relay circuit from locomotive circuits during certain shop maintenance inspections. The switch is a three pole device, with one pole disconnecting the GR relay from ground. The other two poles open the feed to ER and GFC relays. Dropout of ER limits engine speed to idle. Dropout of GFC prevents excitation of the main generator field.

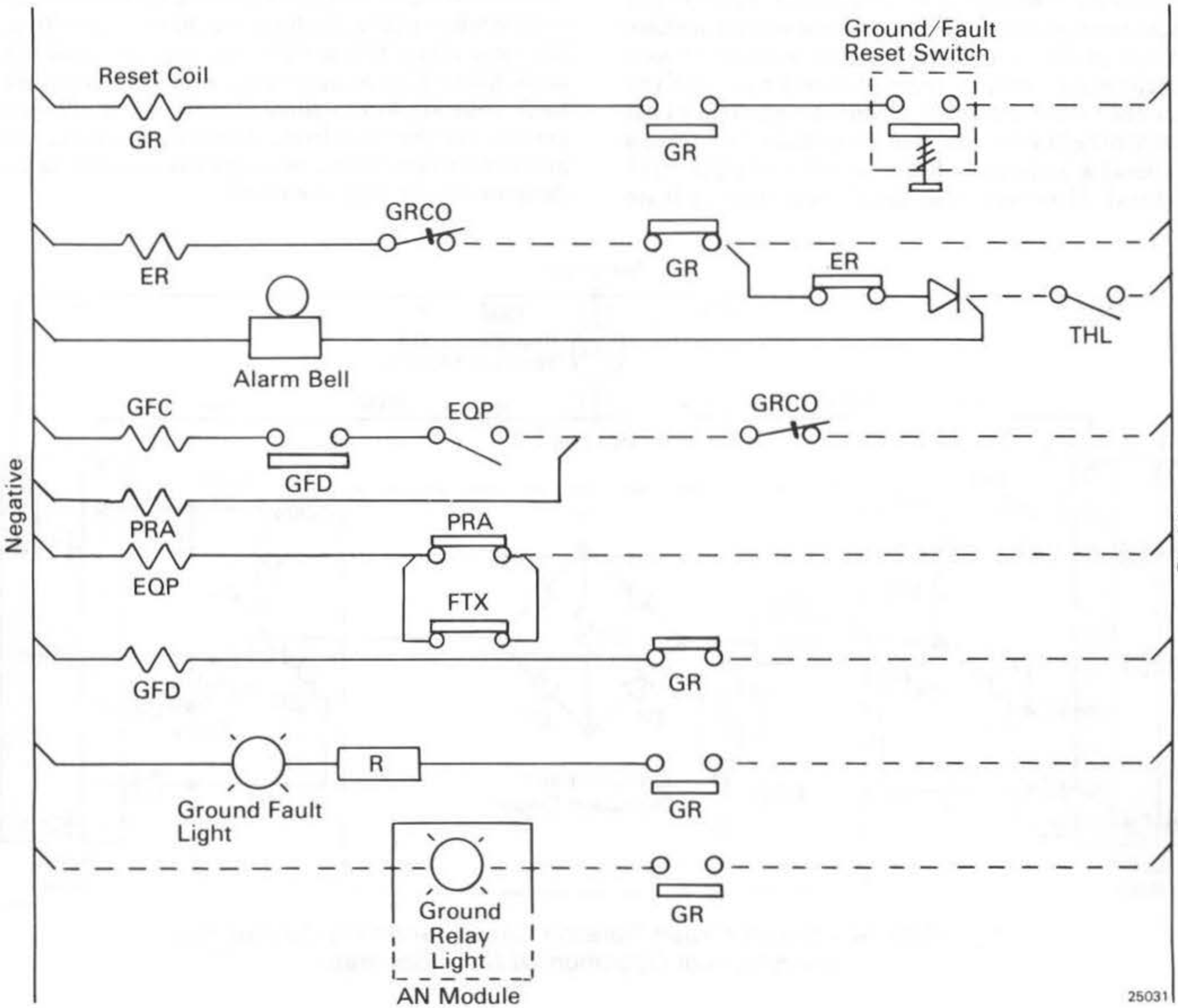

Fig.AR10-13 - Ground Relay Protection Circuit, Simplified Schematic Diagram

MAIN GENERATOR AC GROUND/FAULT

The ground relay detection circuit consists of RE3A, RE3B, GR, the ground relay cutout switch GRCO and four diodes, D1 through D4, Fig. AR10-14. A current of 0.750 to 0.825 amperes through GR will result in pickup of GR. Therefore, a voltage unbalance of approximately 8.15 to 8.96 volts between left and right bank neutral should result in pickup of GR.

An unbalance between the neutrals may be caused by an open phase group on the left or right bank, or by shorted windings in a phase group on the left or right bank. Leakage current to ground from a phase group of the left or right bank will result in a circulating current from ground through the ground/fault detector circuit to neutral. This circulating current may not be sufficient to cause a noticeable unbalance between left and right bank neutral. However, the circulating current from ground through the ground/fault detector circuit will result in pickup of the ground relay, if the leakage to ground occurs at a point which is 8.15 to 8.96 volts or more from the neutral.

RIGHT BANK PHASE A OPEN

A voltage unbalance between left and right bank neutral will occur whenever an open occurs in a left or a right bank phase group. This voltage unbalance results in current flow through the ground/fault detector circuit. A description of this action is presented in the following paragraphs.

Assume that the main generator is operating under a normal balanced condition and at a specific instant of time when left bank phase A is 500 volts positive, left bank phase B is at 500 volts negative, and left bank phase C is at zero volts with respect to left bank neutral. Also assume these same conditions are true for the right bank. The system is balanced and no current flows through the ground/fault detector circuit, Fig. AR10-14.

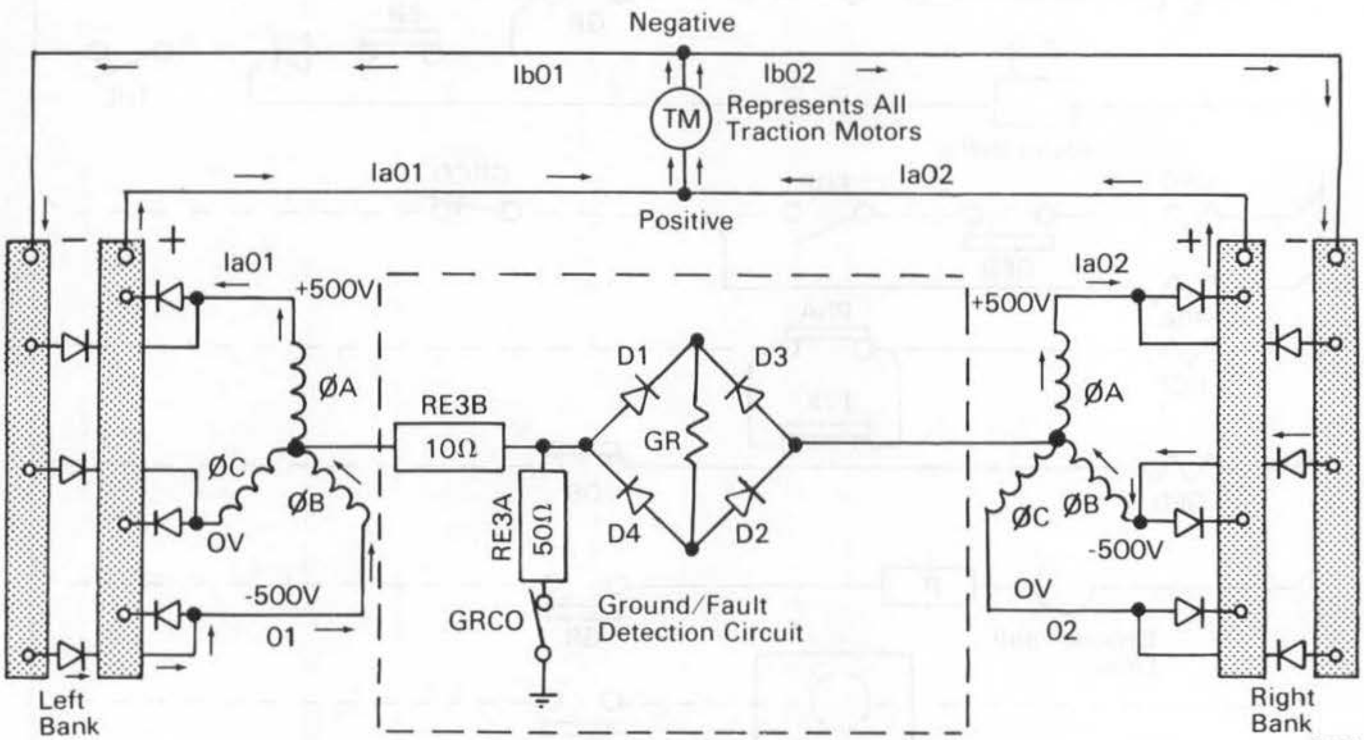

Fig.AR10-14 – Ground/Fault Detector Circuit, Showing Current Flow During Normal Operation Of Main Generator

Now assume that all five positive base diodes in phase A of the right bank become open as shown in Fig. AR10-15. Current will flow from left bank phase A through diode to the positive bus, from positive bus through the traction motor to the negative bus, from negative bus through a negative base diode to left bank phase B, then to neutral and back to left bank phase A. Current will also flow from negative bus through a negative base diode to right bank phase B, through phase B and the ground/fault detector circuit to left bank neutral and back to the left bank phase A. This current through the ground/fault detector circuit results in pickup of GR.

SHORTED TURNS IN RIGHT BANK PHASE A

Shorted turns in any phase group results in an unbalance between left and right bank neutral. This unbalance causes pickup of the GR relay. A description of this action is presented in the following paragraphs.

Assume that the main generator is operating under a normal balanced condition and at a specific instant of time as shown in Fig. AR10-14. The system is balanced and no current flows through the ground/fault detector circuit.

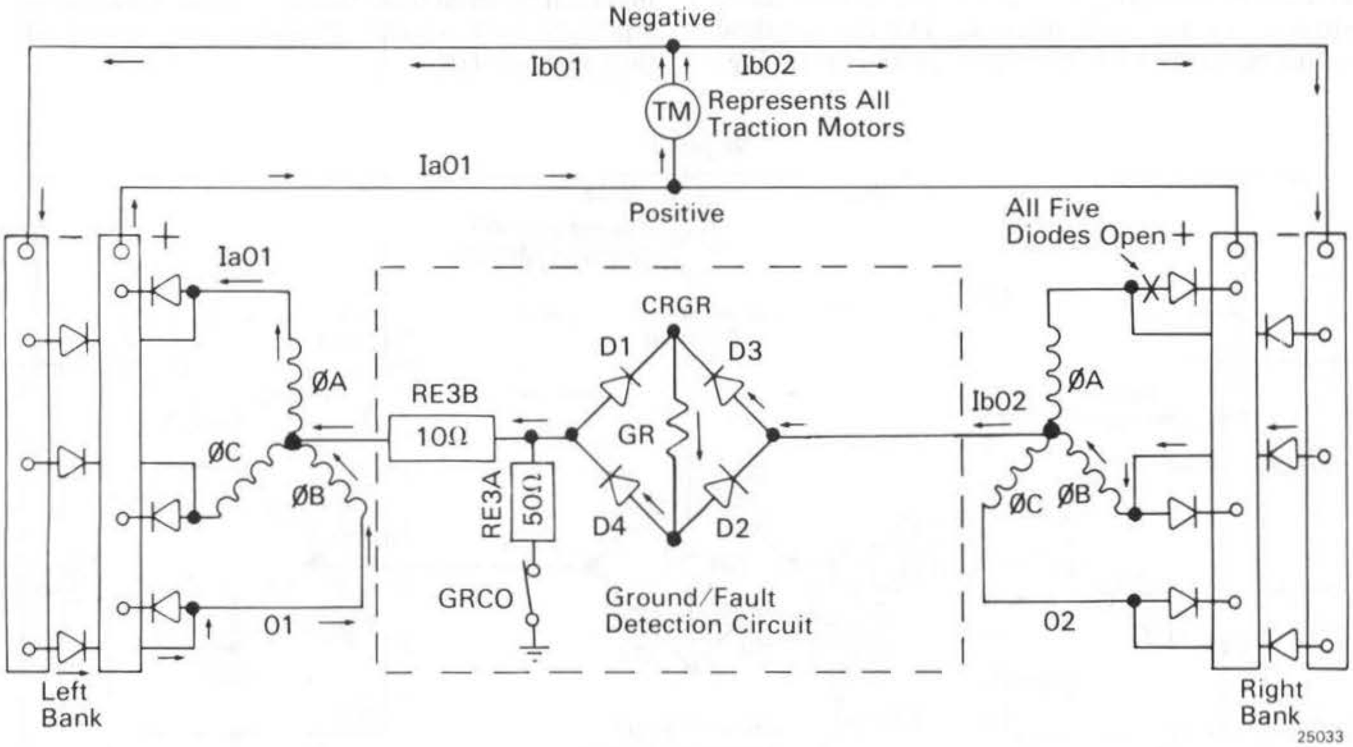

Fig.AR10-15 – Ground/Fault Detector Circuit Operation With The Loss Of One Phase

Now assume that one half the turns of right bank phase A become shorted. This would reduce right bank phase A voltage to +250 volts, Fig. AR10-16. Under these conditions left bank phase A would be the most positive point. Current would flow from left bank phase A to the positive bus, through the traction motors to the negative bus, then from negative bus through left bank phase B and right bank phase B to left bank neutral. This would cause the positive bus to be at +500 volts which would reverse bias the positive base diodes in right bank phase A. The potential on the negative bus would be -500 volts which would reverse bias the negative base diodes in right bank phase A, right bank phase C, and left bank phase C. Therefore, no current would flow through right bank phase A, right bank phase C, or left bank phase C. The current flow would be limited to the circuit as shown in Fig. AR10-16. This is the same circuit for current flow as that shown in Fig. AR10-15. This current flow through the ground/fault detector circuit results in pickup of GR.

AC GROUNDS

The effect on the ground/fault detection circuit due to AC grounds depends upon the location of the AC ground.

Assume that a ground occurs at the right bank neutral. This places a ground on each side of the series combination of the 50 ohm resistor and the GR relay circuit. There will be no difference in potential between these two grounds or between left and right bank neutral. Therefore, no current will flow through GR.

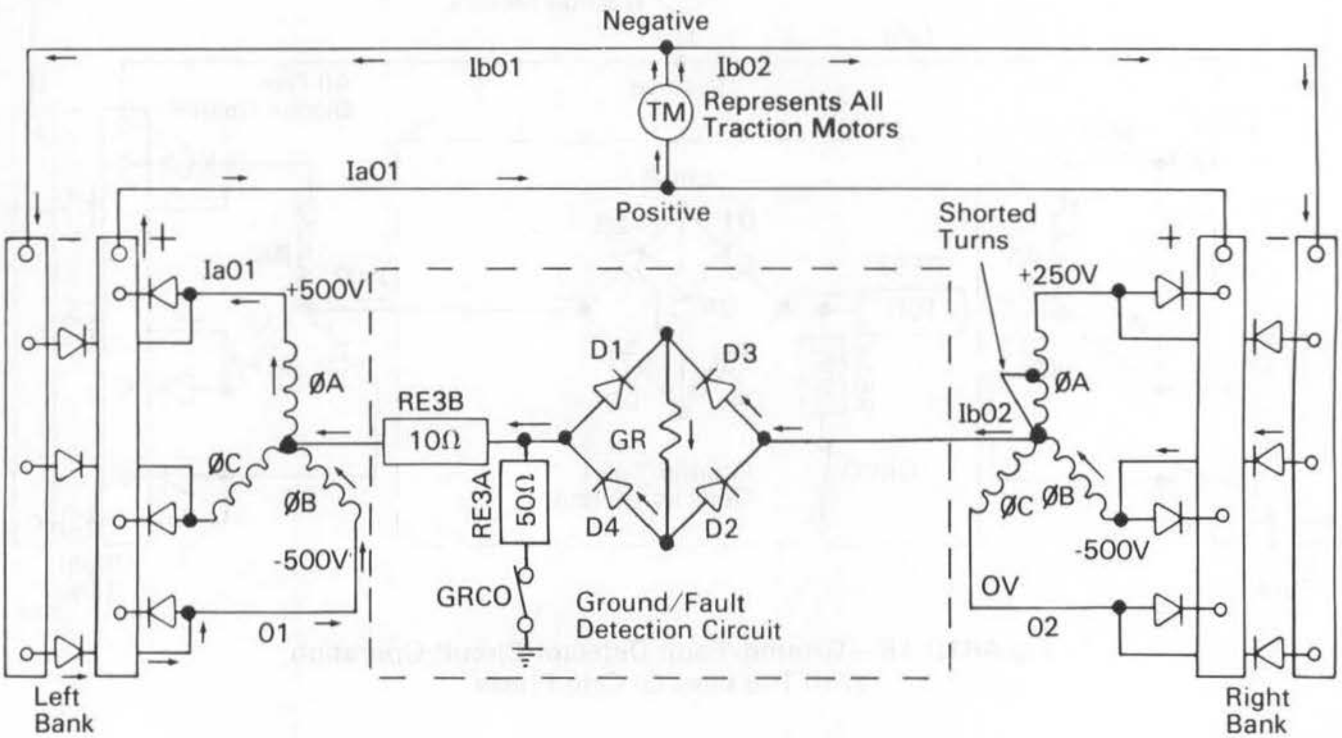

Fig.AR10-16 - Ground/Fault Detector Circuit With Shorted Turns In One Phase

Assume that a ground occurs in right bank phase A at a point that is 10 volts positive with respect to right bank neutral, Fig. AR10-17. This ground results in a potential of +10 volts at point X of the ground/fault detection circuit with respect to right bank neutral. This difference in potential causes a flow of current through GR. The amount of current flow through GR is equal to 10 volts divided by 50.86 ohms or 0.197 amperes. The GR relay requires 0.750 to 0.825 amperes for pickup. Therefore, a ground at a point +10 volts from neutral will not result in pickup of GR.

We will assume pickup of GR with a current flow of 0.788 amperes. Therefore, we must have a potential difference of approximately 0.788 amperes times 50.86 ohms or 40.1 volts between point X and right bank neutral in order to pick up GR. If the ground is in right bank phase A, current will flow from the grounded point through the normally closed GRCO contacts to point X, from point X through the 50 ohm resistor, D1, GR and D2 to right bank neutral. This small amount of current is not sufficient to cause an unbalance between the left and right bank neutral. Therefore, since the two neutrals are at the same potential, current will also flow from point X to left bank neutral. The current flow from point X to left bank neutral will be 40.1 volts divided by 60 ohms or approximately 0.668 amperes. The total current from phase A ground is equal to 0.788 plus 0.668 or approximately 1.456 amperes.

The ground/fault detection system has a ground fault pickup sensitivity rating of 1.00 amperes. This rating means that a ground or insulation leakage to ground that permits a current flow of 1.00 ampere to ground should operate the ground/fault detection system.

If the ground occurs in left bank phase A, current will flow from the grounded point through the normally closed GRCO contacts to point X, and from point X through the 50 ohm and 10 ohm resistors to left bank neutral. Current will also flow from point X through the 50 ohm resistor and the GR relay circuit to right bank neutral.

If ground occurs in right bank phase B, the grounded point will be negative with respect to right bank neutral. Therefore, current will flow from right bank neutral through the GR relay circuit and the 50 ohm resistor to point X, then from point X through the normally closed GRCO contacts to ground. The grounded point is negative with respect to left bank neutral. Therefore, current will flow from left bank neutral through the 10 ohm and 50 ohm resistors and the normally closed GRCO contacts to ground.

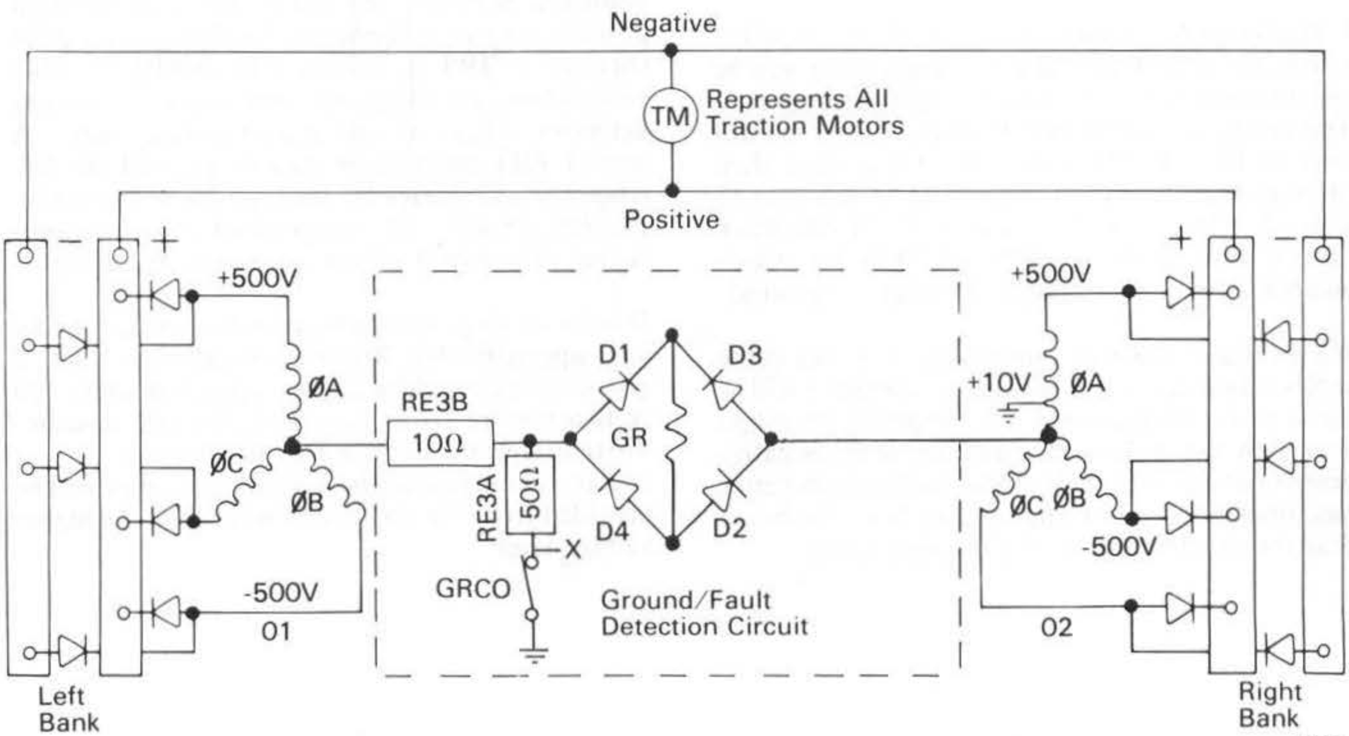

Fig.AR10-17 - Ground/Fault Detector Circuit With DC Ground In One Phase

Again we must have approximately 1.00 ampere of current flow through the grounded point in order to pickup the GR relay.

HIGH VOLTAGE DC GROUNDS

High voltage DC grounds may be caused by traction motor flashover, by current leakage through insulation, or by a positive or negative conductor touching a grounded object.

Traction motor flashover is usually caused by arcing between positive and negative brushes on the traction motor. The arcing results in ionization of air in the vicinity of the arc. The ionized air provides a low resistance path to the grounded traction motor housing.

If flashover to ground occurs near the positive brush, the potential at the grounded point will be positive with respect to the left and right bank neutral. This results in current flow from ground through the normally closed contacts of GRCO then through the 50 ohm resistor, D1, GR and D2 to right bank neutral. Current will also flow through the 50 ohm and 10 ohm resistors to left bank neutral.

If flashover to ground occurs near the negative brush, the potential at the grounded point will be negative with respect to left and right bank neutral. This results in current flow from right bank neutral through D3, GR, D4, and the 50 ohm resistor, then through the normally closed GRCO contacts to ground. Current will also flow from left bank neutral through the 10 ohm and 50 ohm resistors and the normally closed GRCO contacts to ground.

If a ground occurs at the positive bus or at one of the cables attached to the positive bus, operation will be the same as for a flashover near the positive brush of a traction motor. If a ground occurs at the negative brush or at one of the cables attached to the negative bus, operation will be the same as for a flashover near the negative brush of a traction motor.

DYNAMIC BRAKING GRID GROUNDS

Available on special order, the ground protection system can also be used to detect braking grid grounds that occur during dynamic braking. The system operation is essentially the same as during power. Its purpose is to reduce the possibility of electrical fire by removing the source of current from the grounded equipment.

During power operation the main generator is the source of electrical power and the ground protection system function is to disable this source by removing excitation from the main generator field. During braking, however, the electrical power being dissipated by the grids is provided by the traction motors which are then operating as generators.

The ability of the traction motors to operate as generators is disabled by removing excitation from the motor fields. Since motor field excitation is provided by the main generator, the main generator must first be disabled. As during power operation, the ground protection system accomplishes this by removing main generator field excitation.

During locomotive operation in dynamic brake, the ground detection system remains connected between the main generator left and right bank neutrals. In addition, however, the main generator rectified positive output is connected to the braking grids through a BR1 interlock, Fig. AR10-18. This connection provides the current path to the detection circuit should a grid ground occur. A second BR1 interlock is used to parallel the GR relay coil and diodes D1 through D4 with another 10 ohm resistor. The purpose of this resistance change is to adjust the circuit pickup sensitivity.

During braking, the main generator voltage is very low - approximately 70 to 80 volts. However, with a grid current of 700 amperes, approximately 300 volts is present across each 0.43 ohm grid segment. Therefore, in the event a ground occurs in the grid circuit, the current to the detection circuitry will be provided from the grid circuit which is at the higher voltage level.

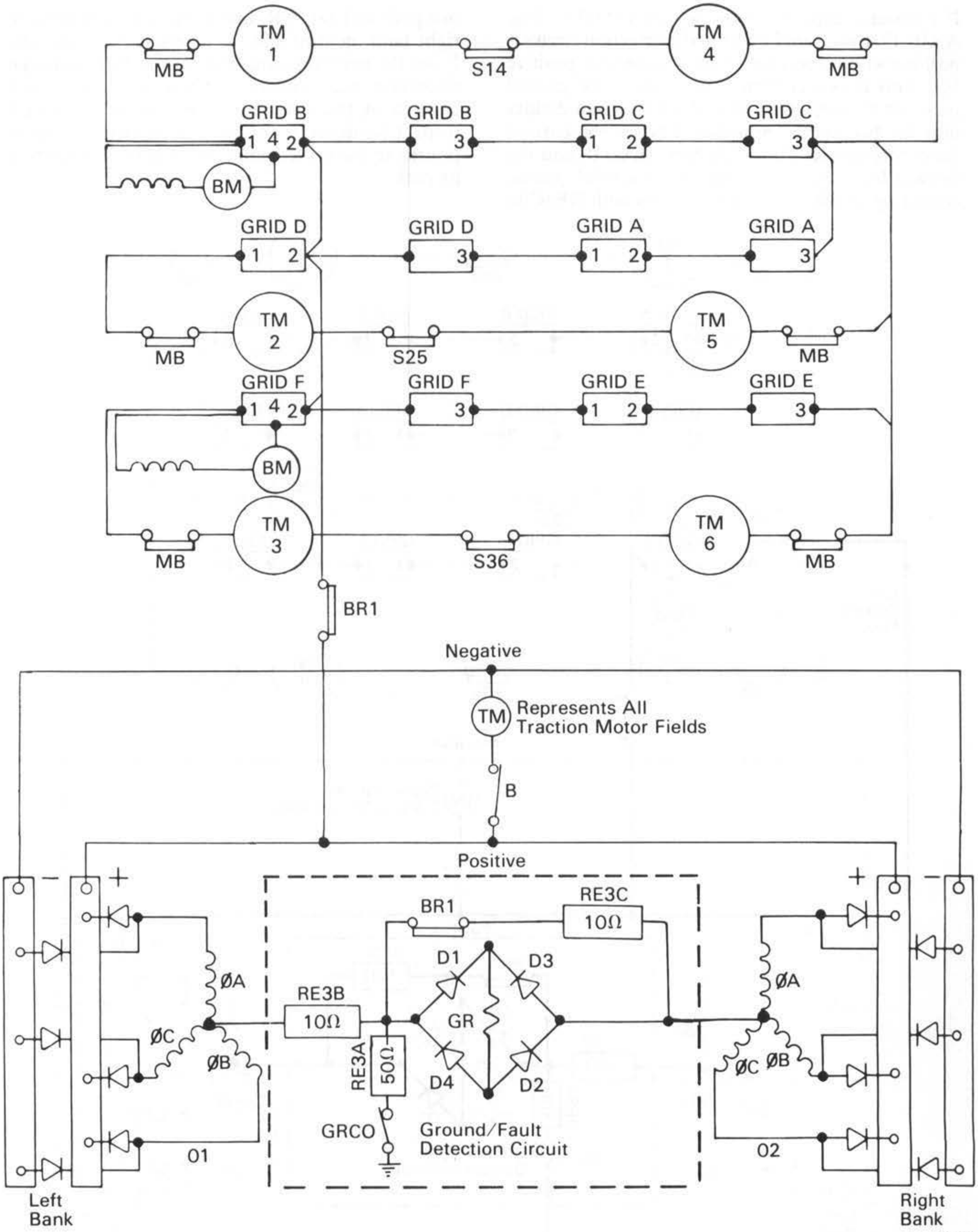

Fig.AR10-18 – Dynamic Brake Grid Ground Detection Circuit, Simplified Schematic Diagram

If a ground appears to the left of GRID F, Fig. AR10-19, the ground point in the detection circuit is positive with respect to the main generator positive bus. This causes current to flow from the ground point up through GRCO and RE3A, then divides into the two circuit branches. Part of the current flows through RE3B to left bank neutral, and the remainder flows through two parallel paths; consisting of BR1 interlock in series with RE3C in one path and D1, GR, and D2 in the other path, to right bank neutral and, as a result, picks up GR. From the neutral points, the current flows through whichever main generator phase winding in each bank is at the most positive voltage level with respect to neutral, follows the positive bus and returns to the center point of GRID F, completing its path.

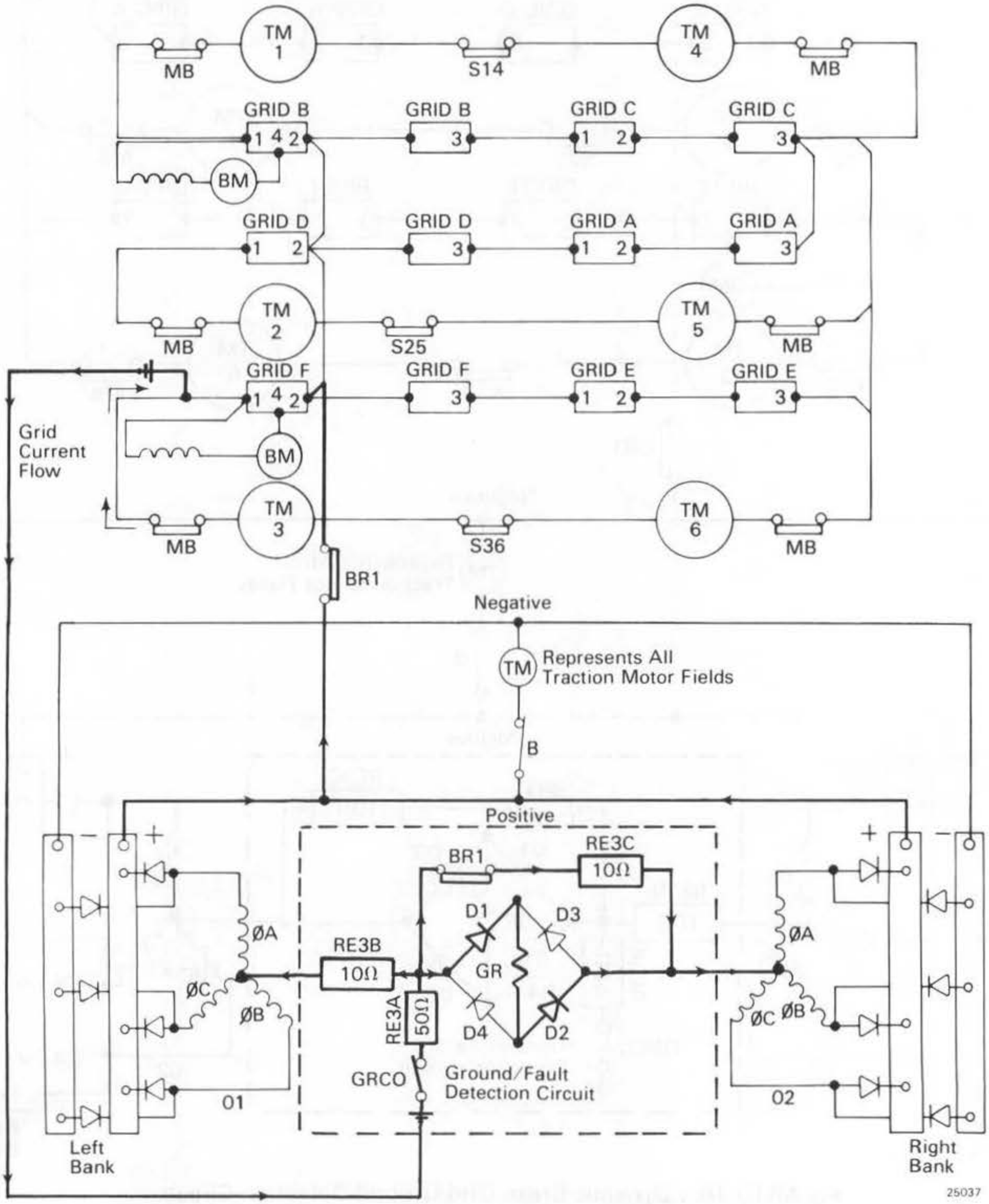

Fig.AR10-19 – Ground Detection System Current Flow With Ground More Positive Than Main Generator Positive Bus

If a ground appears to the left of GRID F, Fig. AR10-20, the ground point in the detection circuit is negative with respect to the main generator positive bus. This causes current to flow from main generator positive bus (center point of GRID F) through the traction motor fields to main generator negative bus. The current then divides into the two diode banks. From the banks, the current flows to neutral through whichever main generator phase winding in each bank is at the most negative voltage level with respect to neutral. From left bank neutral the current flows through RE3B where it joins the current from right bank neutral which had passed through RE3C, D3, GR, and D4, picking up GR.

This combined current then flows down through RE3A and GRCO to the ground point, returns to the grid circuit, and follows the normal grid current flow to complete its path to the center point of GRID F.

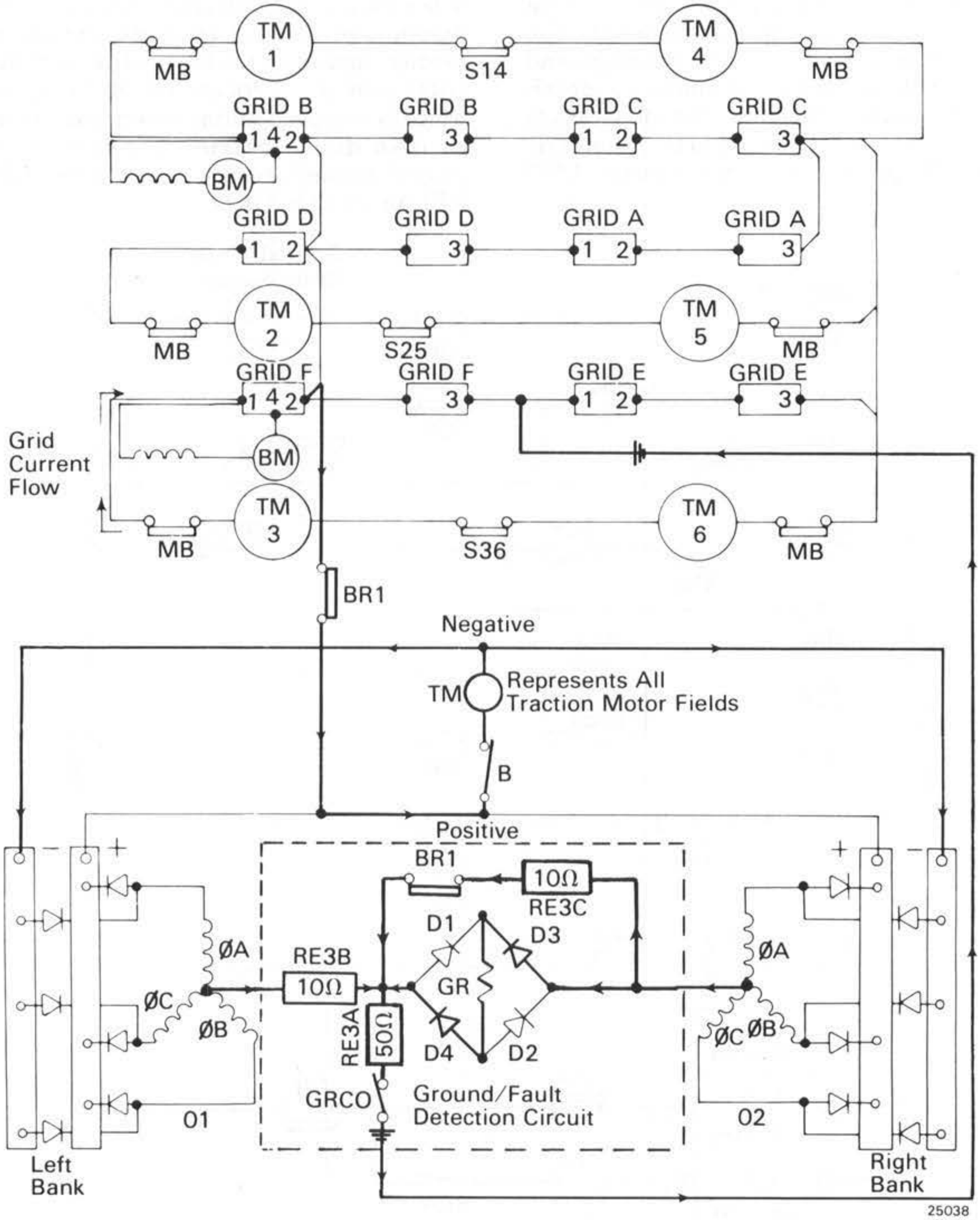

Fig.AR10-20 - Ground Detection System Current Flow With Ground Less Positive Than Main Generator Positive Bus

During power operation, the ground detection system has a ground relay pickup sensitivity rating of 1.00 amperes. This rating means that a ground or insulation leakage to ground that permits a current flow of 1.00 amperes to ground should operate the ground/fault detection system.

During braking, the addition of resistor RE3C recalibrates the detection circuit pickup sensitivity. The current flow required to pick up GR is approximately 0.788 ampere, which produces a voltage drop of approximately 43.47 volts between right bank neutral and the ground point. The current flow between left bank neutral and ground will be 43.47 volts divided by 60 ohms or approximately 0.724 amperes. Therefore, the total leakage current required from a grid ground to operate GR is equal to 0.788 plus 0.724 or approximately 1.512 amperes.

In addition to the circuit operations previously described in the paragraph entitled OPERATION, the braking grid ground protection circuit, Fig. AR10-21, performs another function. A set of interlock contacts on the GFD relay are connected in the B contactor coil feed circuit. Dropout of GFD therefore also causes the B contactor to drop out, disconnecting the traction motor fields from the main generator.

When the ground protection system is used to detect dynamic brake grid grounds, the annunciator module applied to the locomotive contains a D.B. GRD display. Interlocks on the GFA contactor, which is energized during power operation and deenerized during braking, are used to select the proper annunciator display - either GROUND RELAY or D.B. GRD.

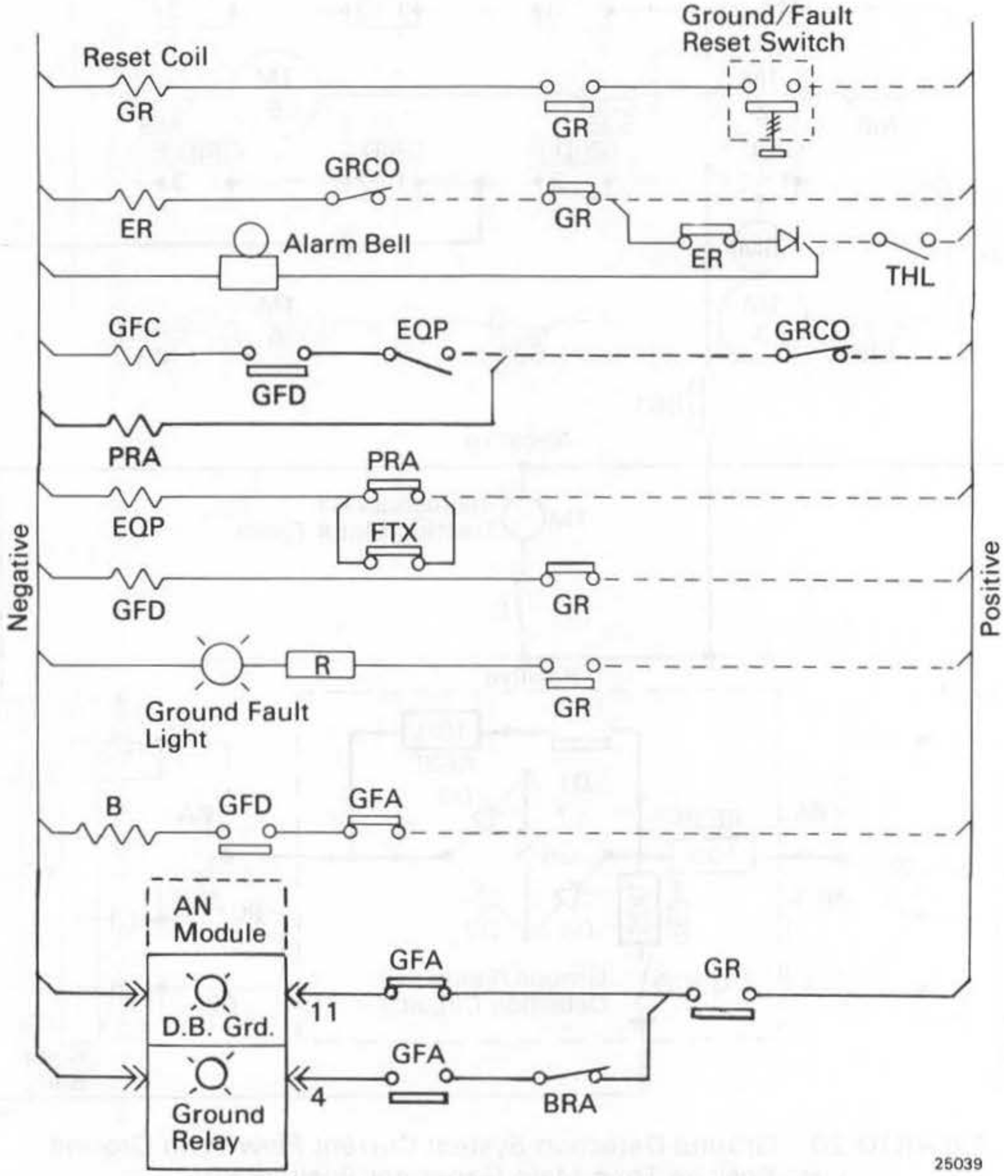

Fig.AR10-21 - Ground Relay Protection Circuit With Dynamic Brake Grid Ground Option, Simplified Schematic Diagram

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

D18 ALTERNATOR

The D18 alternator, Fig. D18-1, is a variable frequency, variable voltage, rotating field, stationary armature, three phase wye connected AC generator with a rating of 250 KVA at 0.8 power factor. Nominal output of the D18 alternator is 215 volts at 120 cycles per second when the diesel engine is rotating at a speed of 900 RPM. The D18 alternator is physically connected to, but electrically independent of the main generator. The D18 alternator and main generator rotating assembly is directly coupled to the crankshaft of the diesel engine.

The D18 alternator provides power for the inertial filter blower motor, radiator blower motors, excitation for the main generator, and for various control circuits. The maximum output of the D18 alternator is approximately 19 amperes for each ampere of field excitation. The auxiliary generator provides approximately 31 amperes of field excitation current to the D18 alternator when the field is hot. The 31 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 D18 alternator field (2.40 ohms). The D18 alternator can provide an output of approximately 600 amperes with the 31 amperes of field excitation. There are no controls in the D18 alternator excitation circuit. Therefore, the D18 alternator will be excited and developing power whenever the diesel engine is running.

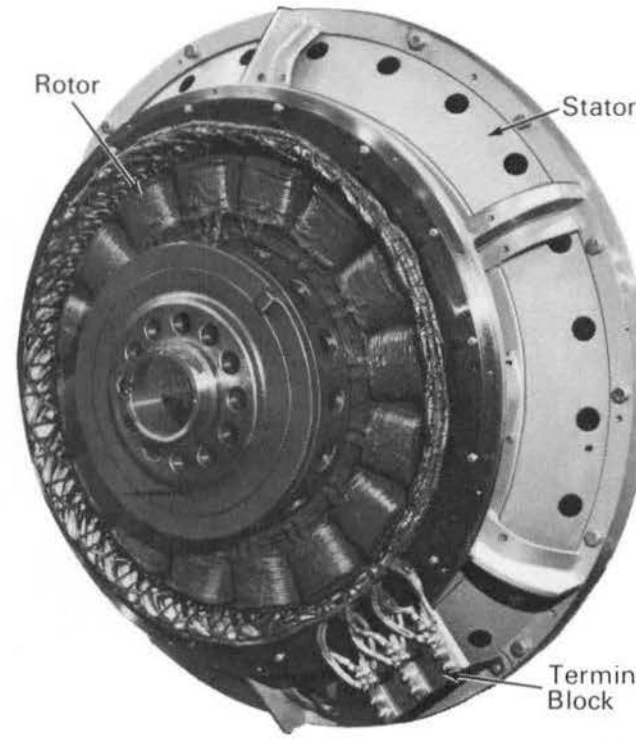

Fig.D18-1 - D18 Alternator

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 ouput 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 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.

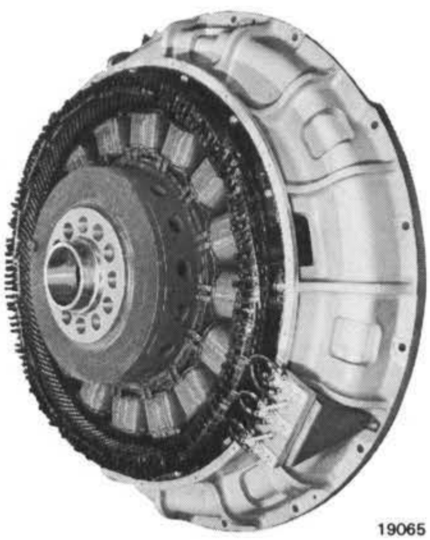

Fig.D14-1 – D14 Alternator

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 speed between 825 and 3,000 RPM, at any load between no load and full rated load and with 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

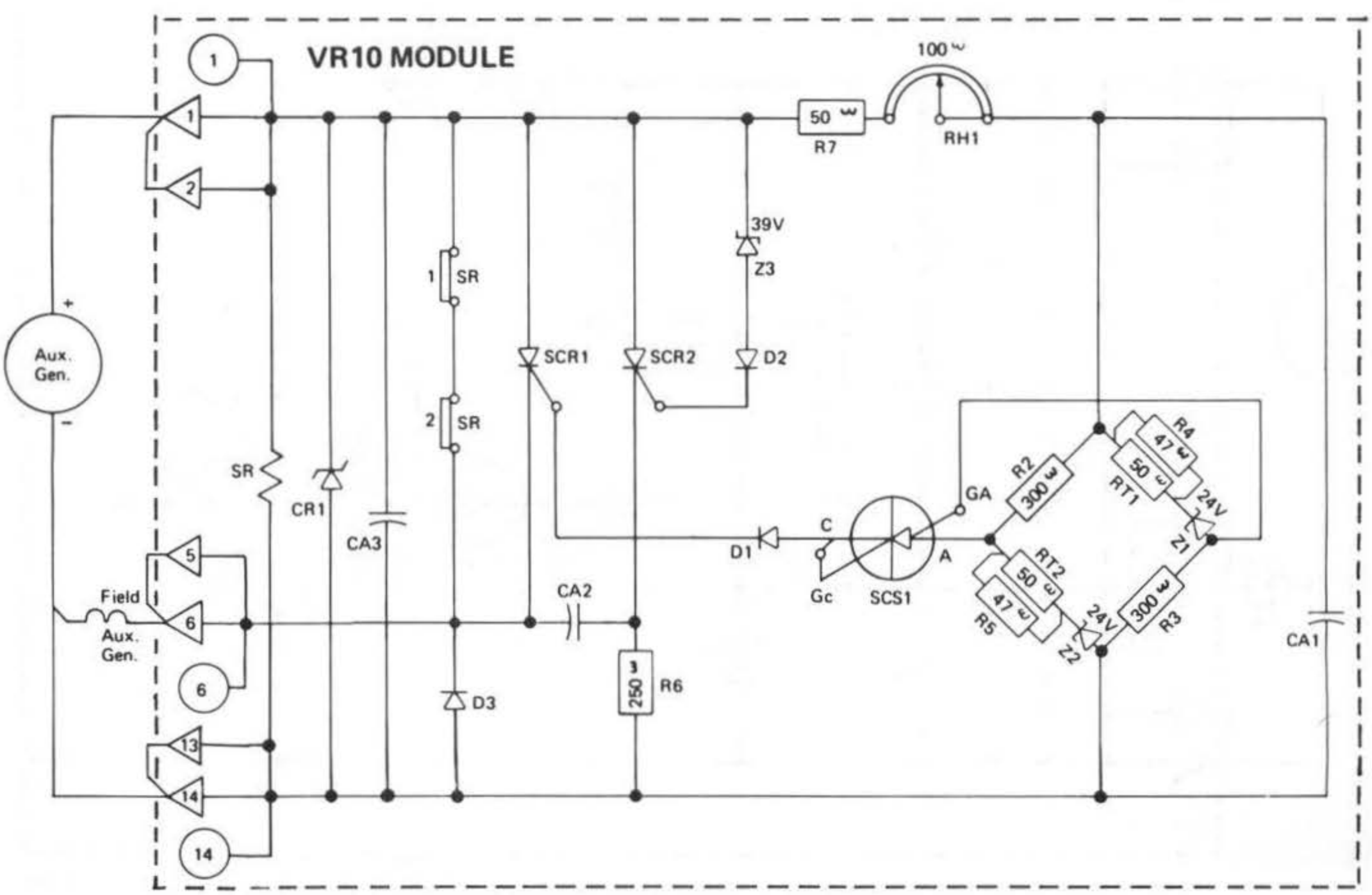

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Fig.VR-1 – Voltage Regulator Module, Simplified Schematic Diagram of oscillation. SCR1 will remain off if the output voltage of the generator is above the "set point" when the positive pulse is received from the oscillator. If the output is below the "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 noticable 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 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, are 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.

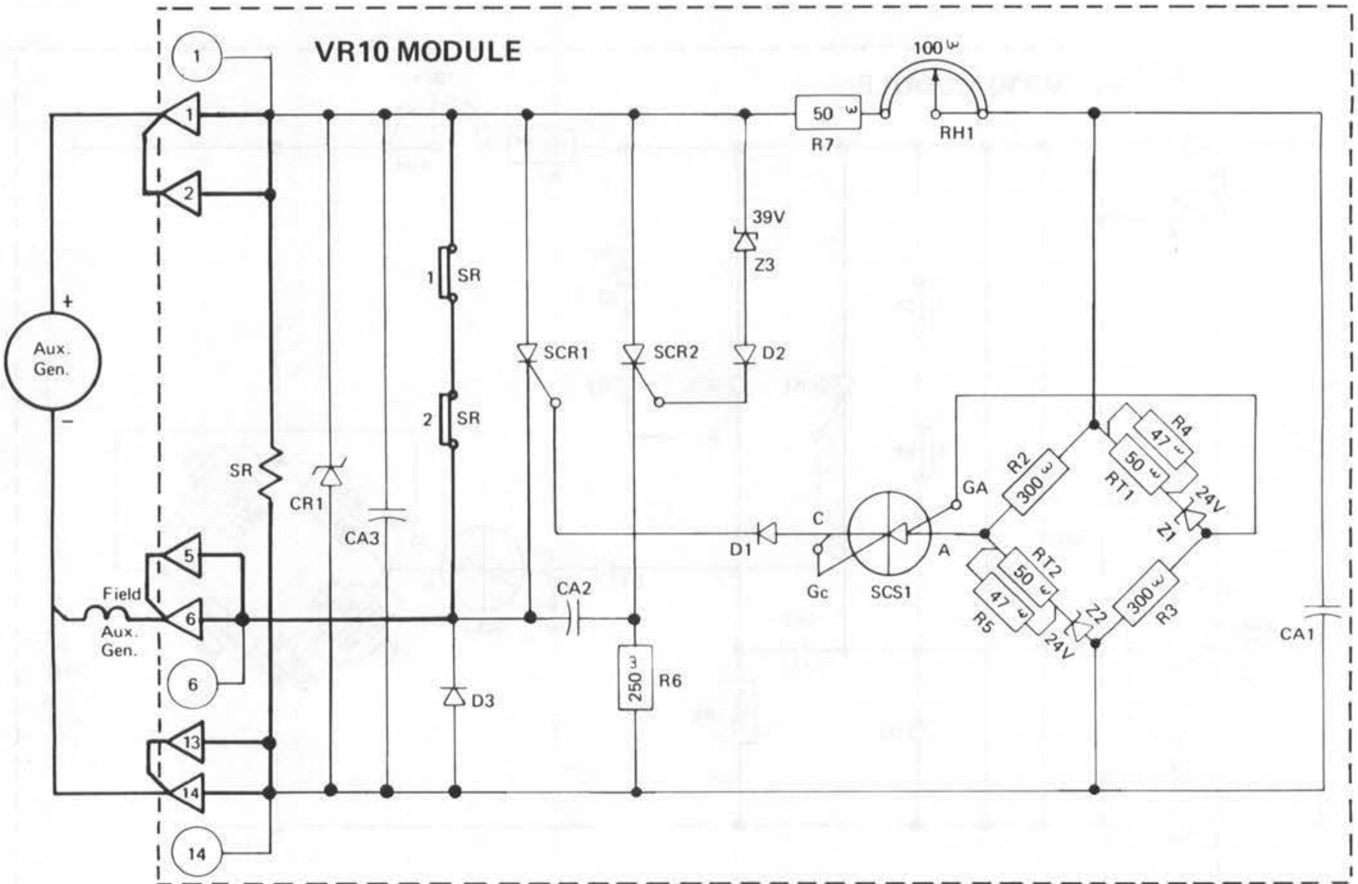

Fig.VR-2 – Voltage Regulator Starting Circuit, Simplified Schematic Diagram

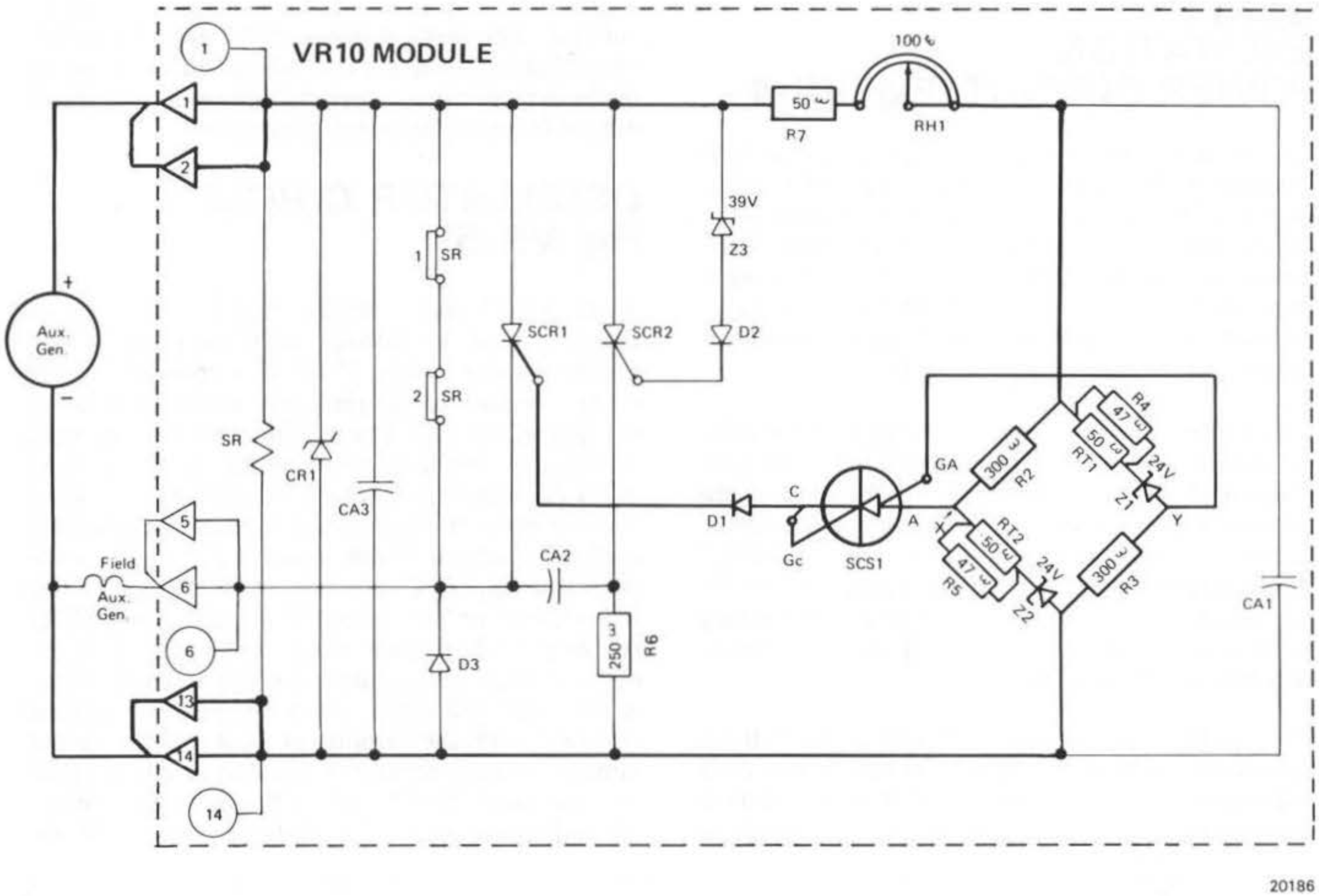

Fig.VR-3 - Voltage Regulator Detector Circuit, Simplified Schematic Diagram

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" and no gating signal is applied to SCS1 or the 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, R5, 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.

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 blow 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.

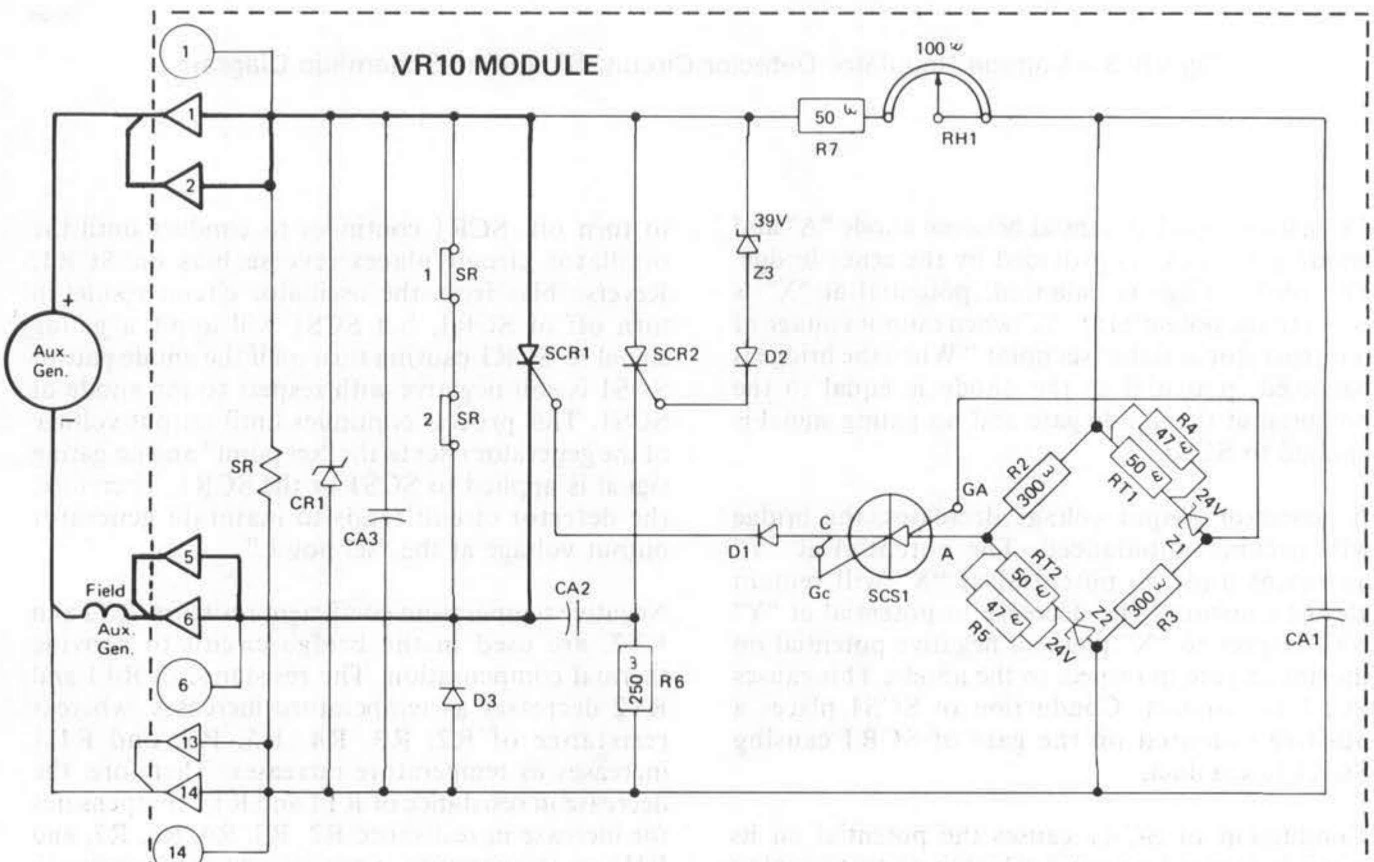

Fig.VR-4 – Voltage Regulator Power Circuit, Simplified Schematic Diagram

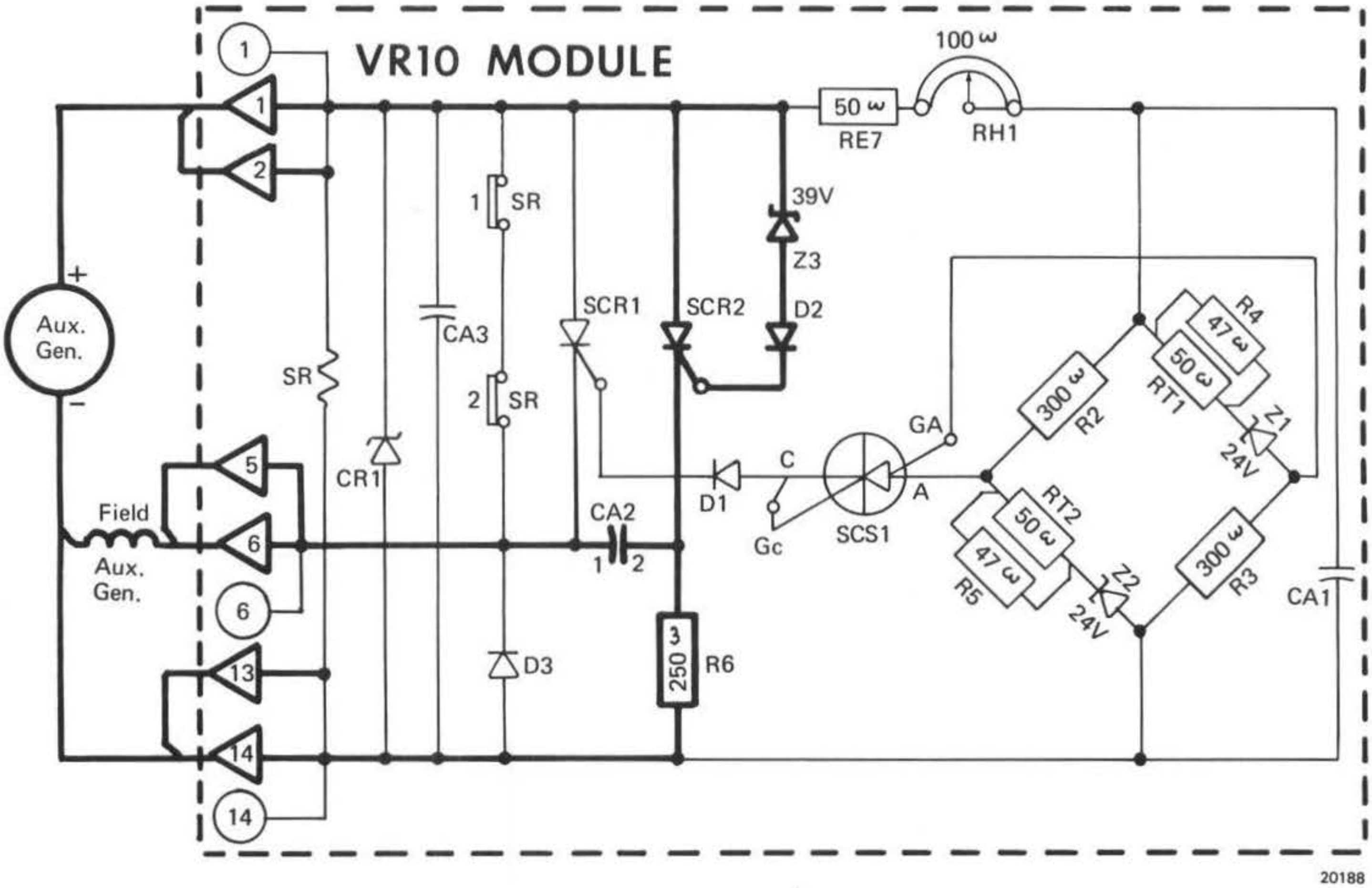

Fig.VR-5 – Voltage Regulator Oscillator Circuit, Simplified Schematic Diagram

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 then 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 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 volts 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.

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

VOLTAGE REGULATOR MODULE, VR13

INTRODUCTION

The VR13 module is a solid state voltage regulator. It monitors the rectified output of the three-phase AC auxiliary generator excitation as necessary to maintain the generator output at 55 VAC, which results in 74 VDC rectifier output.

Section 7, Part A-AG, describes the AC auxiliary generator.

An operating power supply circuit, a starting circuit, a detector circuit, and an excitation output circuit comprise the VR13 module. Fig. VR-1 is a simplified VR13 schematic; use it for reference only. For troubleshooting or maintenance, use the locomotive wiring diagrams.

OPERATION

The lower left portion of the Fig. VR-1 schematic is the VR13 operating power supply. It supplies +15 VDC operating power to OP1A and OP1B, and +6.2 V to RH1 of the detector circuit for use in setting the reference signal level. The rectified AC auxiliary generator output is applied across zener diode Z1 through R1 and R2. Z1 maintains +15 VDC at its cathode. R3 conducts current from the +15 VDC supply to zener diode Z2, which maintains +6.2 VDC at its cathode. The resistors and capacitors in the power supply circuit smooth the ripple in the power supply input.

The starting circuit consists of relay SR1's coil, connected across module terminals 1 and 14, and two normally closed SR1 contacts connected in parallel across module terminals 1 and 8. During normal operation, the AC auxiliary generator's rectified output energizes the SR1 coil, causing the SR1 contacts to be open so that all output to the AC auxiliary generator pilot exciter must come from Q4 and Q5. During startup, SR1 is de-energized and residual magnetism in the AC auxiliary generator provides initial excitation. The closed SR1 contacts provide a low resistance path for the resultant rectified generator output, which is applied through them and through the external 5.7 ohm field resistor to the AC auxiliary generator pilot exciter, where it aids the residual magnetism in generating excitation current. This process continues, quickly increasing the generator output. As generator output increases, the power supply and the detector circuit begin operating, causing Q4 and Q5 to conduct, providing additional parallel conduction paths for the excitation current. When generator output reaches 35 or 40 volts across module terminals 1 and 14, SR1 picks up, opening its contacts.

The detector circuit consists of RH1, OP1A, OP1B, and associated components. Potentiometer RH1 is mounted on the module faceplate. The power supply applies 6.2 VDC across RH1 and R4, and the voltage at RH1's wiper is the reference signal for the detector circuit. RH1 is adjusted so it provides the reference signal level which causes the module to regulate the AC auxiliary generator for 74V rectified output. The reference signal will be a constant level set somewhere between +5.2 and +6.2 VDC by RH1.

The R5/R6 voltage divider produces a scaled down rectified AC auxiliary generator output signal, which is the (-) input for both OP1A and OP1B. During steady-state conditions, the scaled down signal voltage level is the same as the reference signal level, and the OP1A output, which is an adjusted instantaneous reference signal, is also at the same level as the reference signal. The R9/C8/OP1A circuit is a signal averaging amplifier which desensitizes the detector to generator output waveform changes caused by speed and load variations. If the scaled down signal average voltage is lower than the reference signal voltage, the OP1A output rises; if the scaled down signal average voltage is higher than the reference signal voltage, the OP1A output drops. D1 and D2 prevent the adjusted reference signal from varying any more than one diode drop from the scaled down generator average voltage.

OP1B compares the scaled down generator signal to the adjusted instantaneous reference signal. When the instantaneous level of the scaled down generator signal is lower than the adjusted instantaneous reference, the OP1B output is high; when the opposite is true, the OP1B output is low. In normal

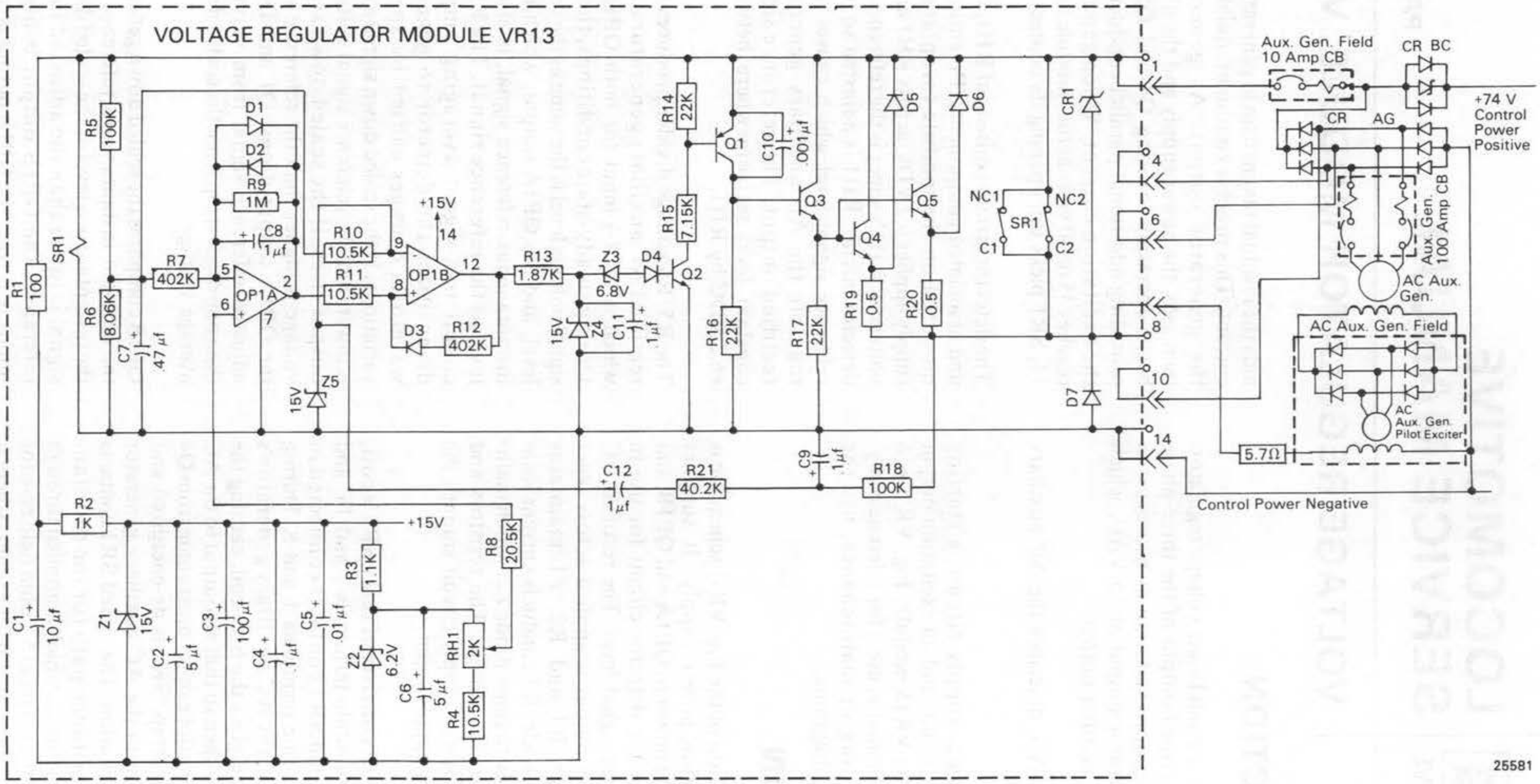

Fig.VR-1 – VR13 Module, Simplified Schematic And Connection Diagram

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operation, the OP1B output is a series of positive pulses, and if the engine speed is constant, the pulse frequency increases as the auxiliary generator load increases. Under heavy load, the OP1B output pulse frequency can increase to the point where the OP1B output just stays at the high level.

The module's excitation output circuit consists of transistors Q1 through Q5 and associated components. When the instantaneous OP1B output level rises above what is necessary to overcome the Z3 zener breakdown voltage plus the D4 forward drop voltage, it will turn on Q2. When Q2 turns on, it turns on Q1; when Q1 turns on, it turns on Q3; and when Q3 turns on, it turns on both Q4 and Q5. When Q4 and Q5 turn on, they conduct rectified AC auxiliary generator output power from pin 1 through R19 and R20 to pin 8, which is connected to the pilot exciter section of the AC auxiliary generator through an external 5.7 ohm resistor.

When the output circuit supplies current to the pilot exciter of the auxiliary generator, the generator output voltage rises. As a result, the scaled down signal on the module rises, causing the detector circuit to stop the excitation output. When excitation stops, generator output voltage falls, and the detector turns the excitation back on. This on/off process causes the excitation output from module pin 8 to be a series of pulses smoothed by the inductance of the pilot exciter circuit. Excitation current level is proportional to the pin 8 average pulse frequency.

Under constant load and changing auxiliary generator speed conditions, the module varies the excitation current level in the direction opposite to the generator speed variation in order to maintain constant generator output voltage. If auxiliary generator speed is constant while the load varies, the module varies excitation current level in the same direction as the load variations in order to maintain constant generator output voltage.

CAUTION

Do not remove the VR13 module while the engine is running. Doing so would cause arcing at the module connector, which may damage the module.

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 valve 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.

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

THROTTLE POSITION	*ENGINE RPM	*TH14 OUTPUT	*RC12 OUTPUT
LO IDLE**	255	0.0	0.0
IDLE	318	0.0	0.0
1	318	10.9	8.45
2	388	21.6	16.20
3	497	28.6	21.30
4	570	35.7	26.50
5	655	43.3	32.00
6	730	51.2	37.80
7	829	61.4	45.20
8	904	68.0	50.00

*Approximate Nominal Values With SB Module Disconnected Or During Normal Road Operation.

**When Equipped

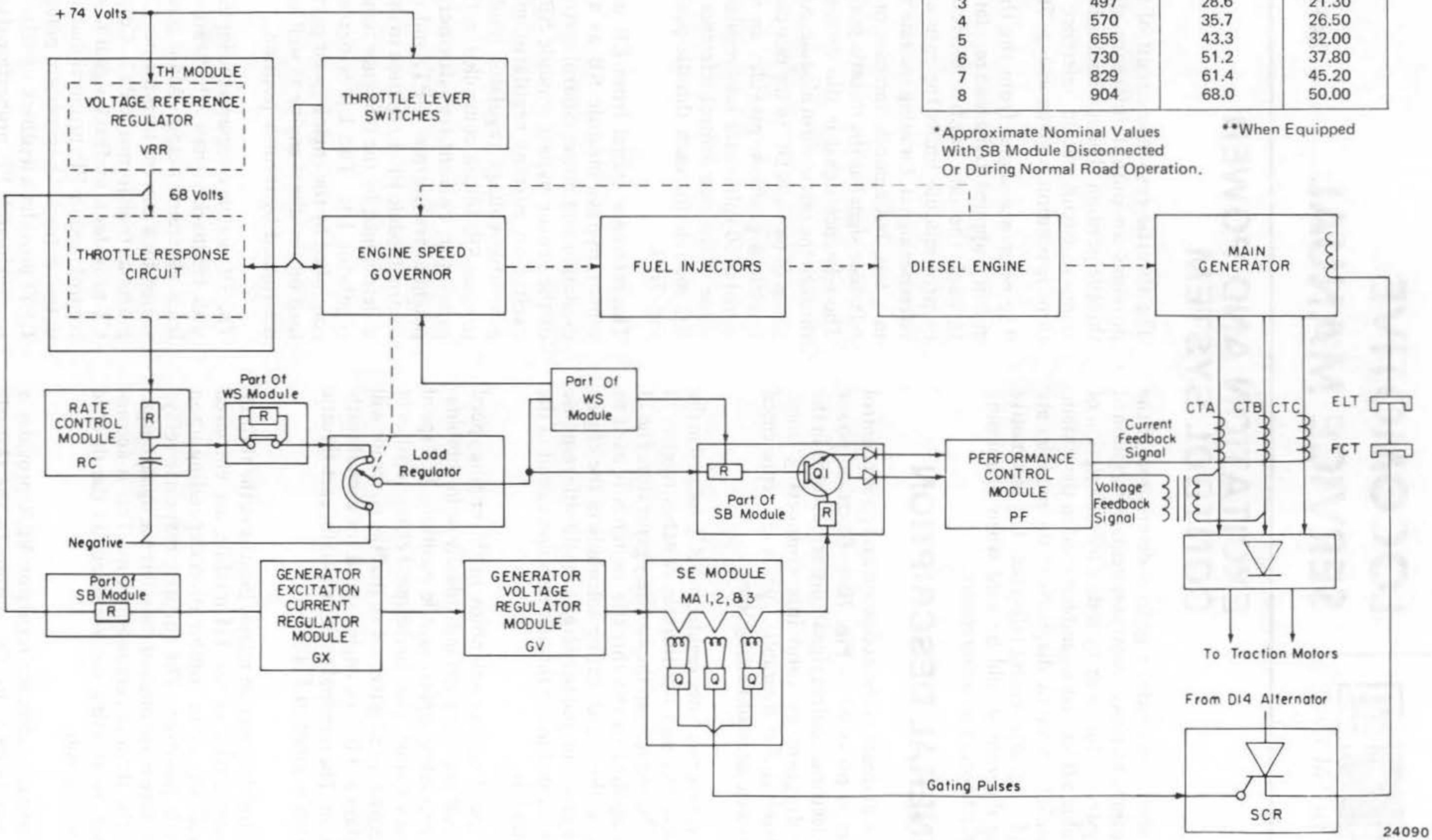

Fig.7B-1 – Excitation And Power Control System, Simplified Flow Diagram with a second potential transformer GPT2. The current feedback signal and the voltage feedback signal from GPT1 are combined by the PF module to provide a power control feedback signal. When applicable, a performance control feedback 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 baised 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 volts signal line from point "A" to point "B" in Fig. 7B-2.

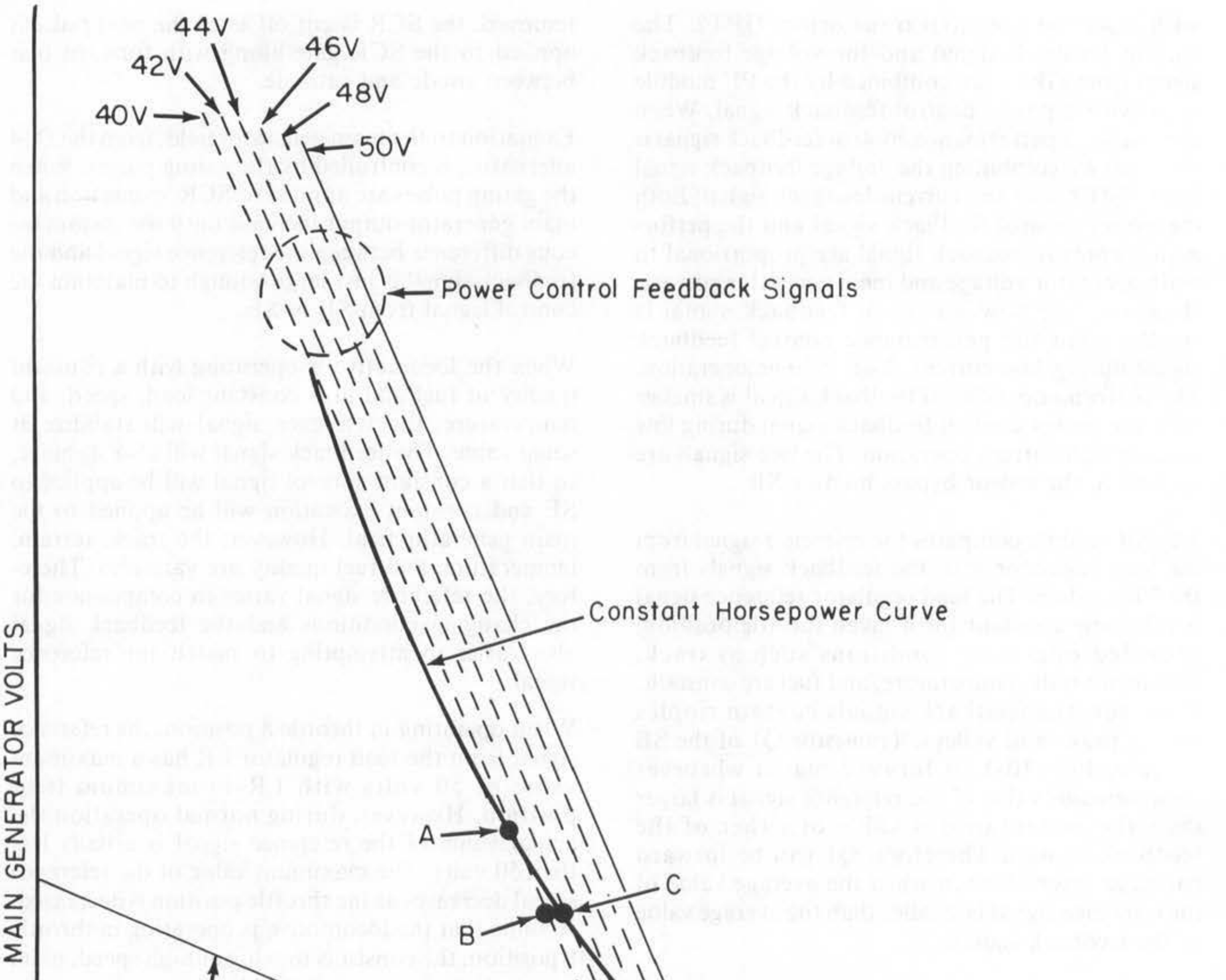

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Fig.7B-2 – Constant Horsepower Curve With Power Control Feedback Signals And Performance Control Feedback Signals

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 hydrualic 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 high 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.

CONTENTS

The contents of Section 7 Part B are presented in the following order:

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 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 trouble-shooting 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 single 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.

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.

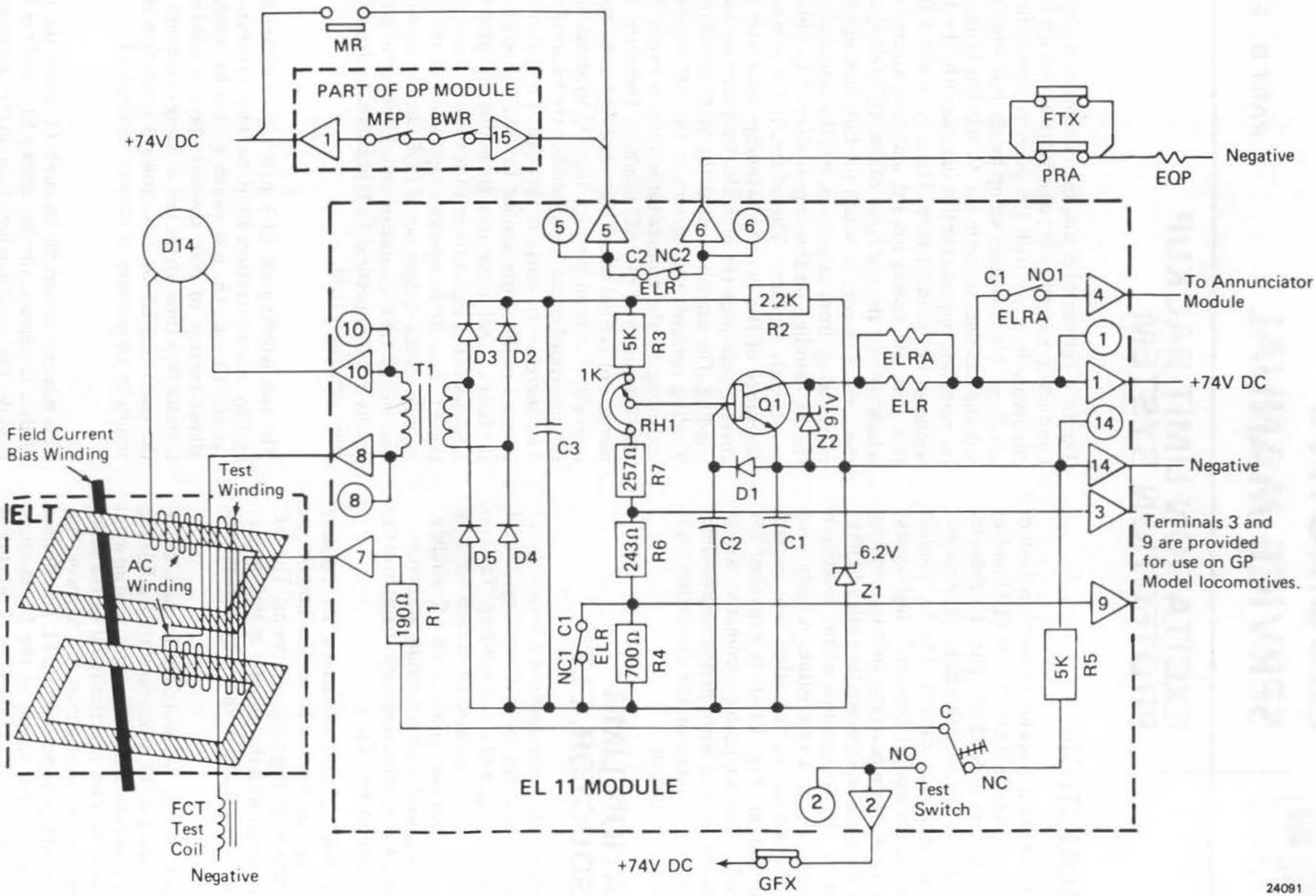

Fig.EL-1 – Excitation Limit Protection System, Simplified Schematic Diagram

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.

On SD model locomotives, the EL module provides backup protection at 114 amperes field current at all track speeds.

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 R6 and R7. Refer to the shaded area of Fig. GV-1 for values of R6 and R7.

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 R5 and capacitor C1 in series causing a voltage to be developed across C1. The voltage developed across C1 is applied to the base of transistor Q1. The series combination of capacitors C2 and C3 is connected in parallel with C1. The emitter is connected to the junction of C2 and C3, 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 rectifier output of T1 and T2 is applied to the series combination of resistor R4, diode D2, and capacitor C1. The voltage developed across C1 is applied to the base of Q1. The rectified output of T1 and T2 is also applied to a voltage divider consisting of resistor R1, rheostat RH1, resistors R2, R6, and R7. 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 C1 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.

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.

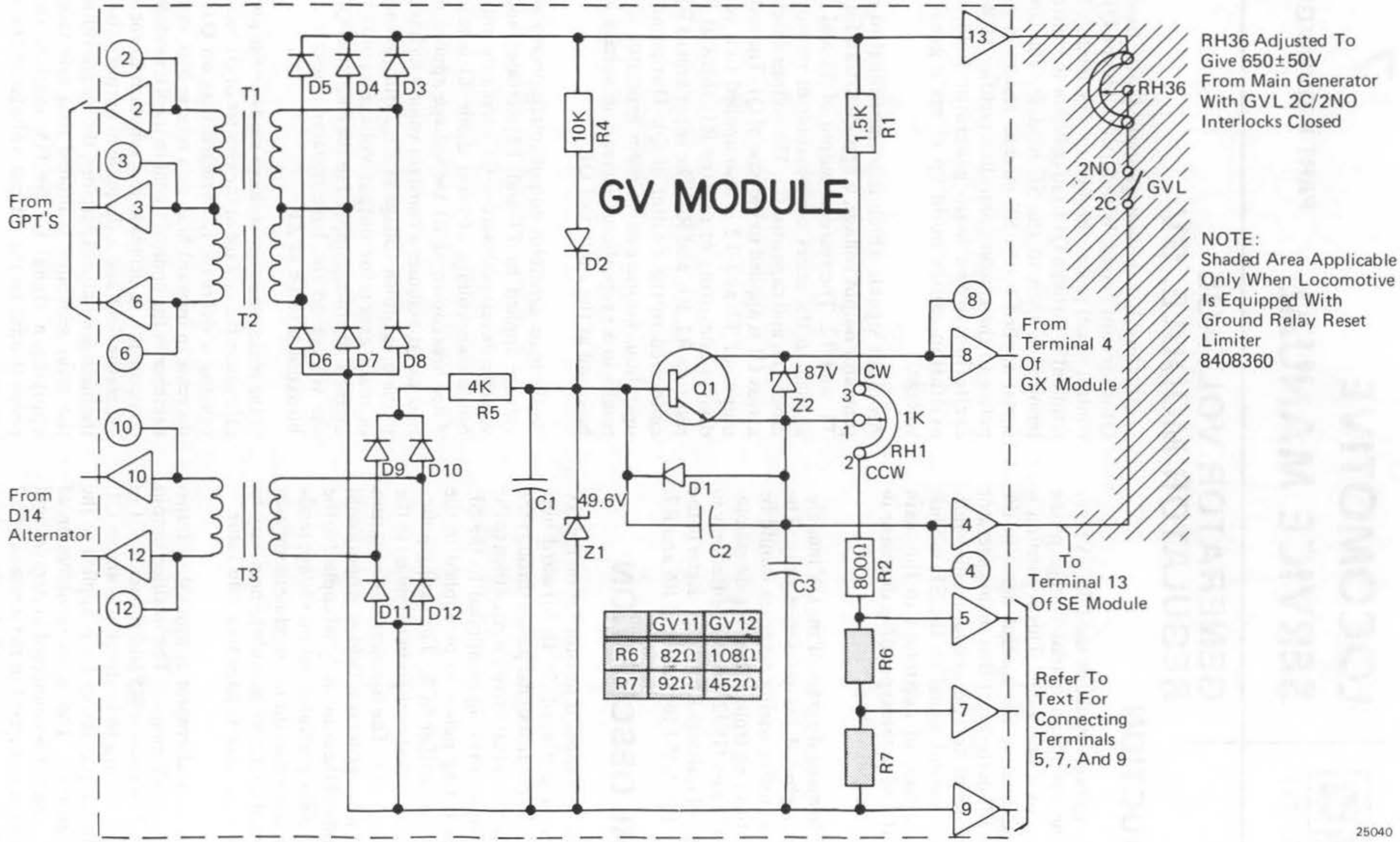

Fig.GV-1 - Generator Voltage Regulation Module GV, Simplified Schematic Diagram

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 the 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 the 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 GP39-2, GP38-2, SD38-2, SD40-2, and SD45-2 model locomotives are equipped with the GV12 module with terminal 5 connected to terminal 9. This provides for maximum output voltage of 1250 volts for these locomotives.

AUTOMATIC GROUND RELAY RESET LIMITER RECALIBRATION OF THE GV MODULE

The automatic ground relay reset limiter assembly is available upon specific request from the customer. The automatic ground relay reset limiter assembly provides a feed to the generator voltage limit relay GVL after the fourth pickup of the ground relay in any given sequence. Pickup of GVL connects GV module receptacles 13 to 4, through RH36. Refer to Fig. GV-1. This recalibrates the GV module so that main generator voltage is limited to a maximum value of 650 ± 50 volts until the automatic ground relay reset limiter is reset to zero. This reduced voltage reduces the probability of ground relay pickup in the presence of low leakage moisture grounds. Therefore, it may be possible to continue locomotive operation at reduced power output until the moisture is dissipated and then return to normal operation.

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 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.

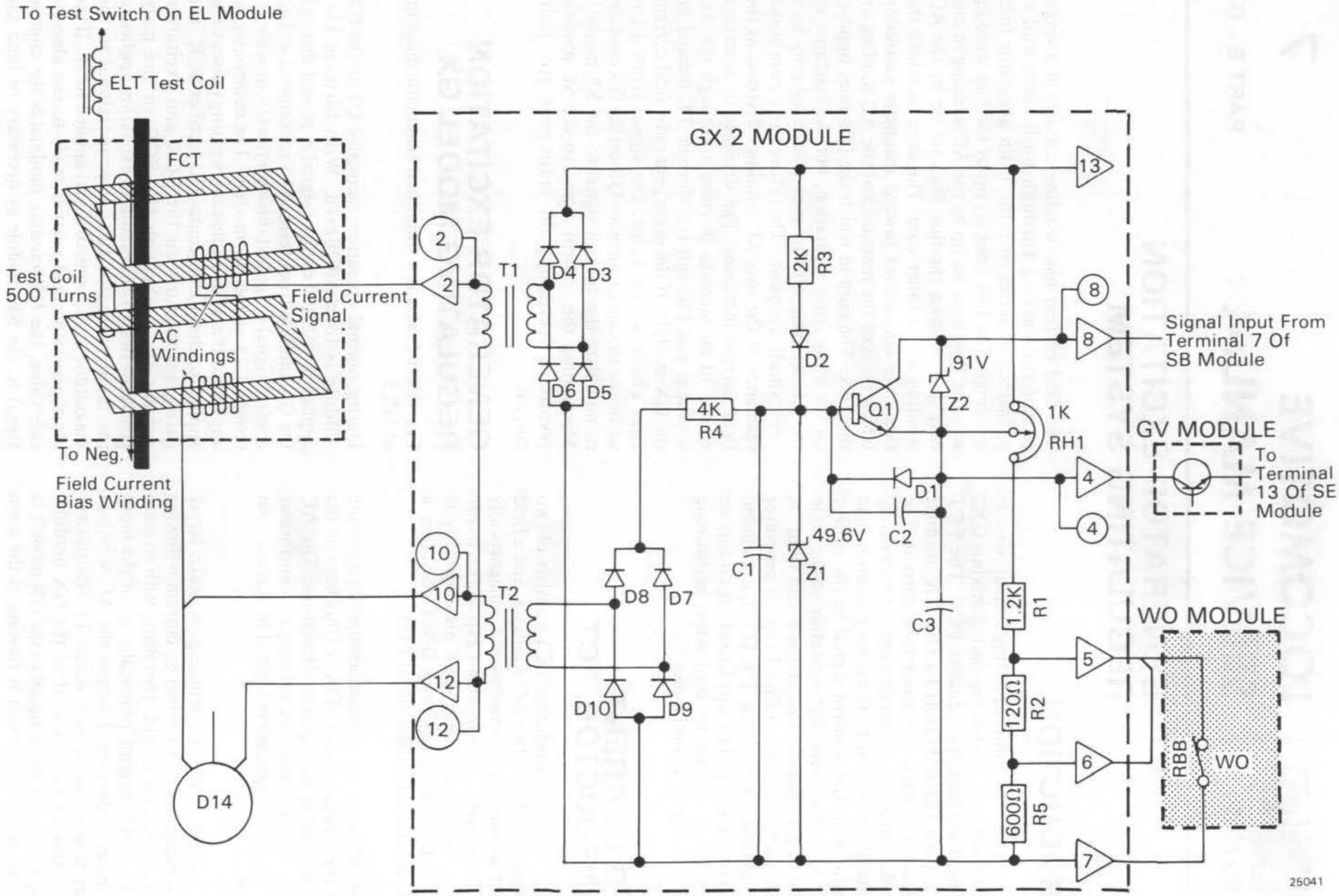

Fig.GX-1 – Generator Excitation Regulating Module – Simplified Schematic Diagram

Output voltage of the D14 alternator is applied to transformer T2 on the GX module. The rectified output of T2 is applied to resistor R4 and capacitor C1 in series, causing a voltage to be developed across C1. The voltage developed across C1 is applied to the base of transistor Q1. The series combination of capacitors C2 and C3 is connected in parallel with C1. The emitter is connected to the junction of C2 and C3, 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 R3, diode D2, and capacitor C1. The voltage developed across C1 is applied to the base of Q1. The rectified output of T1 is also applied to a voltage divider consisting of rheostat RH1, resistor R1, R2, and R5. 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 maintain forward bias on Q1.

As main generator field current increases, the voltage applied to T1 increases and the voltage developed across C1 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 a 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 R2 is shorted out by external connection between terminals 5 and 6. During low speed operation resistor R5 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 R2 and R5 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 R5. Field current is limited to 108 amperes after recalibration.

SD MODEL LOCOMOTIVES

On SD model locomotives, resistor R2 is shorted out by external connection between terminals 5 and 6, but 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.

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

LOAD REGULATOR ASSEMBLY

The load regulator assembly LR consisting of a 1500 ohm 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 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

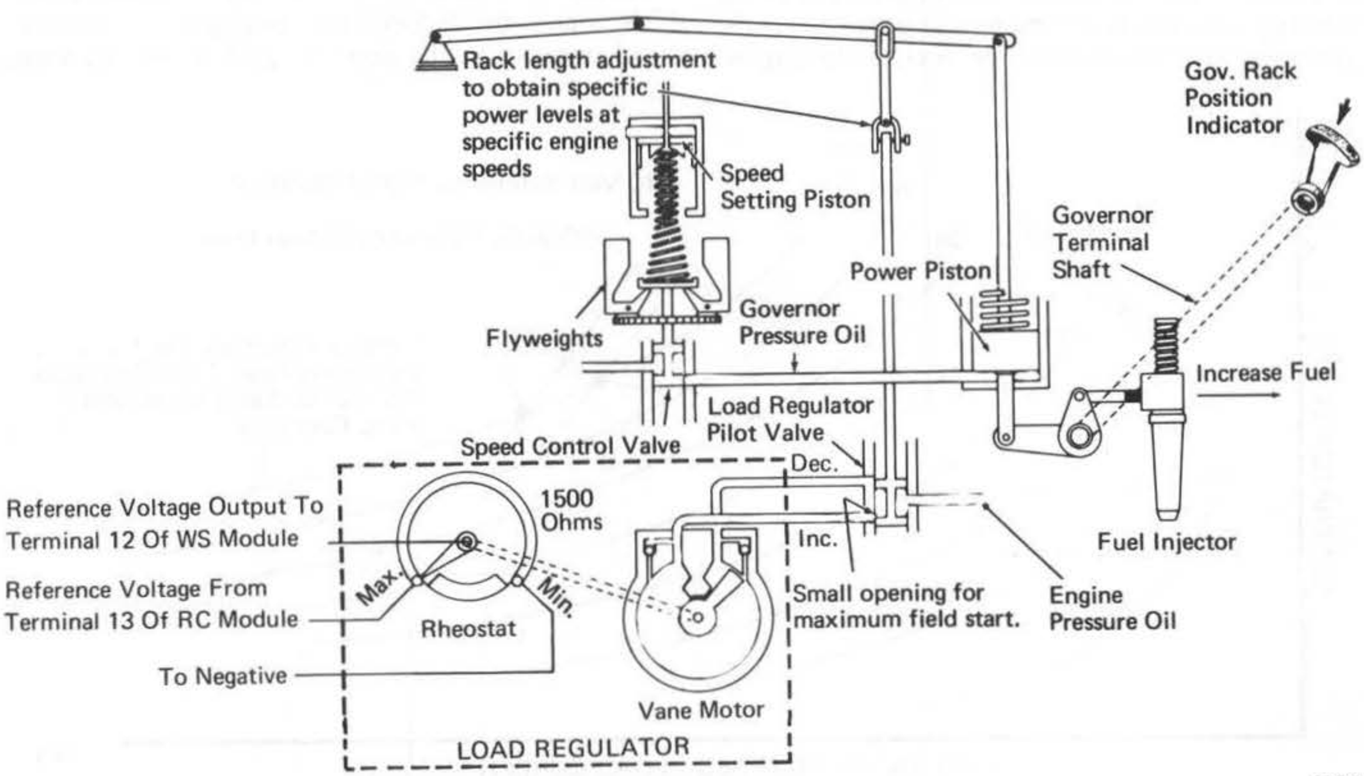

Fig.LR-1 – Load Regulator, Simplified Diagram current results in a decrease in voltage. This decrease in voltage is partly due to the increased I^2R and IZ losses in the main generator.

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 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

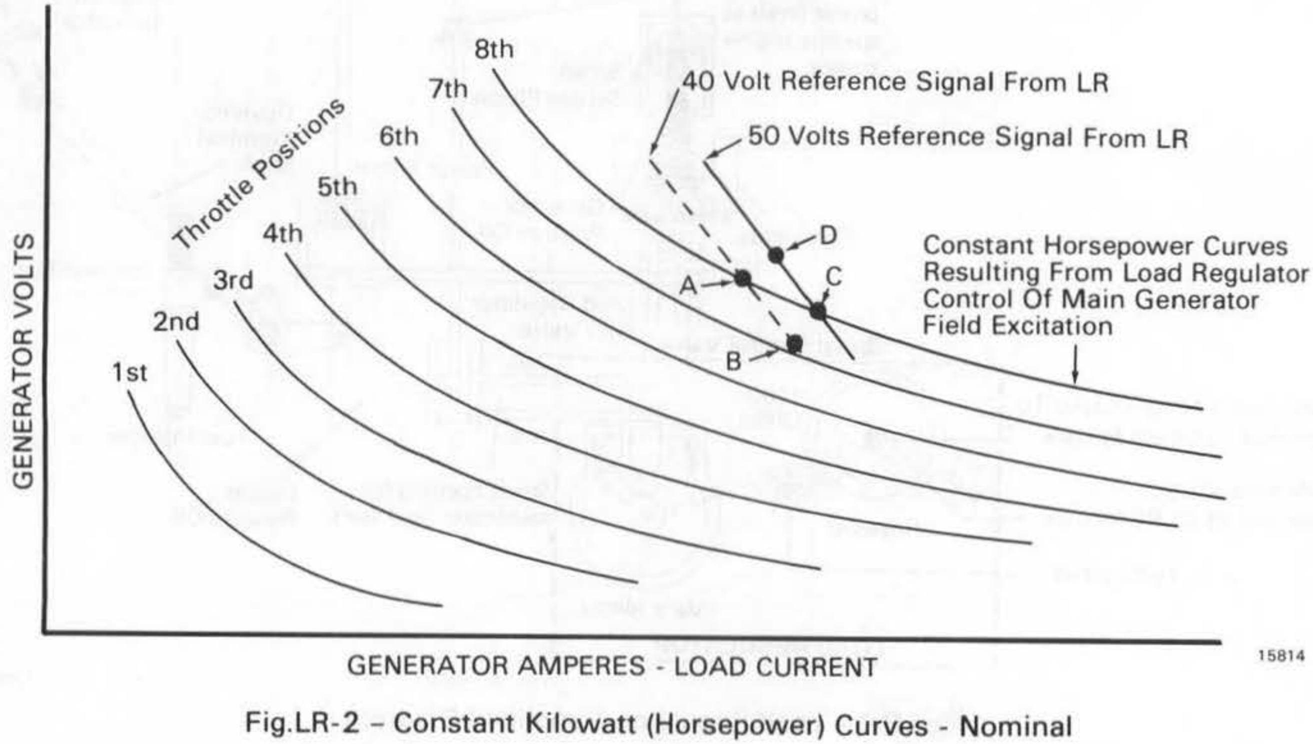

Fig.LR-2 – Constant Kilowatt (Horsepower) Curves - Nominal motor to drive the load regulator wiper arm toward minimum field position. Therefore, the engine speed governor maintains a constant engine speed and the load regulator maintains a constant horsepower output within the normal operating range 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 value of main generator current of 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.

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

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 trouble-shooting 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 wilth 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.

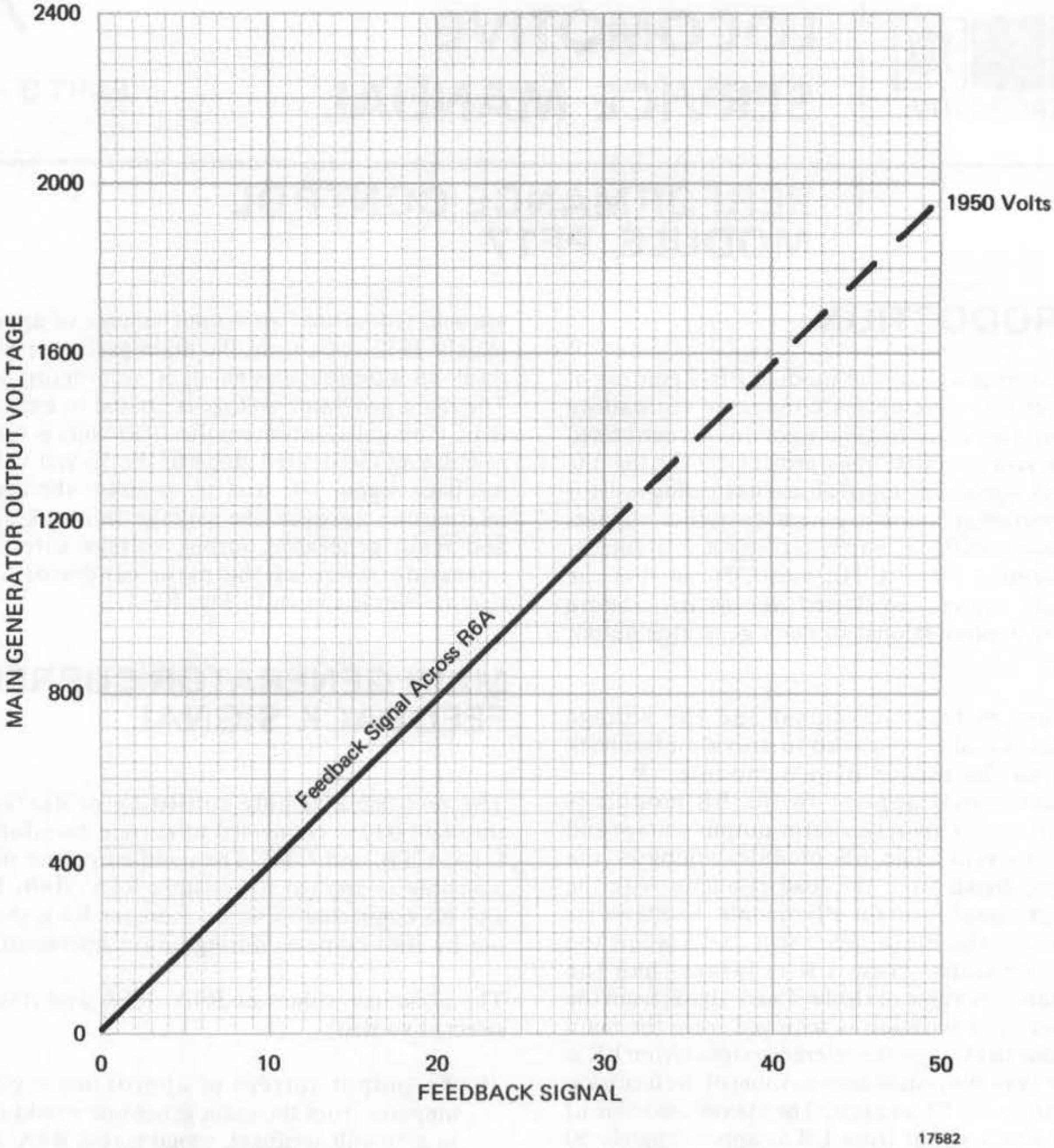

Fig.PF-1 - Relationship Between Feedback Signal And Main Generator Voltage

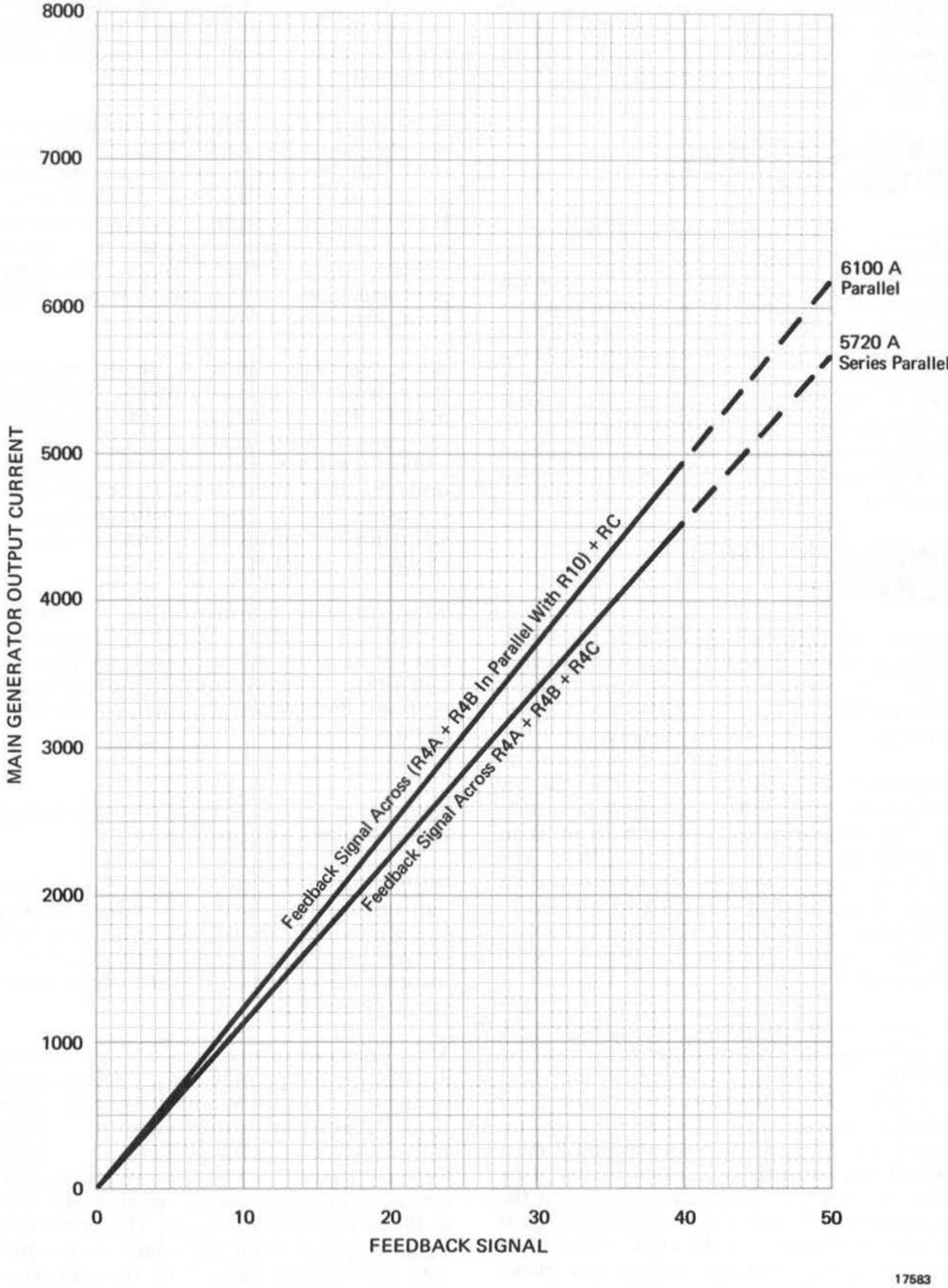

Fig.PF-2 – Relationship Between Feedback Signal And Main Generator Current

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 generator 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.

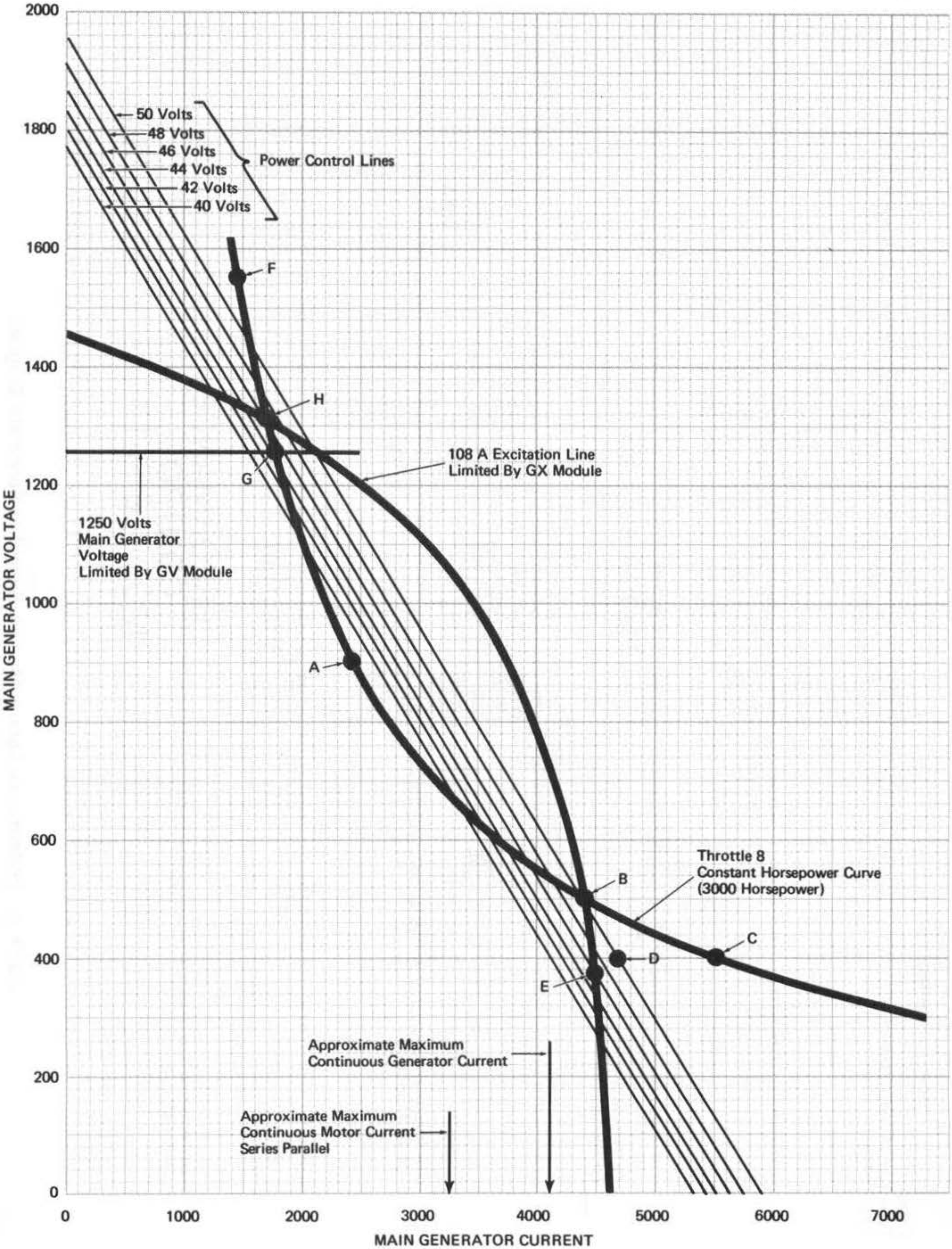

Fig.PF-3 - Power Control And Constant Horsepower Curves

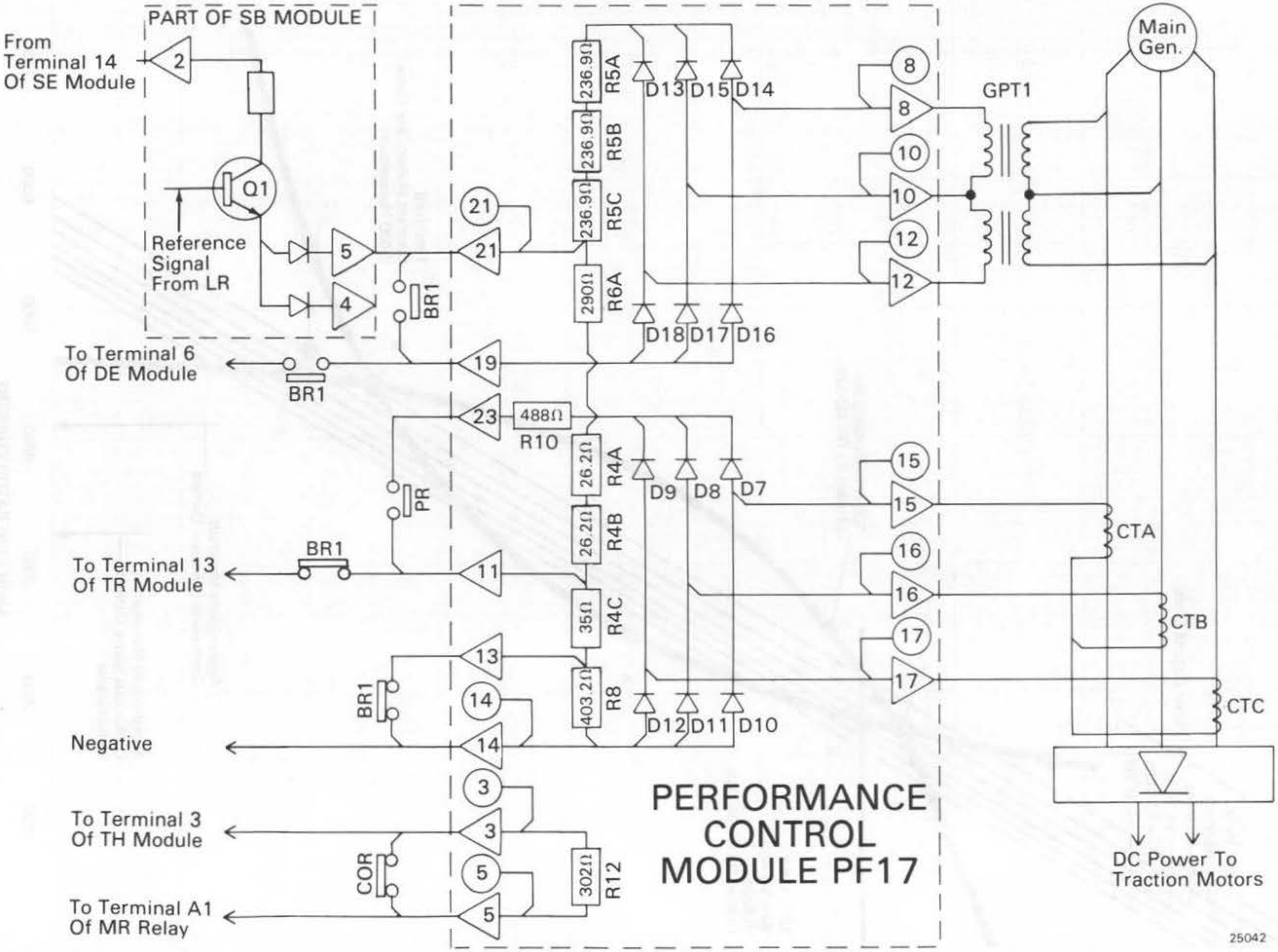

Fig.PF-4 – Performance Control Module, Simplified Schematic Diagram

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 feeback signals to the senor 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 OPERATIONN

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).

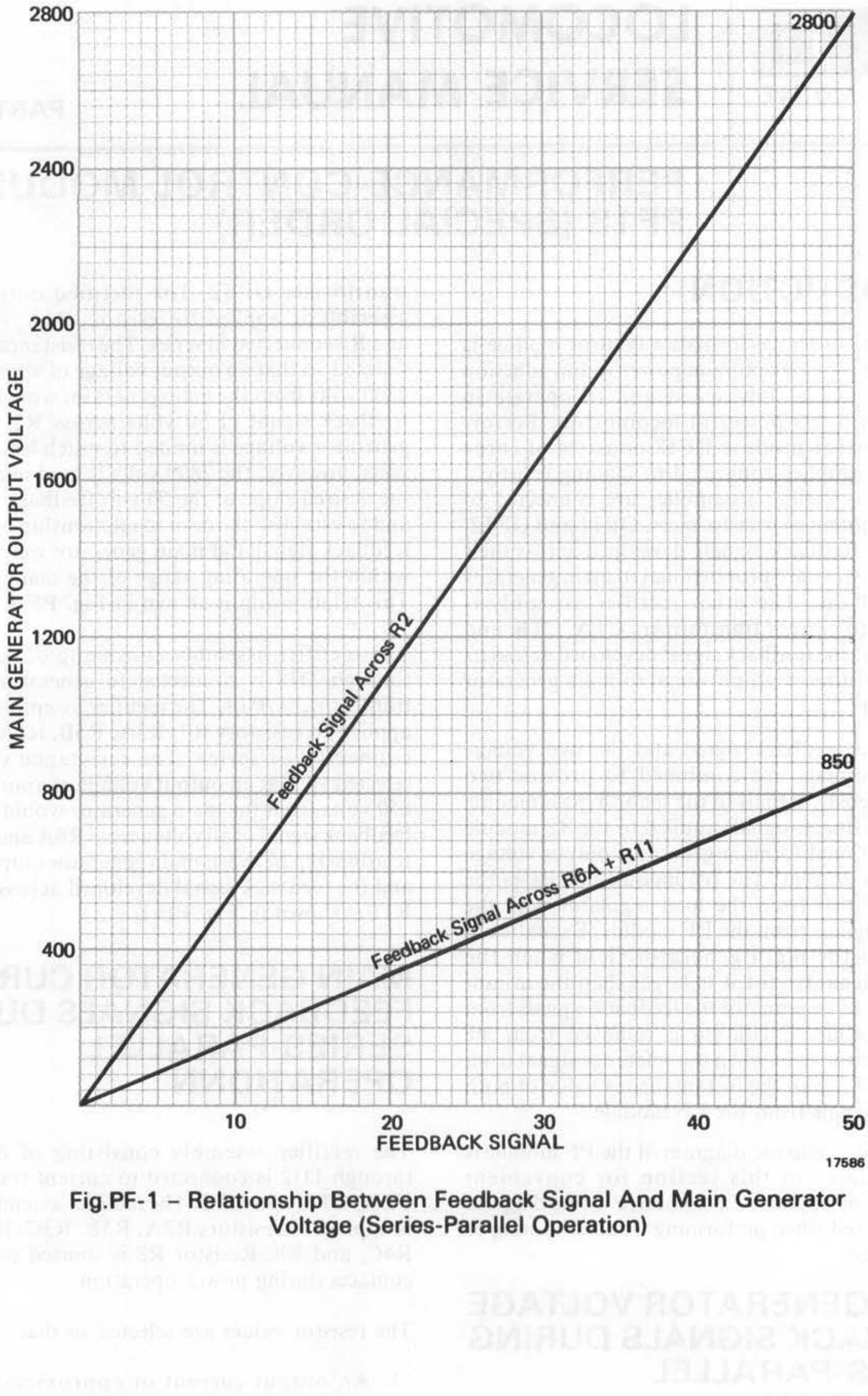

Fig.PF-1 – Relationship Between Feedback Signal And Main Generator Voltage (Series-Parallel Operation)

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 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. FP-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 toward point E instead of toward point F. Movement of the operating point toward point E provides for a larger

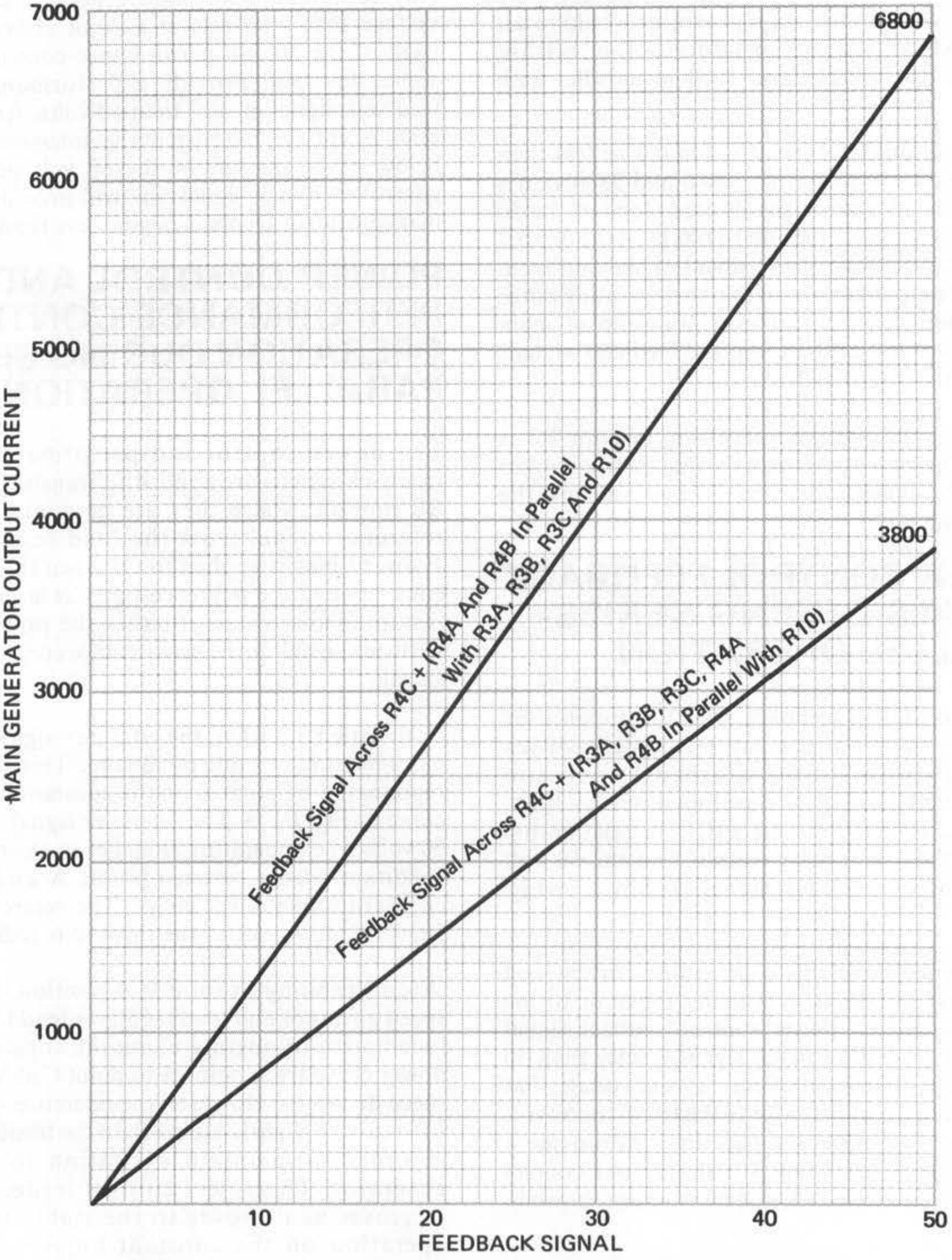

Fig.PF-2 - Relationship Between Feedback Signal And Main Generator Current (Series-Parallel Operation)

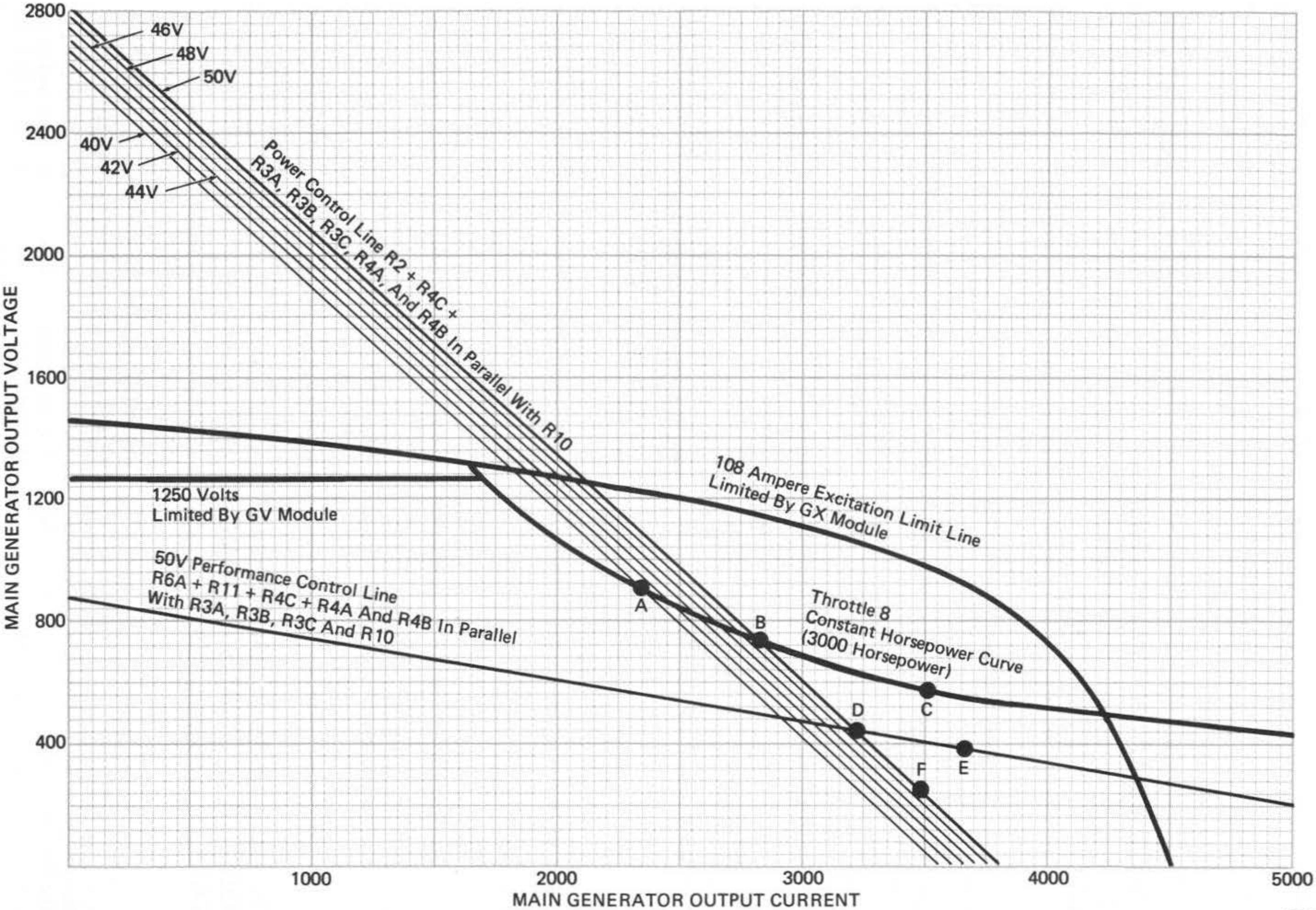

Fig.PF-3 – Relationship Of Power Control Feedback Signal, Performance Control Feedback Signal And Main Generator Output (Series-Parallel Operation) horsepower output than movement toward point F, but any increase in current from point D should be for a short time only. The purpose of the performance 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 reistors 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.

PERFORMANCE CONTROL FEEDBACK SIGNAL DURING PARALLEL OEPRATION

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

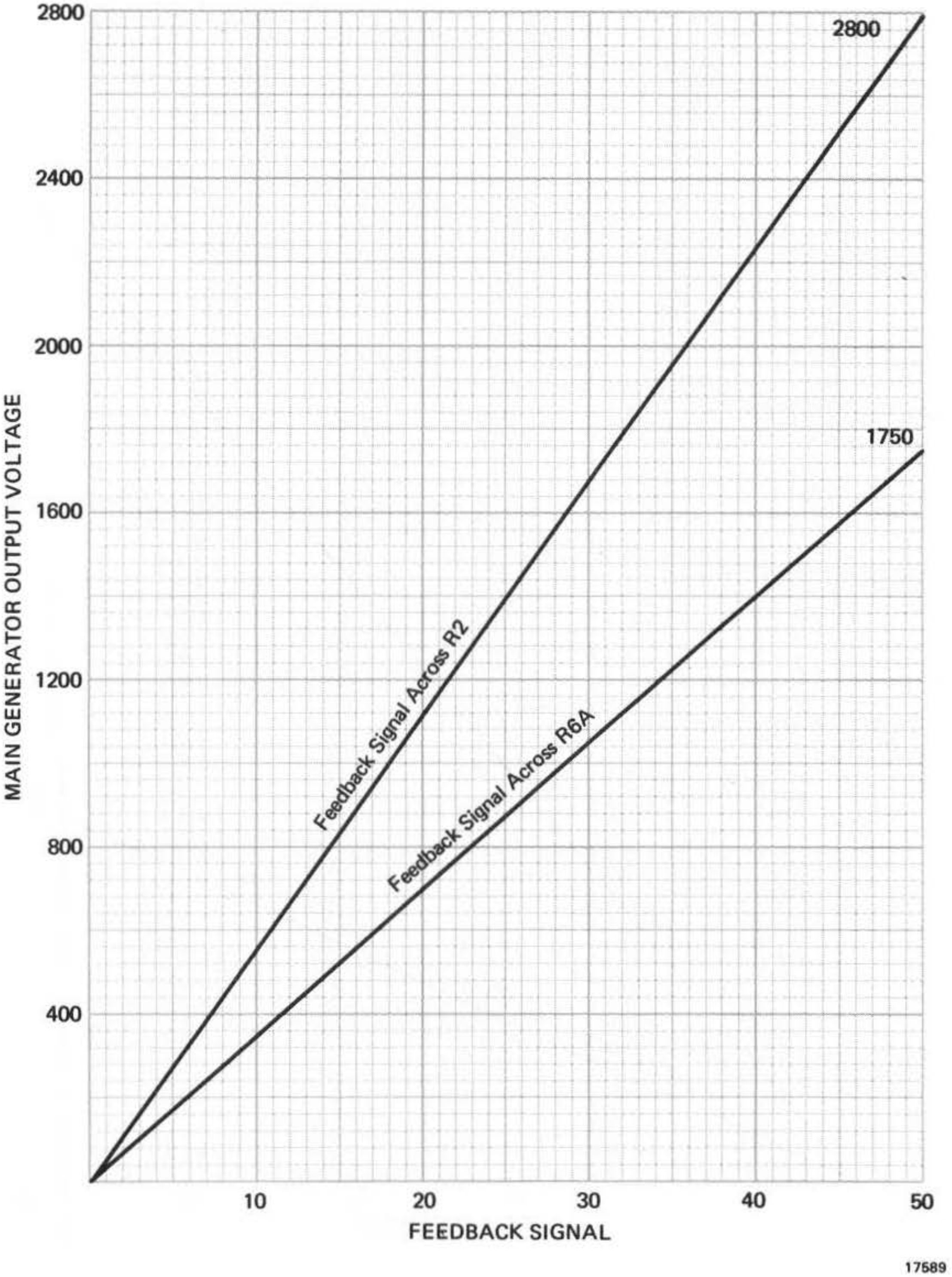

Fig.PF-4 - Relationship Between Feedback Signal And Main Generator Voltage (Parallel Operation)

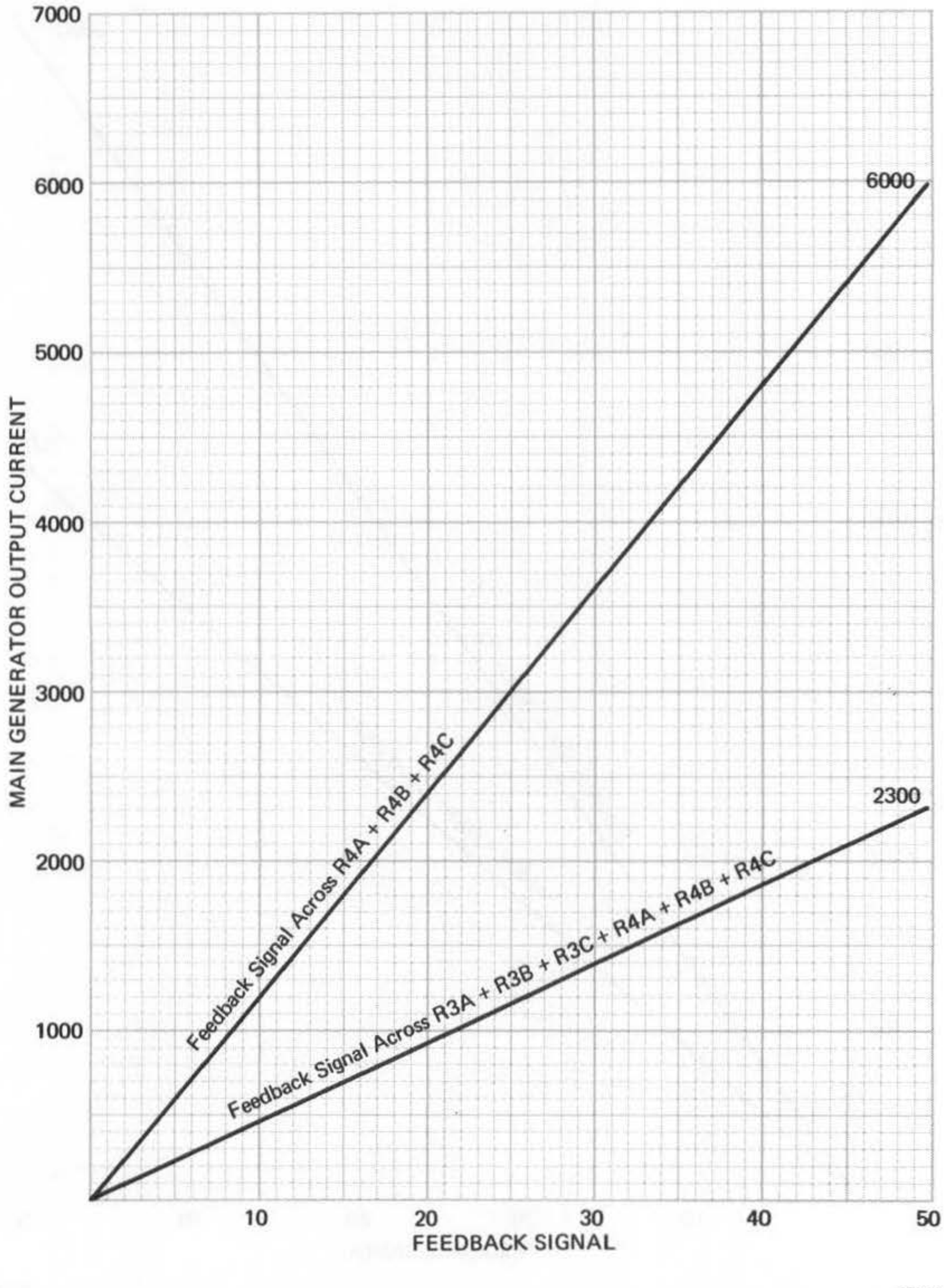

Fig.PF-5 - Relationship Between Feedback Signal And Main Generator Current (Parallel Operation)

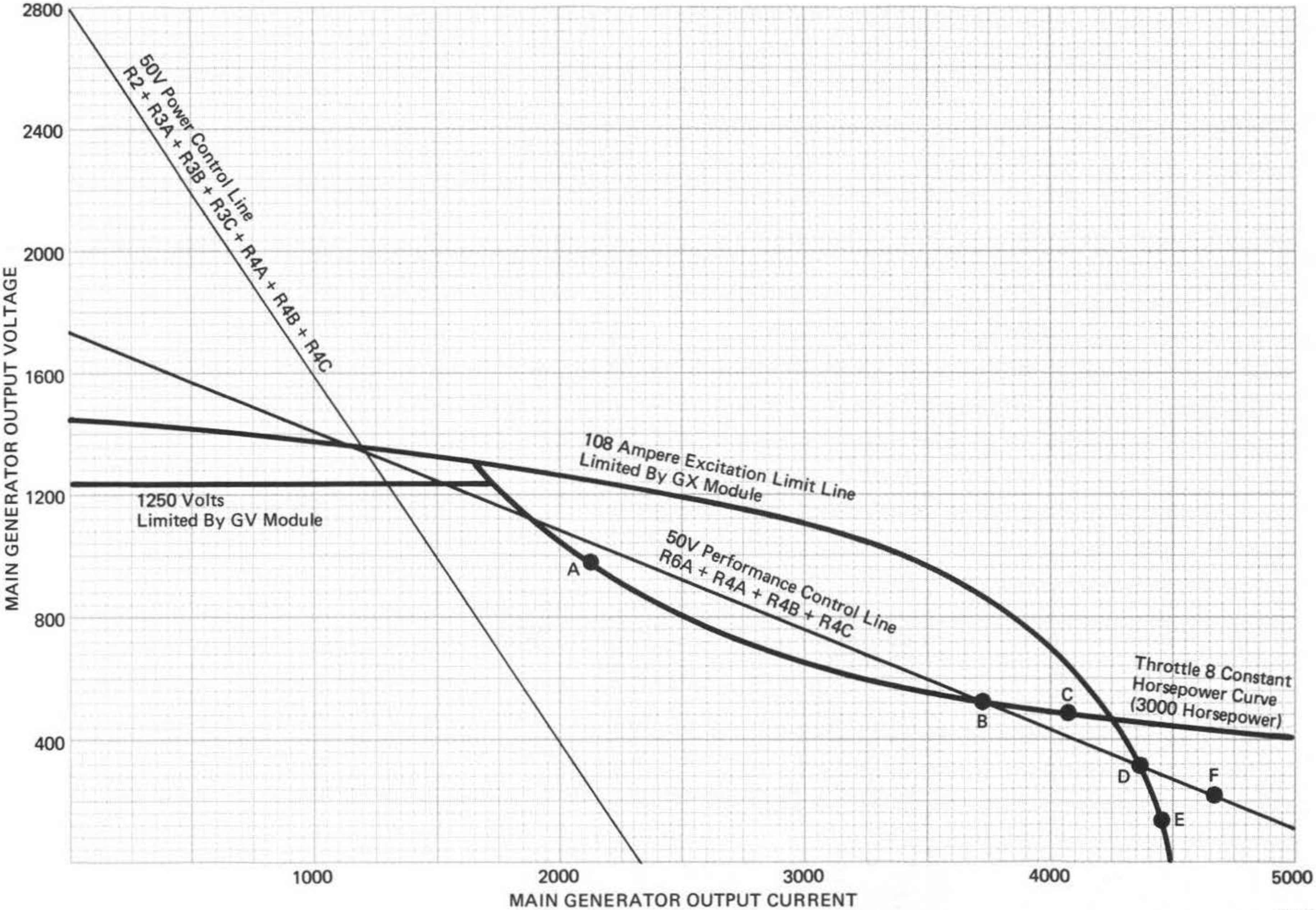

Fig.PF-6 – Relationship Between Power Control Feedback Signal, Performance Control Feedback Signal, And Main Generator Output (Parallel Operation) combination of R4A, R4B, and R4C. The relationship between main generator output and the performance control feedback signal is shown in Fig. PF-6.

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. Ths 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.

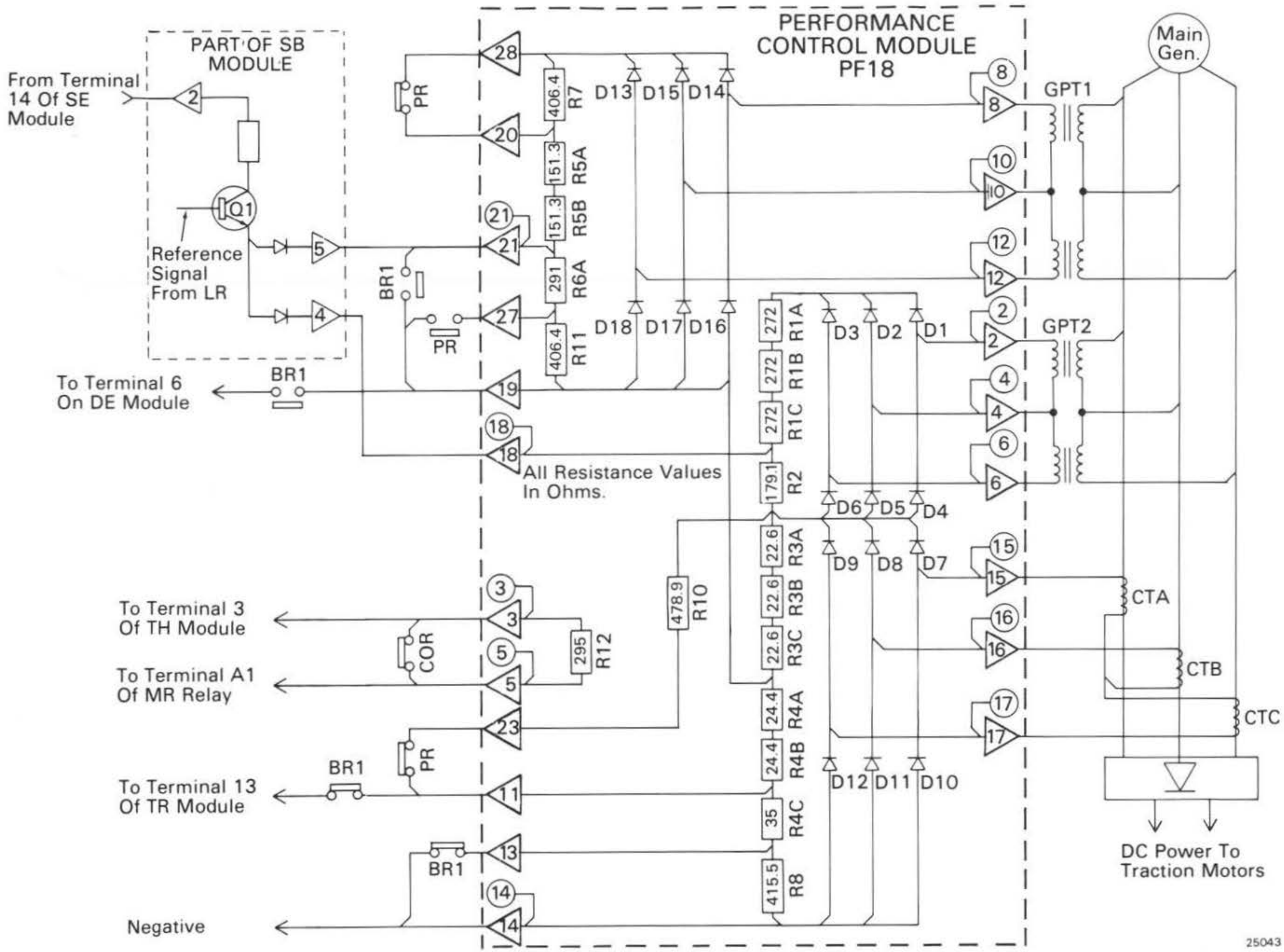

Fig.PF7 - Performance Control Module, Simplified Schematic Diagram

LOCOMOTIVE SERVICE MANUAL

PERFORMANCE CONTROL MODULE, PF29 (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 PF29 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 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 signal developed across its loading resistors is proportional to main generator output current.

The main function of the performance control module PF29 is to provide feedback signals to the SB module. These feedback signals are indicative of main generator output voltage and current. They are utilized by the main generator field excitation control circuitry to increase or decrease field current as necessary. The performance control module provides two separate feedback signals to the SB module. Each of these feedback signals is developed in the PF module by combining two voltage levels, one level proportional to main generator current, the other level proportional to main generator voltage. Although both feedback signals are therefore related to main generator power output, a change in power level will not necessarily be reflected by equal level changes in both feedback signals. This results from the method by which the feedback signals are developed. The power control feedback signal is largely dependent on the generator current level, while the performance control feedback signal is more dependent on voltage level. Fig. PF-1 illustrates the method used to develop these feedback signal levels. The power control feedback signal is made up of a portion of the GPT2 output plus the entire output level of the current

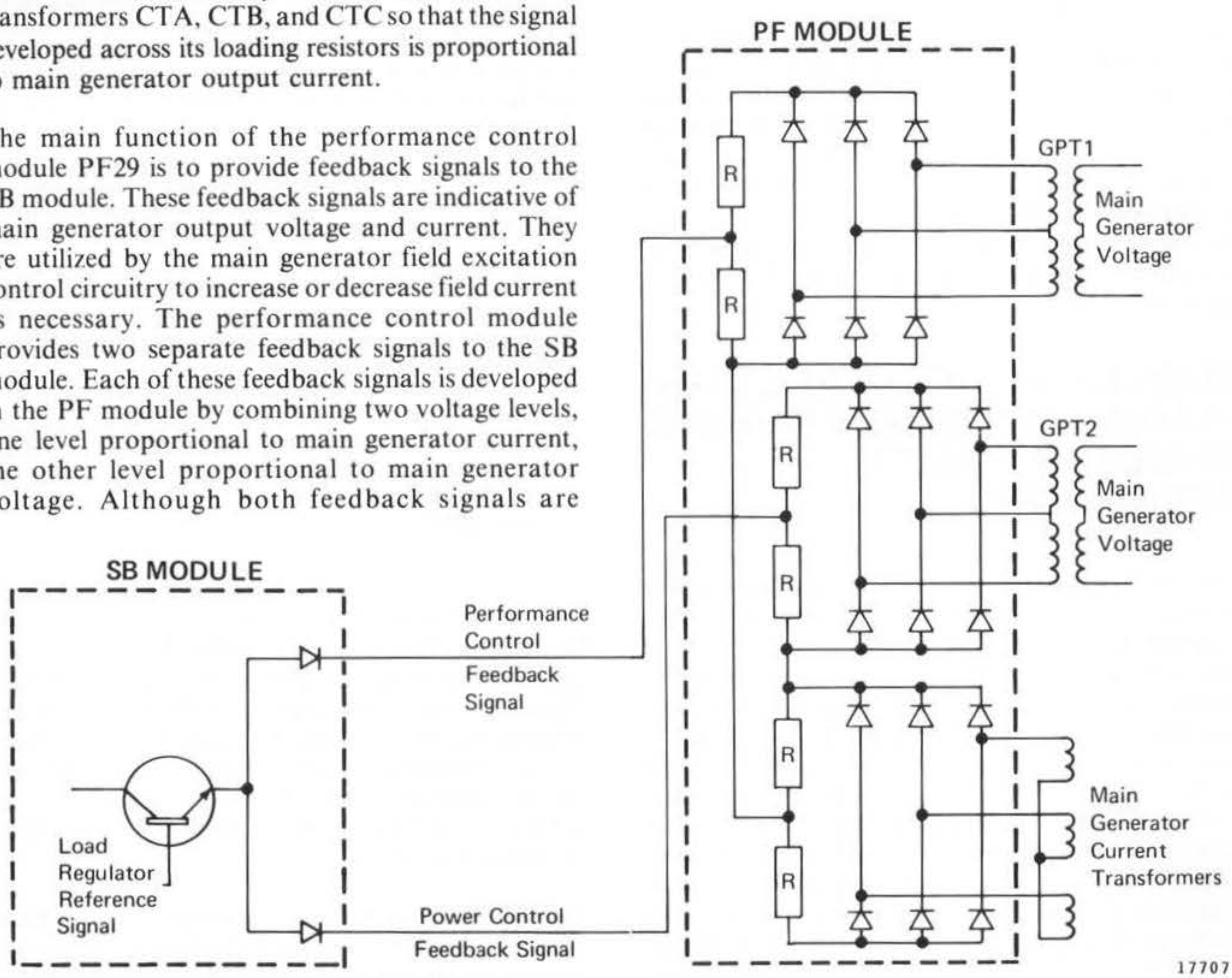

Fig.PF-1 - Performance Control Module Feedback Signal Generation, Block Diagram transformers; the performance control feedback signal is made up of a portion of the GPT1 output plus only a portion of the output level of the current transformers.

The SB module compares the reference signal from the load regulator LR with the feedback signals from the PF module. If the LR reference signal is at a higher voltage level than either PF feedback signal, excitation is applied to the main generator field. The amount of excitation applied is proportional to the difference between the LR signal and the PF feedback signal. If the LR reference signal is at a lower voltage level than both PF feedback signals, main generator field excitation is removed.

A simplified schematic diagram of the PF29 module, Fig. PF-2, is provided for convenient reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

Two sets of PR relay contacts are used with the PF29 module. These contacts are connected in parallel with selected rectifier assembly loading resistors and are used to either remove these resistors from the circuits or add them into the circuits. These circuit changes provide different voltage divider resistor networks from which the performance control feedback signal is obtained, thereby changing locomotive operating characteristics when switching from series-parallel to parallel operation.

MAIN GENERATOR VOLTAGE FEEDBACK SIGNALS DURING SERIES-PARALLEL OPERATION

The recifier 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 2400 volts from the main generator would result in a feedback signal of 50 volts across R2. Although the main generator voltage is limited to much less than 2400 volts, this value is used to calculate 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-3.

The rectifier assembly consisting of diodes D13 through D18 is connected to generator potential transformer GPT1. The rectifier assembly output is applied to resistors R5A, R5B, R6A, R6B, and R11 connected in series. (R7 is shorted during series parallel operation.) The resistance values are selected so that an output voltage of approximately 920 volts from the main generator will result in a feedback signal of 50 volts across R6A, R6B, and R11. The relationship between main generator output voltage and the feedback signal developed across R6A, R6B, and R11 is shown in Fig. PF-3.

Resistors R6A, R6B, and R11 are shorted during braking operation by BR1 contacts.

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 R3B, R3C, R4A, R4B, R4C, and R8 connected in series. Resistor R8 is shorted out by BR1 contacts during power operation.

The resistor values are selected so that:

1. A current of approximately 6600 amperes from the main generator would result in a 50 volt feedback signal across R4A, R4B, and R4C.

2. A current of approximately 4300 amperes from the main generator would result in a 50 volt feedback signal across R3B, R3C, R4A, R4B, and R4C.

Although the normal output current is limited to less than 6600 amperes, the 6600 and 4300 values are used to calculate 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 to the feedback signals is shown in Fig. PF-4.

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.

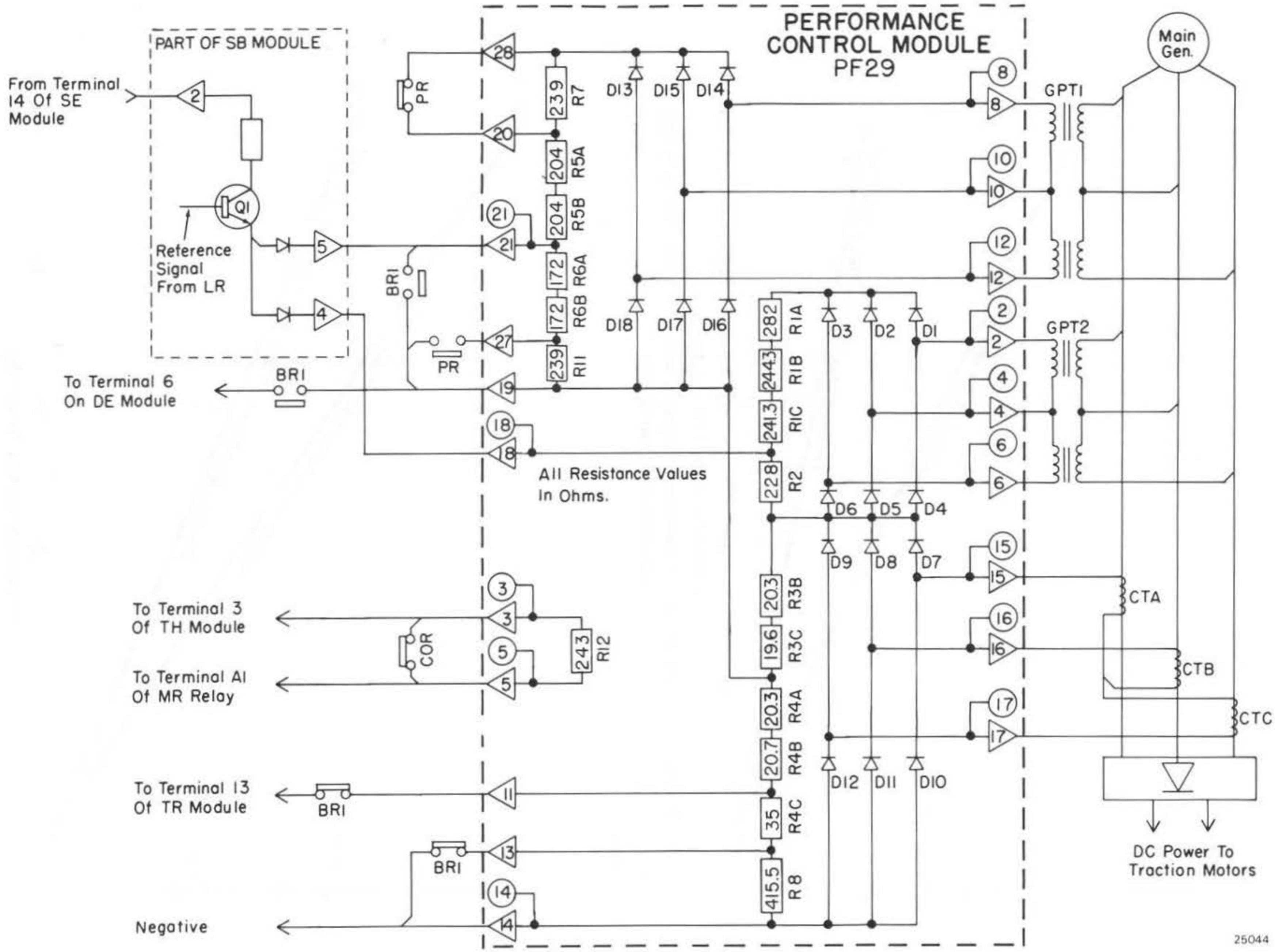

Fig.PF-2 – Performance Control Module, Simplified Schematic Diagram

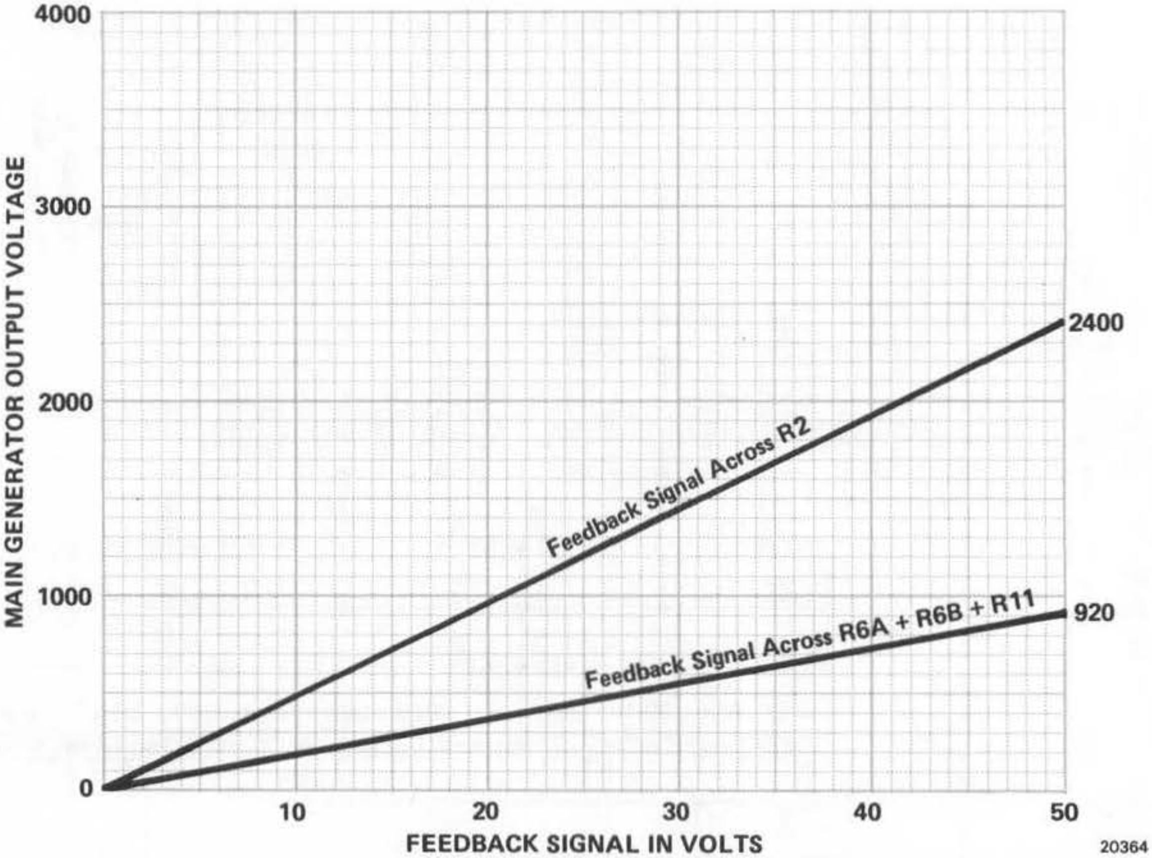

Fig.PF-3 – Relationship Between Feedback Signals And Main Generator Voltage (Series-Parallel Operation)

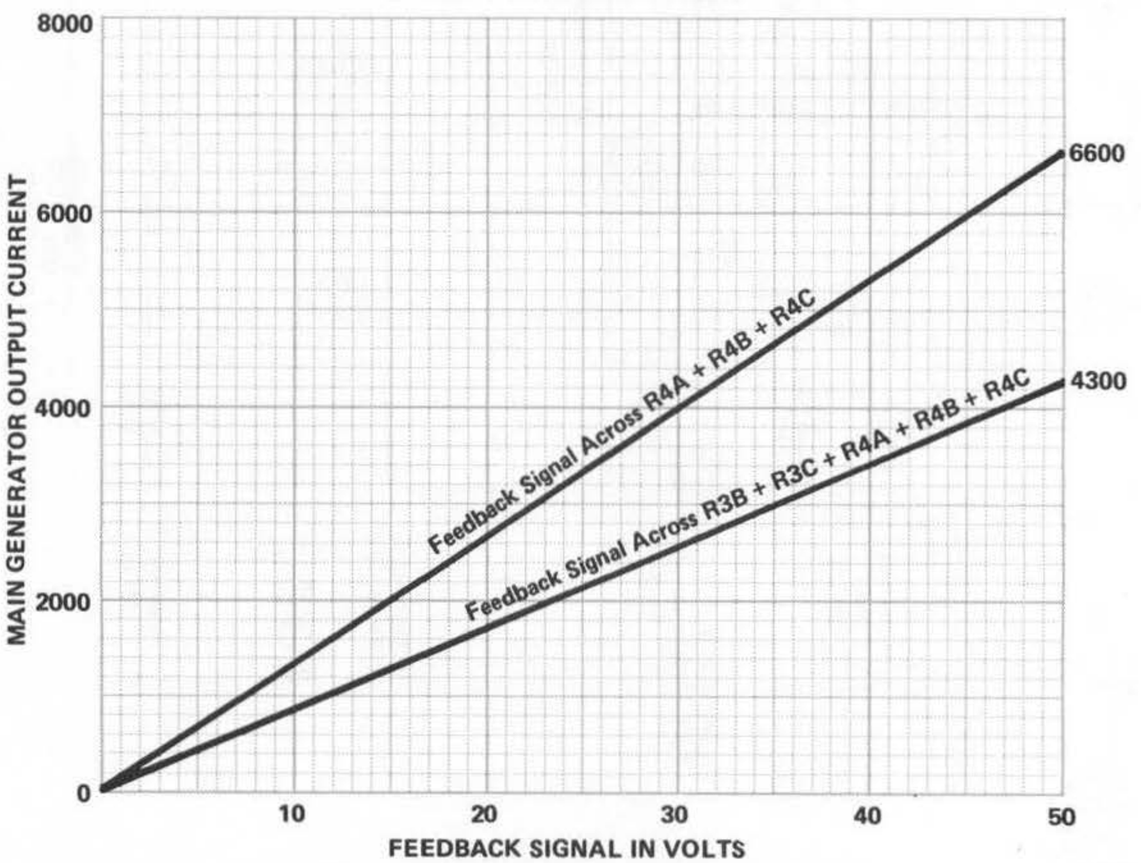

Fig.PF-4 – Relationship Between Feedback Signals And Main Generator Current (Series-Parallel Or Parallel Operation)

POWER CONTROL FEEDBACK SIGNAL DURING SERIES-PARALLEL OPERATION

The power control feedback signal is obtained by combining the main generator voltage feedback signal developed across R2 with main generator current feedback signal developed across 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-5.

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 44, 46, 48, and 50 volts are shown in Fig. PF-5.

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, R6B, 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-5.

Any combination of main generator current and voltage that intersects at a point above or to the right of the 50 volts 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 AND PERFORMANCE CONTROL 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.

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 in Fig. PF-5 from point A to point B as locomotive speed decreases. Also during throttle 8 operation, the LR reference signal has a maximum value of 50 volts. This condition is represented by point B on Fig. PF-5. 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. Also between these points, the power control feedback signal is less than 50 volts which enables the SB module to maintain main generator field excitation at the level required for a 3000 horsepower output. As speed continues to decrease, the locomotive operates along the power control line from point B to point D rather than along the constant horsepower curve toward point C. Operation on the constant horsepower curve from point B toward point C cannot occur as the LR reference signal has a maximum value of 50 volts and the power control feedback signal would be above 50 volts between points B and C on the horsepower curve. Operation along the power control line from point B to point D results in a decrease in horsepower output from the locomotive.

A further decrease in speed from point D causes the locomotive to operate along the performance control line toward point E rather than 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.

As locomotive speed decreases past point E, the operating point follows the performance control line to the generator excitation limit line and then continues down the limit line.

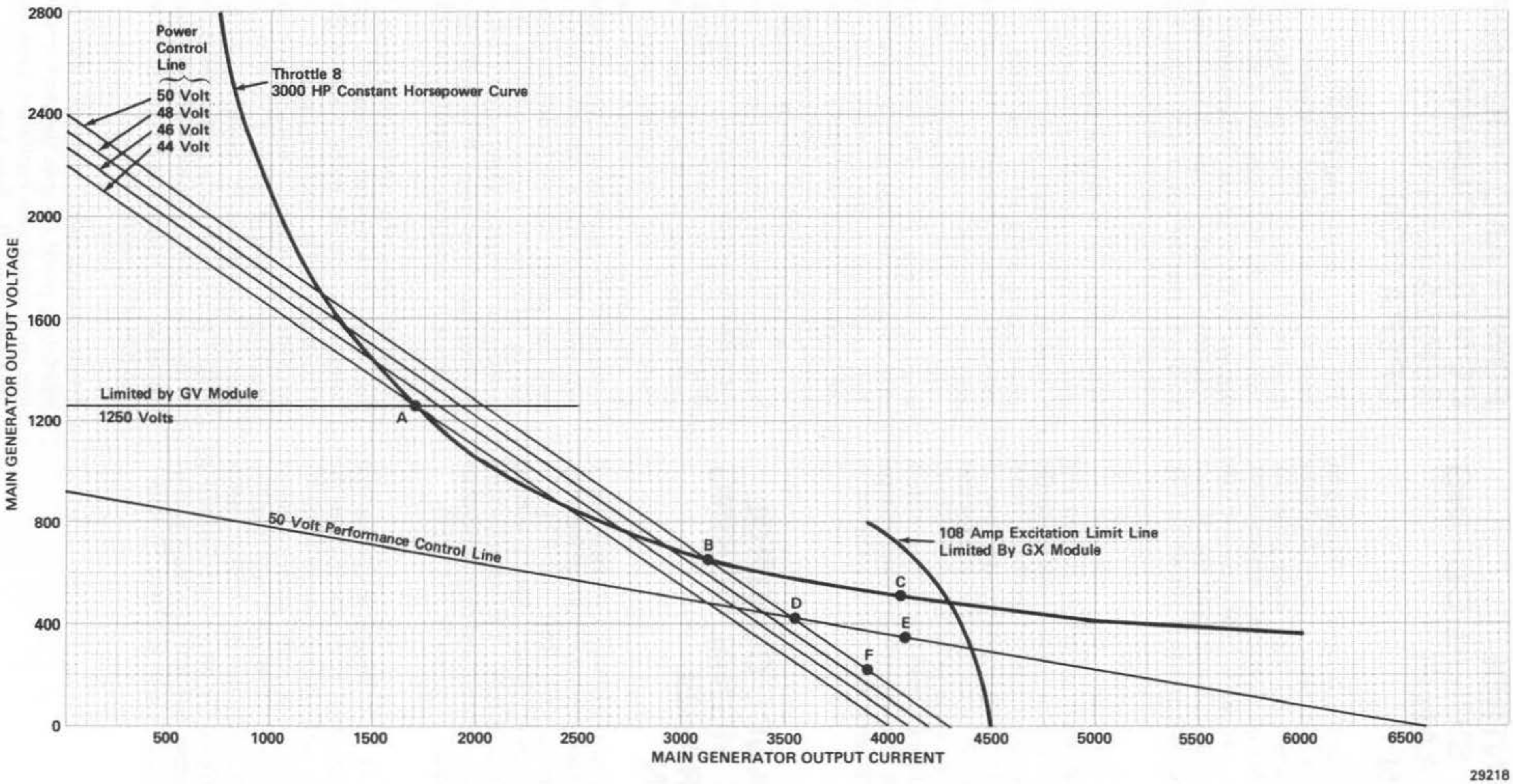

Fig.PF-5 – Relationship Of Power Feedback Signal, Performance Control Feedback Signal And Main Generator Output (Series-Parallel Operation)

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 2400 volts from the main generator would result in a feedback signal of 50 volts across R2. Although the main generator voltage is limited to much less than 2400 volts, this value is used to calculate 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-6.

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 R6B connected in series. (R11 is shorted during parallel operation.) The resistance values are selected so that an output voltage of approximately 1450 volts from the main generator would result in a feedback signal of 50 volts across R6A and R6B. Although the main generator voltage is limited to less than 1450 volts, this value is used to calculate 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-6.

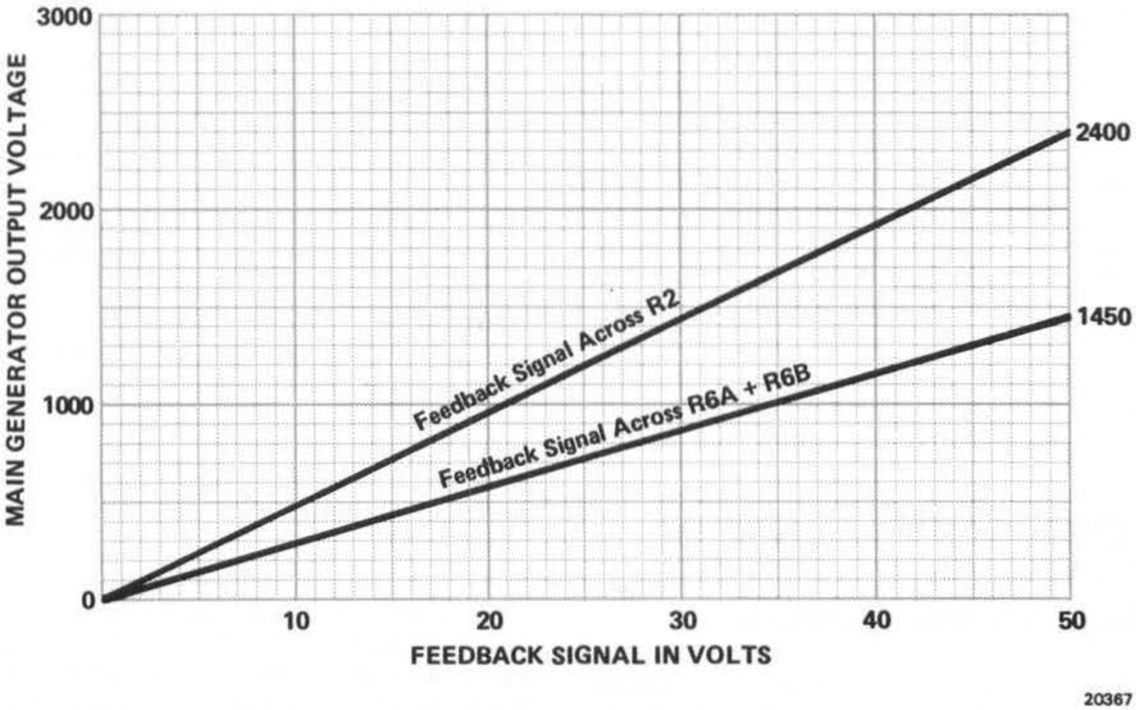

Fig.PF-6 - Relationship Between Feedback Signals And Main Generator Voltage (Parallel Operation)

MAIN GENERATOR CURRENT FEEDBACK SIGNALS DURING PARALLEL OPERATION

The current feedback signals used during parallel operation are the same as the current feedback signals used for series-parallel operation. Refer to the paragraph describing the series-parallel current feedback signals and to Fig. PF-4 for a complete description.

POWER CONTROL FEEDBACK SIGNAL 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 R3B, R3C, R4A, R4B, and R4C. This relationship between main generator output and the 50 volt power control feedback signal line is shown in Fig. PF-7.

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 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 44, 46, 48, and 50 volts are shown in Fig. PF-7.

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 and R6B 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-7.

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 AND PERFORMANCE CONTROL DURING PARALLEL OPERATION

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 in Fig. PF-7 from point A to point B as locomotive speed decreases. While the locomotive is operating in this range, either or both the power control and performance control feedback signals are less than 50 volts, and the LR reference signal is also less than 50 volts due to engine speed governor control.

These power 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. This enables the SB module to maintain main generator field excitation at the level required for a 3000 horsepower output.

When operating at point A, an increase in track speed tends to cause the operating point to move toward point C. However, main generator voltage is limited to approximately 1250 volts by the generator voltage regulator module GV, and the operating point actually moves along the 1250 volt line.

When operating at point B, a decrease in track speed causes the operating point to move down the generator excitation limit line.

When operating in a throttle position lower than throttle 8, the feedback signals, the reference signal, and the 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.

SECONDARY PF29 MODULE FUNCTIONS

The PF29 module also provides a feedback signal to the TR module. The signal utilized is developed across resistor R4C by the current transformers and is therefore proportional to main generator output current.

Resistor R12, also located on the PF29 module, provides another performance control function. If the locomotive is so equipped, the resistor is connected across a set of motor cutout relay COR contacts. These contacts are connected in series with the voltage reference line from the throttle response module to the rate control module. When operating with a pair of traction motors cut out, these COR contacts are open. This places resistor R12 in the circuit which reduces the maximum reference signal available from the load regulator, and thereby reduces horsepower output of the locomotive.

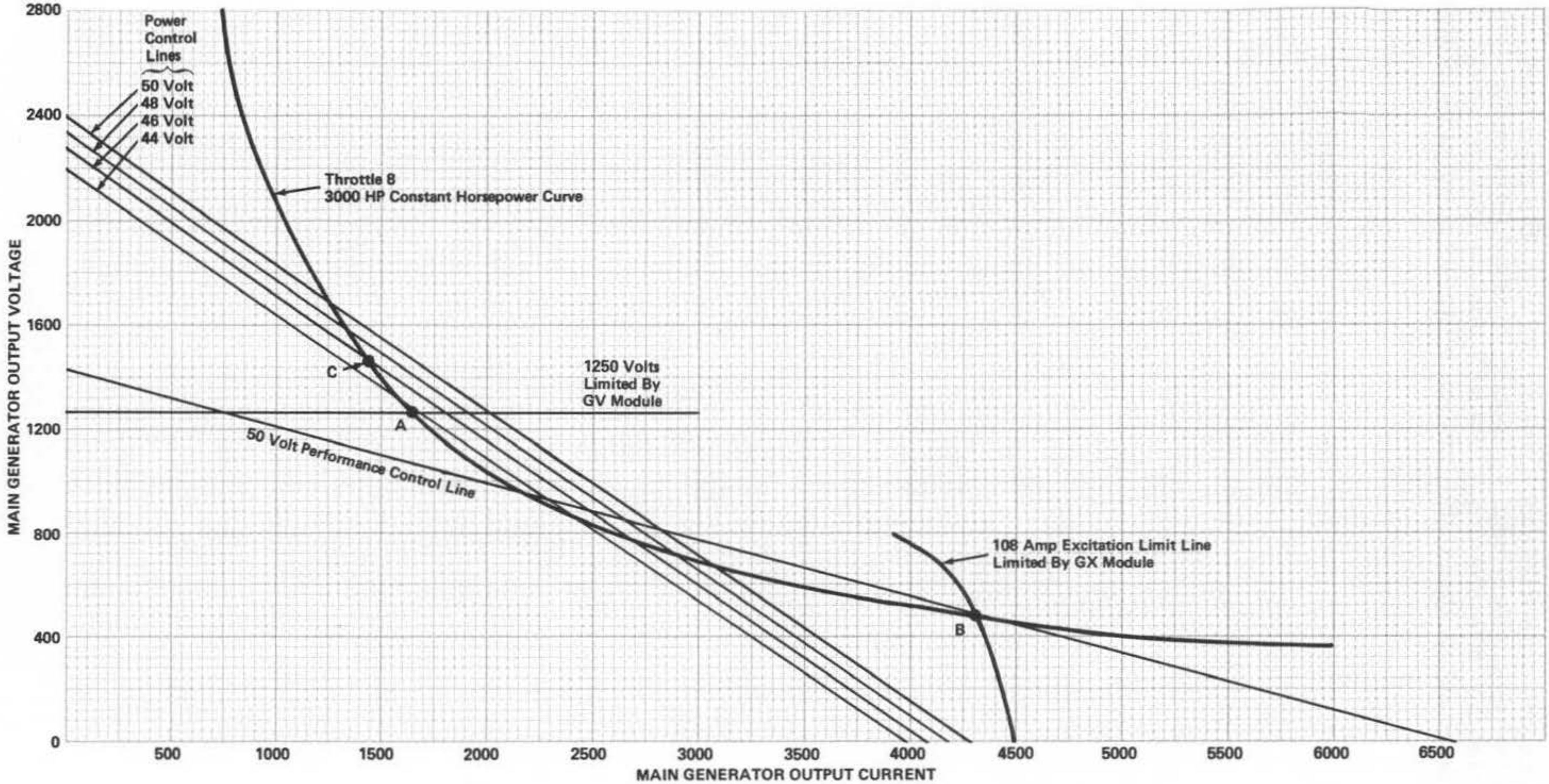

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Fig.PF-7 – Relationship Of Power Control Feedback Signal, Performance Control Feedback Signal And Main Generator Output (Parallel Operation)

RATE CONTROL MODULE, RC12

INTRODUCTION

The main generator excitation system has a fast response time. An increase in throttle position tends to cause a sudden increase in power. The rate control module RC12 provides for a 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 is described in the following paragraphs. Simplified schematic diagrams, Figs. RC1 and RC2, are provided for reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance on the system.

OPERATION WITH THROTTLE IN IDLE POSITION

With the throttle in IDLE, there is no reference signal input to terminal 3 of 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, diode D3, rheostat RH2, transistor Q2 (which is on), to capacitors C1, C2, and C3, and resistors R5, R8, and R14. The resistance ratio of R1 and RH2 to the parallel connection of R5 with R8 and R14 permits a very small charge on the rate control capacitors. This very small charge provides an initial forward bias for Q1 and results in a very small current flow through 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 IN POWER MODE

The MR and GFX relays pick up when the throttle is advanced to Run 1 position. Pick up of MR and GFX provides a feed of approximately 12.5 or 10.9 volts (depending on which TH module is used) 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 rate control capacitors C1, C2, and C3 and immediate power response. Otherwise, there would be a short time delay in power response while charging the rate control capacitors through R7 from terminal 3. The initial charge on the rate control capacitors from terminal 12 of the TH module is less than the potential applied to terminal 3. Therefore, the rate control capacitors 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, due to the initial charge on the rate control capacitors. After this initial response, the rate of increase in forward bias is determined by the rate at which the rate control capacitors charge. This rate is determined by the circuit controlling operation of Q2. Current through Q2, to charge the rate control capacitors, is held constant regardless of input voltage, by zener diode Z4. A constant voltage drop between the base-emitter junction of Q2, created by RH2 and Z4, controls the amount of current through Q2. Therefore the rate at which the rate control capacitors charge is determined by the resistance of RH2.

Controlling operation of Q2 provides a linear output voltage to the load regulator, regardless of input voltage to the RC module. Linear control of generator excitation allows the engine to respond more normally to increased load, resulting in less smoke and engine wear.

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 relationship between throttle position, input voltage from TH module, and output from the RC module is shown in Fig. RC-1.

During transition, generator excitation is removed for a short time (GFX dropped out) while the actual transition sequence is completed. A set of wheel delay relay WD contacts is connected to complete the input circuit to terminal 3 of the RC module during transition. This prevents discharge of the rate control capacitors. A second set of WD contacts are connected to the discharge path from terminal 6 of the RC module. This set of contacts opens during transition to prevent a false wheel slip signal from discharging the rate control capacitors. When transition is complete a set of PR contacts connect 74 volts to terminal 5 of the RC module. This 74 volts causes Q3 to turn on, shorting out the resistance of R14. Shorting out R14 allows for faster discharge of the rate control capacitors during a high speed wheel slip.

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 and Q3.

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 and R14 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 WITH BASIC DYNAMIC BRAKES, Fig. RC-1

When the dynamic brakes are applied, a reference signal from the dynamic brake rheostat (proportional to dynamic brake handle position) is applied to terminal 2 of the RC module. This signal causes a current flow through R2, D3, TH2, and Q2, to rate control capacitor C1 and resistor R5. This current flow results in voltage build up across capacitor C1 and consequently forward bias on the base of Q1. An increase in forward bias on the base of Q1 results in an increase of current flow from collector to emitter of Q1 and a larger voltage is developed across the load regulator LR. This increase in current is supplied from terminal 2 through R3 and to the collector of Q1.

It should be noted that the voltage across LR does not increase suddenly as the braking lever is advanced, but increases at the same rate as the increase in forward bias applied to the base of Q1. The rate of increase in forward bias is determined by the rate at which C1 charges. This rate is determined by the circuit controlling operation of Q2. Current through Q2, to charge C1, is held constant regardless of input voltage, by zener diode Z4. A constant voltage drop between the base-emitter junction of Q2, created by RH2 and Z4, control the amount of current through Q2. Therefore the rate at which C1 charges is determined by the resistance of RH2.

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 19 volts. Therefore, Z2 breaks down when the voltage across R3 reaches 19 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 capacitor C1 slowly discharges 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.

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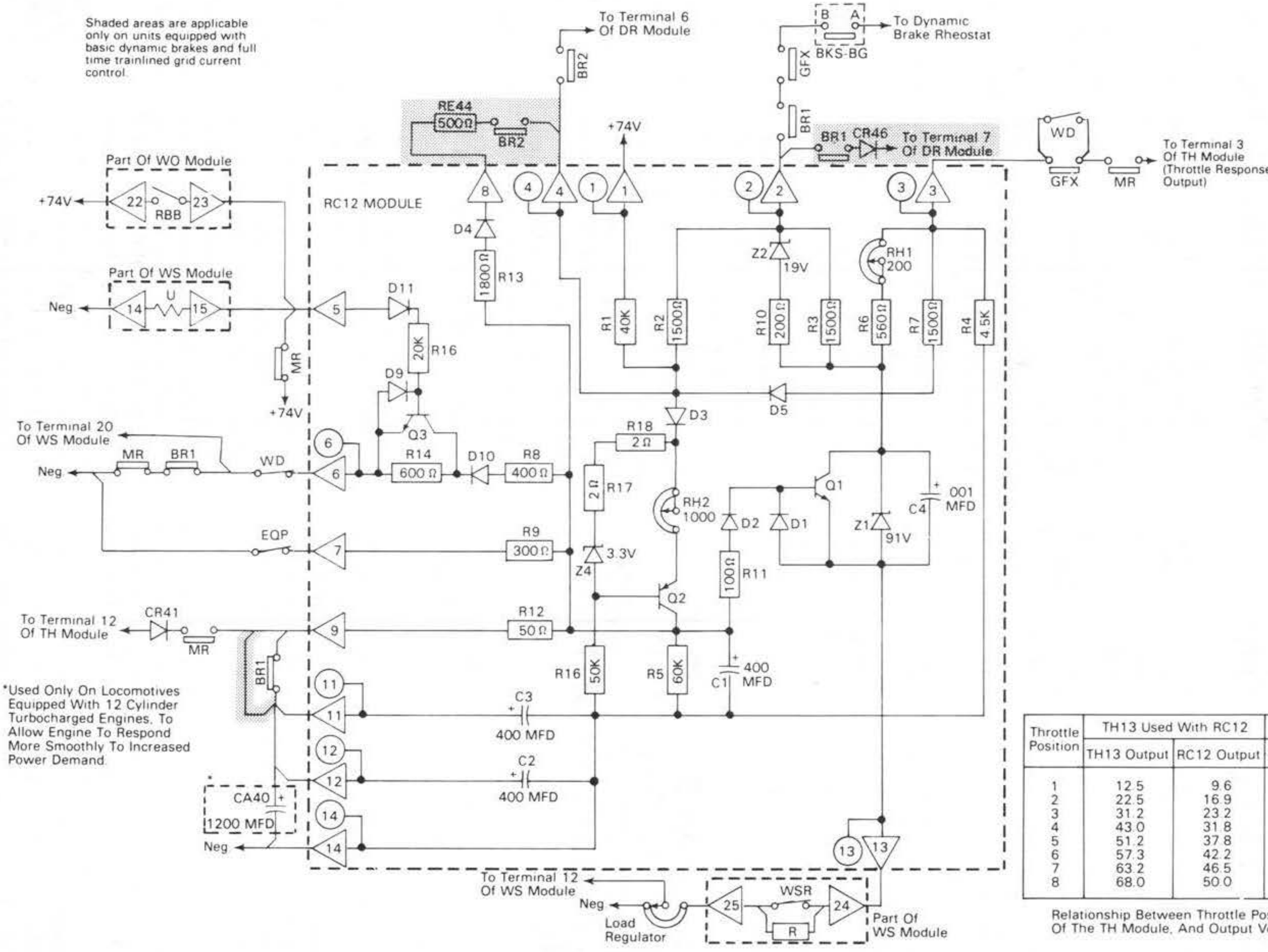
7B-RC12-3



Throttle Position	TH13 Used With RC12		TH14 Used With RC12	
	TH13 Output	RC12 Output	TH14 Output	RC12 Output
1	12.5	9.6	10.9	8.45
2	22.5	16.9	21.6	16.20
3	31.2	23.2	28.6	21.30
4	43.0	31.8	35.7	26.50
5	51.2	37.8	43.3	32.00
6	57.3	42.2	51.2	37.80
7	63.2	46.5	61.4	45.20
8	68.0	50.0	68.0	50.00

Relationship Between Throttle Position, Output Voltage Of The TH Module, And Output Voltage Of The RC Module.

25045

Fig.RC-1 – Rate Control Module Simplified Schematic Diagram
(For Units Equipped With Basic Dynamic Brakes)

If the braking lever is positioned to release the brakes, the BR1 relay drops out and C1 will rapidly discharge through R8 and Q3 to terminal 6 and then to negative. Capacitor C1 will discharge through R9 to terminal 7 and then to negative if the EQP relay drops out.

LIMITING BRAKING GRID CURRENT TO 700 AMPERES

Terminal 4 of the RC module is connected, through BR2 contacts, to terminal 6 on the dynamic brake regulator module DR. If the braking grid current increases above 700 amperes, terminal 4 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 allowing discharge through R5 of the RC module. Discharging of C1 results in less voltage across LR and less braking effort. When braking grid current decreases below 700 amperes, terminal 4 is disconnected from negative and the brake control signal is again applied to C1. 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.

LOCOMOTIVES EQUIPPED WITH BASIC DYNAMIC BRAKES AND TRAINLINED GRID CURRENT CONTROL, Fig. RC-1

NOTE

Shaded areas of Fig. RC-1 denote modifications to the basic dynamic brake circuit to obtain trainlined grid current control.

As an optional extra, the locomotive may be equipped to regulate braking grid current at a value proportional to braking lever position. The following paragraphs describe the operation of the RC module when trainlined grid current control 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 R13 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.

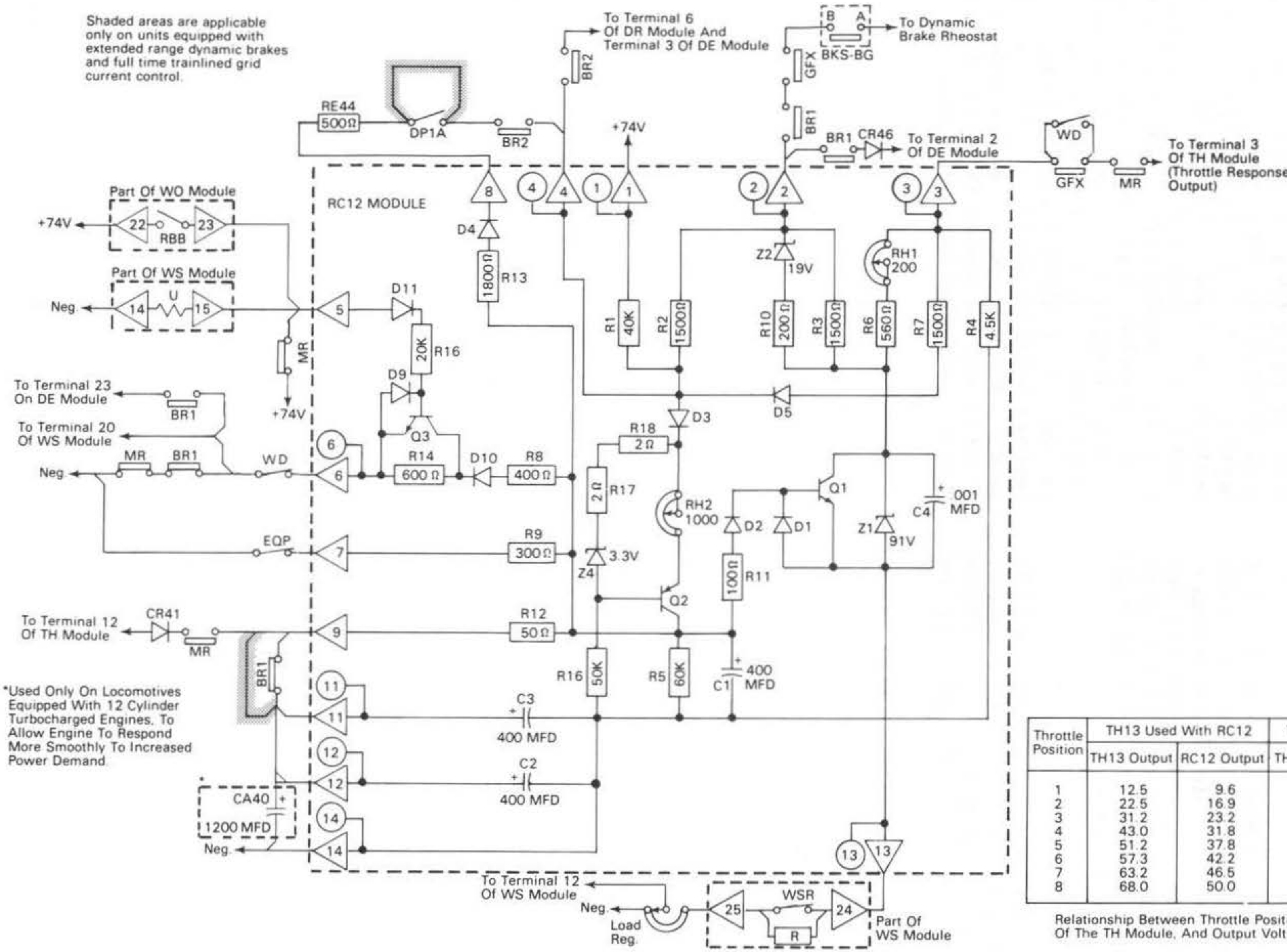
OPERATION WHEN EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES, Fig. RC-2

On locomotives equipped with extended range dynamic brakes, terminal 6 of the RC module is connected to terminal 23 of the DE module, terminal 2 of the RC module is connected to terminal 2 of the DE module, and terminal 4 of the RC module is connected to terminal 6 of the DR module and terminal 3 of the DE module. During extended range dynamic brake operation, terminal 8 of the RC module is connected to terminal 6 of the DR module and terminal 3 of the DE module.

The connection between terminal 4 of the RC module and terminal 6 of the DR module limits braking grid current to a maximum value of 700 amperes. This limiting action is the same as that provided for basic dynamic brakes.

The connection between terminal 6 of the RC module and terminal 23 of the DE module provides a fast discharge path for C1 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 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 is through R8 and Q3 to terminal 6 on the RC module, then through the DE module to negative.

The connection between terminal 2 of the 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 during extended range dynamic brake operation, the DE module operates to complete a path between terminals 4 and 5 of the DR module. This signal results in discharging capacitor C1 through R13 and terminal 8 on the RC module then to negative through the DR module. This action limits dynamic braking grid current to a value proportional to the braking lever signal during extended range dynamic brake operation. Refer to description of the DR and DE modules for further information on this limiting action.



Throttle Position	TH13 Used With RC12		TH14 Used With RC12	
	TH13 Output	RC12 Output	TH14 Output	RC12 Output
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2	22.5	16.9	21.6	16.20
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5	51.2	37.8	43.3	32.00
6	57.3	42.2	51.2	37.80
7	63.2	46.5	61.4	45.20
8	68.0	50.0	68.0	50.00

Relationship Between Throttle Position, Output Voltage Of The TH Module, And Output Voltage Of The RC Module.

25046

Fig.RC-2 – Rate Control Module Simplified Schematic Diagram (For Units Equipped With Extended Range Dynamic Brakes)

LOCOMOTIVES EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES AND FULL TIME TRAINLINED GRID CURRENT CONTROL, Fig. RC-2

On locomotives equipped with extended range dynamic brakes and full time trainlined grid current control, terminal 8 of the RC module is connected through RE44 and BR2 contacts to terminal 6 of the DR module. The DP1A contacts are not used in this circuit. Terminal 9 is connected to terminal 11 and the BR1 contacts are not used.

The braking lever signal, from terminal 2 of the RC module, is provided to terminal 2 of the DE module. The grid current signal is provided between terminals 7 and 11 of the DE module. The DE module compares the braking lever signal with the grid current signal. If the grid current signal rises above the braking lever signal, the DE module operates to complete a path between terminals 4 and 5 of the DR module. Completing a path between terminals 4 and 5 of the DR module turns on a transistor on the DR module which provides a discharge path from terminal 8 of the RC module to negative, through the DR module. This decreases excitation which results in decreasing braking grid current to a value proportional to the braking lever signal. This limiting action takes place before as well as after going into extended range dynamic brake operation. Whereas on locomotives equipped with extended range dynamic brakes, but not equipped with full time trainlined grid current control, the limiting action occurs only after going into extended range dynamic brake operation. Refer to description of the DE and DR modules for a more detailed description of this full time limiting action.

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

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 resistor 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 and GV modules, 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.

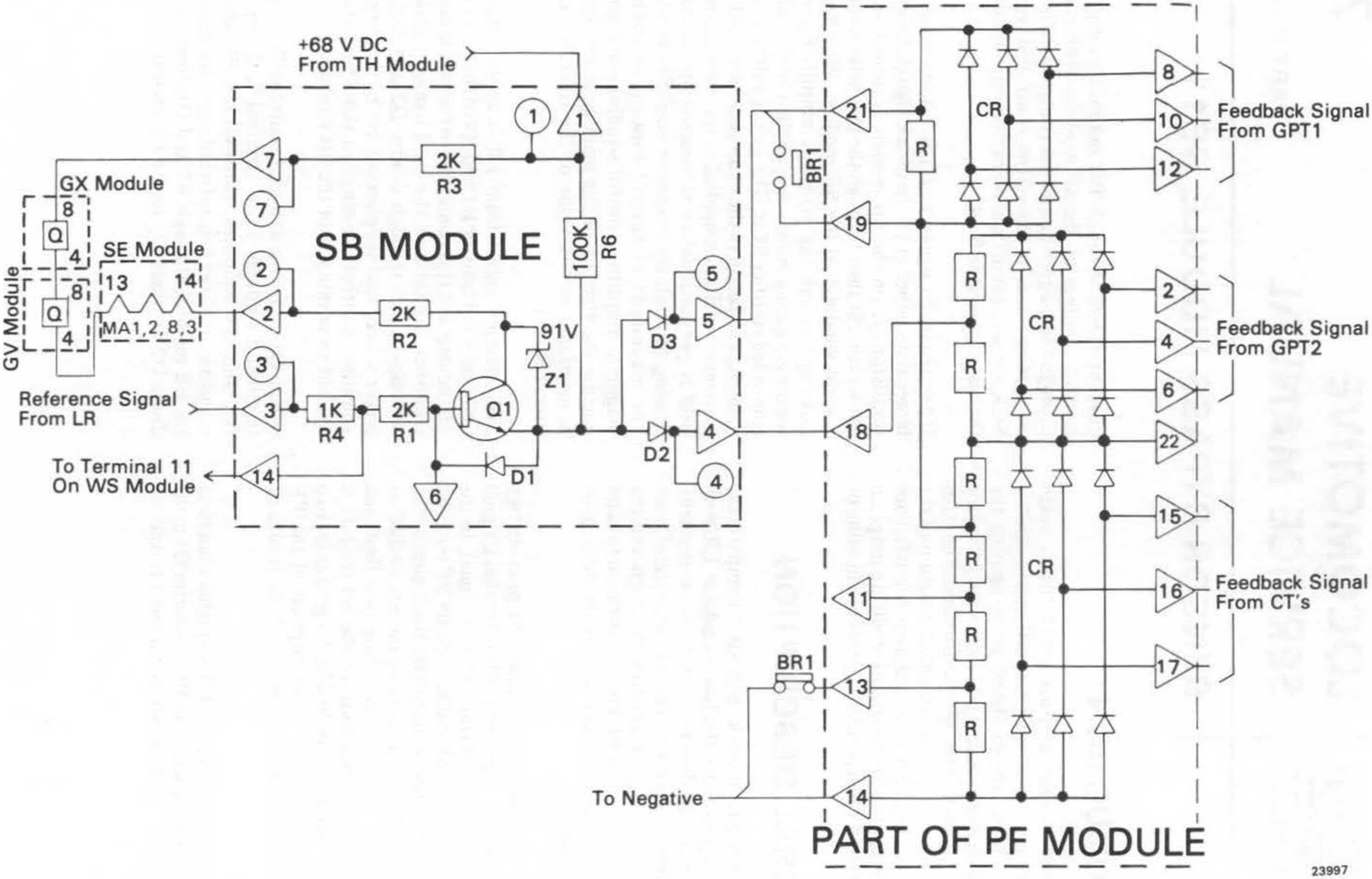


Fig.SB-1 – Sensor Bypass Module, Simplified Schematic Diagram

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 thyristor 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.

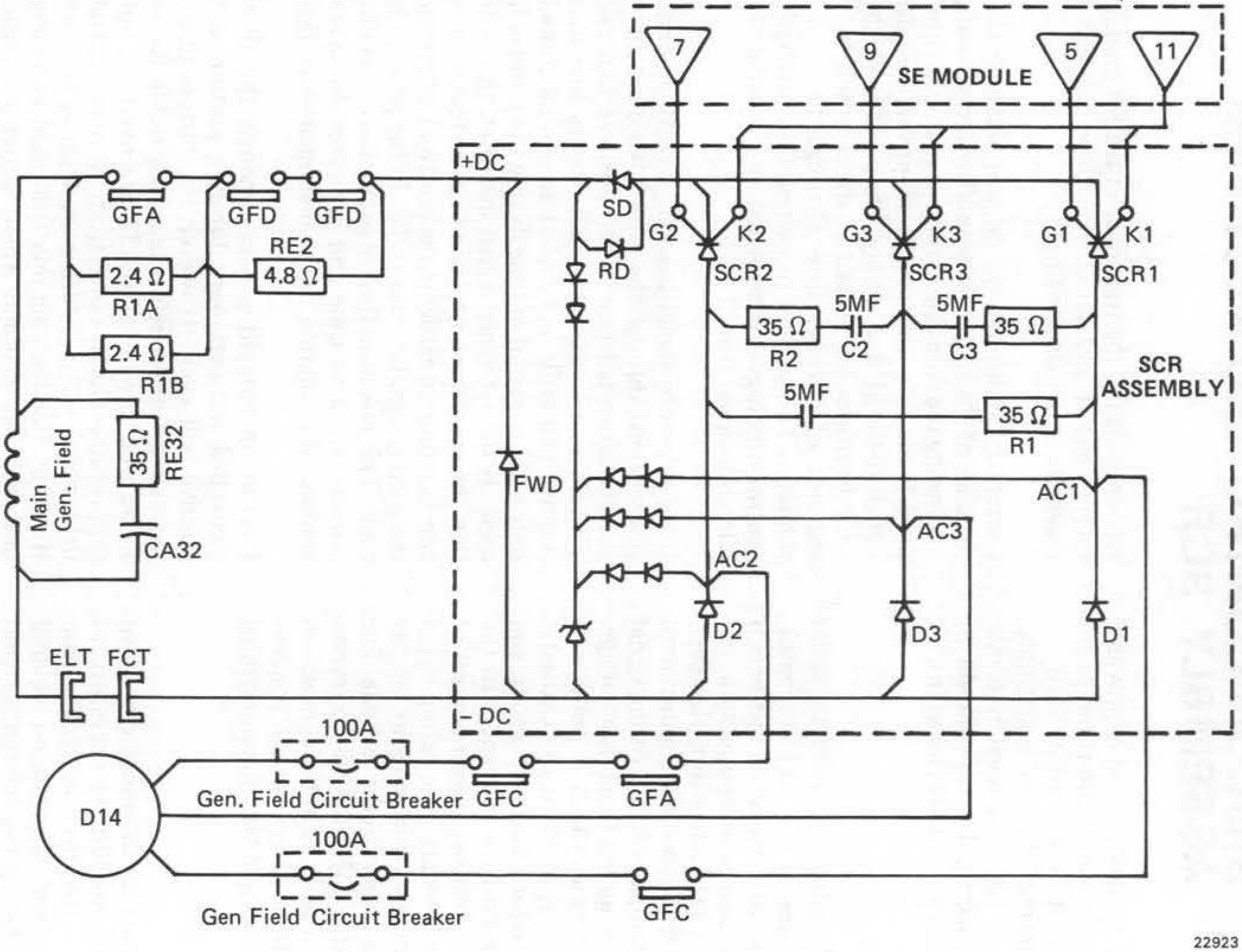


Fig.SCR-1 – SCR Assembly, Simplified Schematic Diagram

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

SENSOR MODULE, SE13 - 9532050

GENERAL DESCRIPTION

The sensor module SE13 controls main generator field excitation current level. Field excitation current is provided by the companion alternator through silicon controlled rectifiers SCR1, SCR2, and SCR3 on the SCR assembly. These silicon controlled rectifiers will not conduct until they are forward biased (anode positive with respect to cathode) and a gating signal is applied to the cathode gate. The gating signal is a voltage, applied to the cathode gate, which is positive with respect to the cathode. After conduction starts, the gating signal loses control, and conduction continues as long as the anode is positive with respect to the cathode. The SE module, Fig. SE13-1, control field excitation current by:

1. Providing the gate signals to the SCR's.
2. Controlling the time in the voltage cycle at which they occur.

Since the SCR's form part of a three-phase diode bridge, each SCR is not forward biased continuously, but only during the positive half of one phase plus a small portion of the succeeding phase. To allow SCR conduction, the gate pulse must also

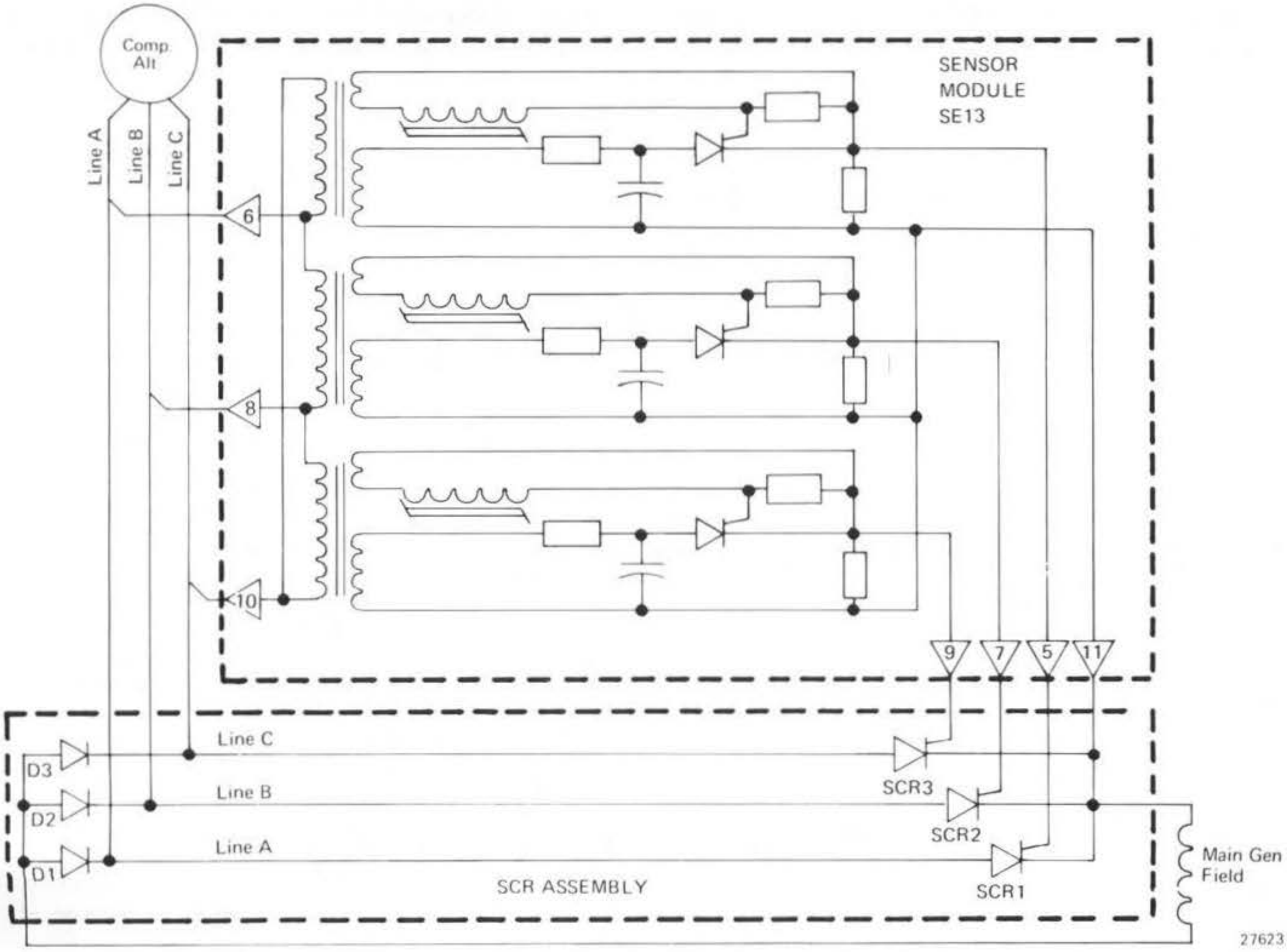


Fig.SE13-1 – SCR Assembly Gate Control Block Diagram occur during this time. The time the SCR is forward biased, is fixed. Therefore, changing the point at which the gate pulse appears, results in changing the average amount of current flow through the SCR, and likewise through the main generator field. An early gate pulse allows conduction for a long period of time resulting in some average current level. A late gate pulse, however, allows conduction for a shorter period of time resulting in a lower average current level.

Since the SE module consists of three identical channels, one for each SCR, only one channel, Fig. SE13-2, is described.

The SCR gate pulse from the SE module to SCR1 in the SCR assembly is the voltage developed across resistor R61. This voltage is present only when SCR1 (in SE) is turned on, providing a path for current flow from transformer T1 terminals 1 and 2. Turn-on of SCR1 (in SE) is controlled by operation of magnetic amplifier M1. Current flow through the magamp control windings drives the magamp core into saturation. Saturating the core allows current to flow through D31, R51, and R31, causing turn-on of SCR1 (in SE). The point in time, at which the core becomes saturated, is determined by the amount of current flow through the magamp control winding. This current level is regulated by the FP module.

The amount of main generator field excitation required is determined by comparing the reference signal from the load regulator (LR) with feedback signals from the feedback performance (FP) module. When the LR reference signal is larger than a feedback signal, a transistor in the FP module is turned on, providing a path for current flow through the magamp control windings. The amount of current is related to the difference between the reference signal and the feedback signal.

When a small difference exists between the reference signal and the feedback signals, a low current level flows in the magamp control windings. This low current level results in core saturation being reached and the gate signal being developed near the end of SCR forward bias time. Therefore, main generator field current flows for only a short period of time, resulting in a low average field current level. A greater difference between the reference signal and feedback signals results in a higher current level in

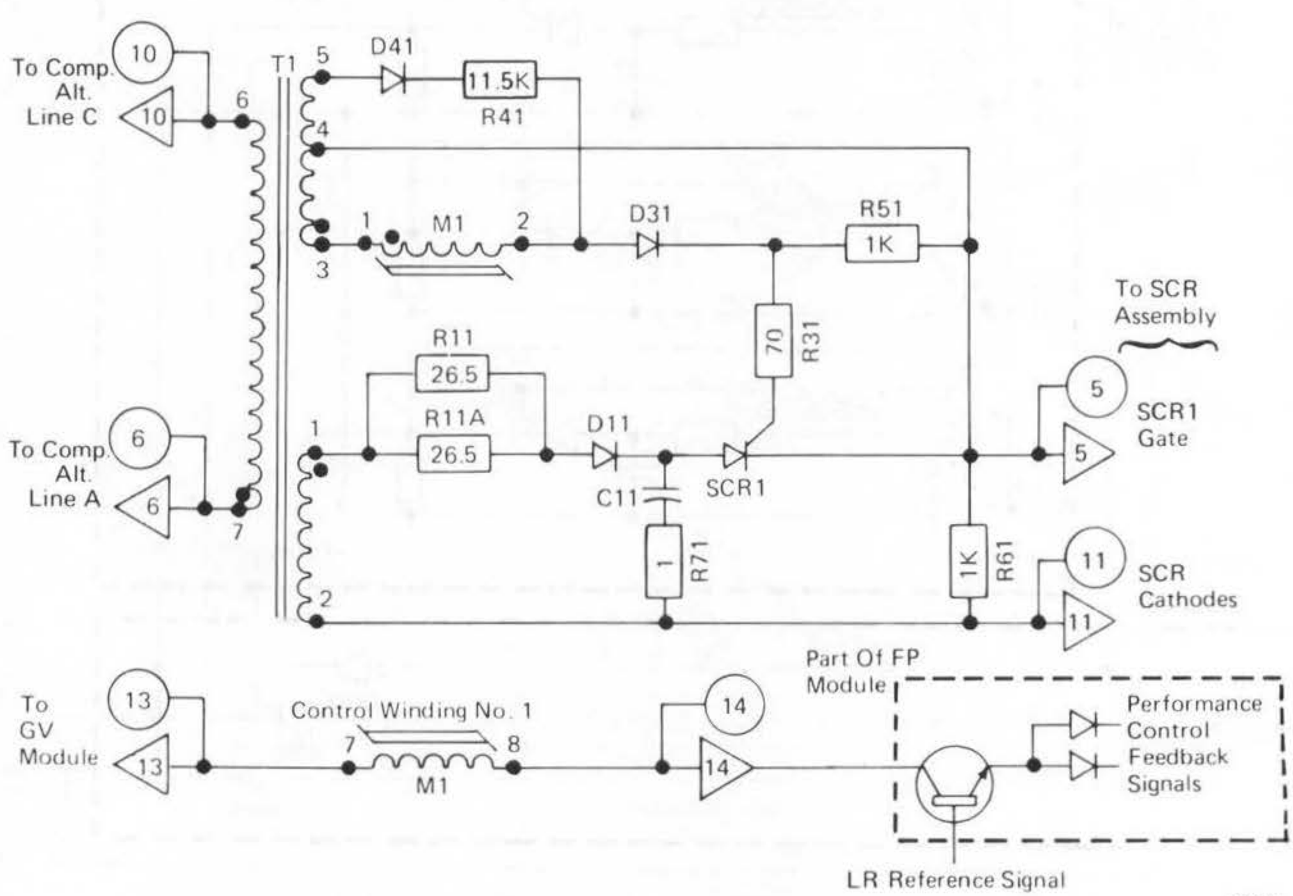


Fig.SE13-2 – SE13 Partial Schematic Diagram the magamp control winding, earlier core saturation, earlier SCR turn-on and, as a result, a higher average main generator field excitation current level.

During dynamic braking, a second magamp control winding is connected across the main generator output voltage. The resulting current flow through this winding opposes the core saturation effects of control winding 1 causing the main generator to operate at a lower output level during braking.

A simplified schematic diagram of the SE module, Fig. SE13-15, is provided later in this section for convenient reference. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance.

SE/SCR ASSEMBLY DETAILED OPERATION

The three-line, three-phase output of the companion alternator, Fig. SE13-3, is applied to the SCR assembly bridge, and results in the SCR's being forward biased (anode positive with respect to cathode) in the sequence — SCR1, SCR3, and SCR2.

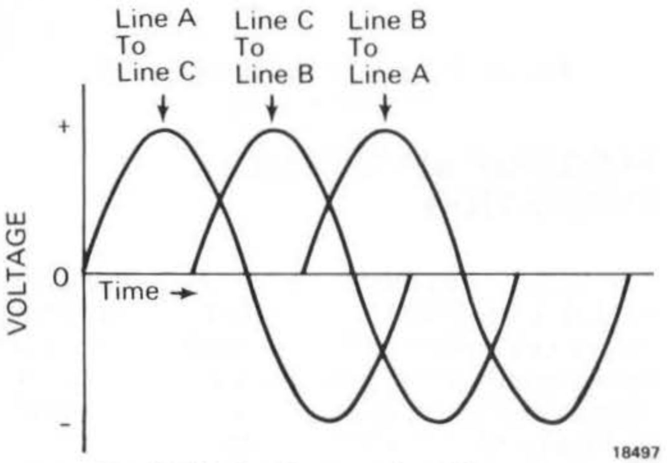


Fig.SE13-3 - Companion Alternator Three-Phase Output

Diodes D1 through D3, Fig. SE13-4, provide two current paths for each SCR. Therefore, each SCR is forward biased by two phases of the line-to-line voltages. For example, SCR1 is connected to lines B and C through diodes D2 and D3.

The instantaneous voltage across SCR1 is therefore the difference in potential of either line A with respect to line C, or line A with respect to line B, whichever is greater. This results in forward bias applied to each SCR for a time period longer than a half cycle, Fig. SE13-5.

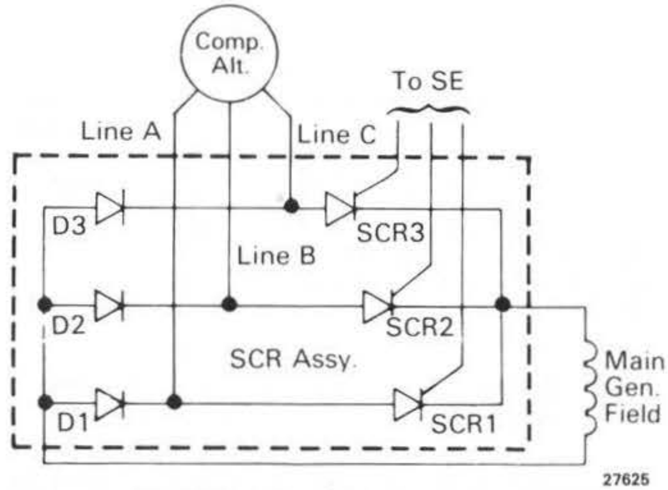


Fig.SE13-4 - SCR Assembly

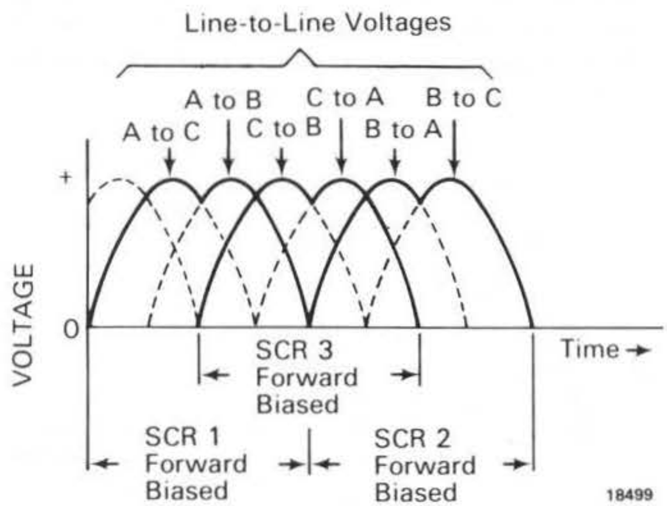


Fig.SE13-5 - SCR Assembly Forward Bias Waveform

The SCR bridge output is connected to the main generator field. Turning on an SCR with a gate pulse allows current to flow through that SCR and the main generator field. If an SCR is gated on at the same time that forward bias is applied, the SCR could conduct for the full forward bias time. With this condition, main generator field current, Fig. SE13-6, is the result of each SCR conducting for the maximum possible time, and field current is at the highest level possible.

The resulting waveshape is due to the commutation characteristics of a three-phase SCR (or diode) bridge circuit. Commutation occurs at the instant one SCR (or diode) stops conducting and another starts. A conducting SCR is essentially a short circuit, therefore its cathode voltage approaches the level of its anode voltage. Since the SCR cathodes are all electrically common, the anode voltage of a

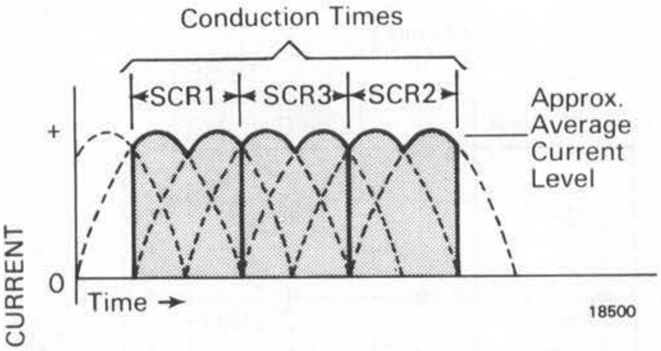


Fig.SE13-6 - Main Generator Field Current With Maximum SCR Conduction

conducting SCR is also present at the cathode of the other SCR's. Until anode voltage of a non-conducting SCR exceeds this value, the SCR's are reverse biased. Therefore, prior to these SCR commutation points in the waveform, Fig. SE13-7, the gating signal has no control over turning on the SCR.

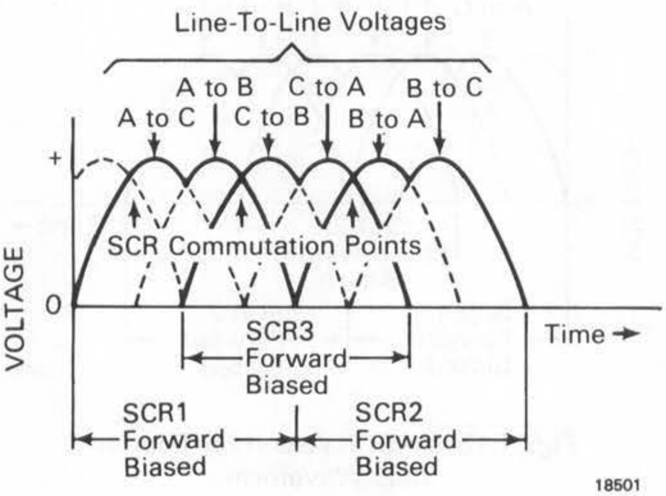


Fig.SE13-7 - Three-Phase Bridge SCR Commutation Points

The function of the SE13 module, to control main generator field excitation current level, is accomplished by delaying the SCR gate signal past these commutation points. Delay SCR turn-on, results in lower average current levels, Fig. SE13-8.

The gate pulse, from the SE module to SCR1 in the SCR assembly, is the voltage developed across resistor R61. This voltage is present only when SCR1 (in SE) is turned on, providing a path for current flow. SCR1 (in SE) is turned on by the gate voltage across R51. Since SCR turn-on is very rapid, the gate signal to the SCR assembly is present at the same time the voltage across R51 reaches SCR1 (in SE) turn-on level. Therefore, controlling the time at which the R51 voltage reaches that level, also controls SCR assembly turn-on delay. This turn-on delay, as described above, determines main generator field excitation current level.

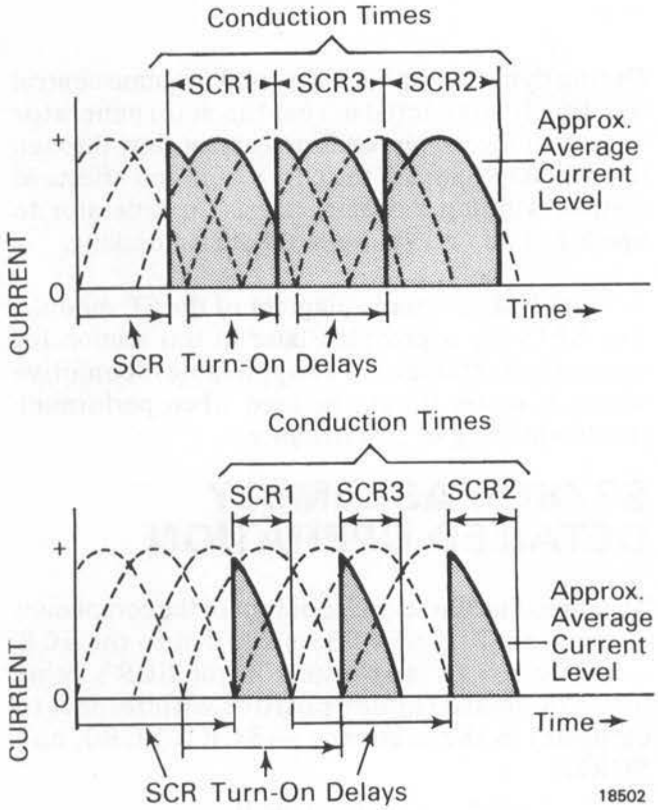


Fig.SE13-8 - Main Generator Field Current Levels

MAGAMP M1 DETAILED OPERATION

The magnetic amplifier, magamp M1, is the device used to control R51 voltage level. The magamp output coil, resistor R51, and diode D31 form a series circuit connected across transformer T1 output winding terminals 3 and 4. The input signal to T1, Fig. SE13-9, is the same line-to-line voltage that provides the leading portion of the forward bias to SCR1 in the SCR assembly.

The magamp output coil presents either a very high or a very low impedance to the input signal. The high impedance results in nearly the entire input signal being dropped across the coil. A low impedance, however, causes nearly the entire input signal to appear across R51.

The coil provides a low impedance if the magnetic core is saturated with flux lines, and the input signal is attempting to produce additional flux in the same direction. The high impedance is presented, however, if the applied voltage is attempting to reverse the direction of flux present in the core.

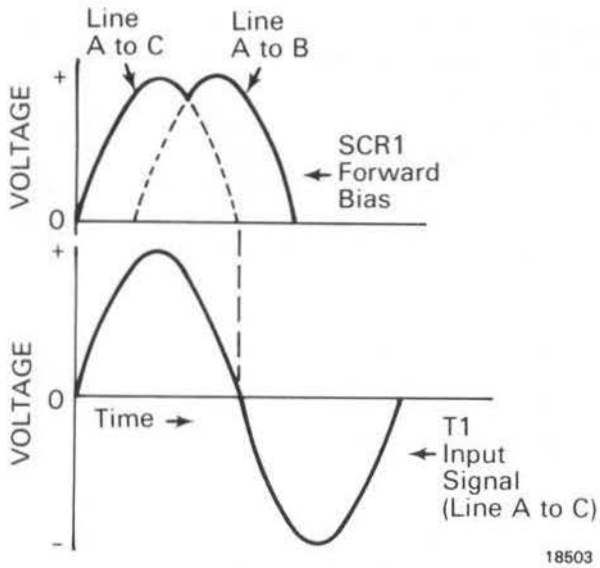


Fig.SE13-9 – SE13 Module Input Voltage

Applying a positive voltage to the output coil, produces a change in flux level in the positive direction. The total amount of flux change is the product of coil voltage and length of time the voltage is present (flux change = volts x time). A graph of total flux change, Fig. SE13-10, produced by a sinusoidal voltage reaches a peak at the end of the positive half cycle.

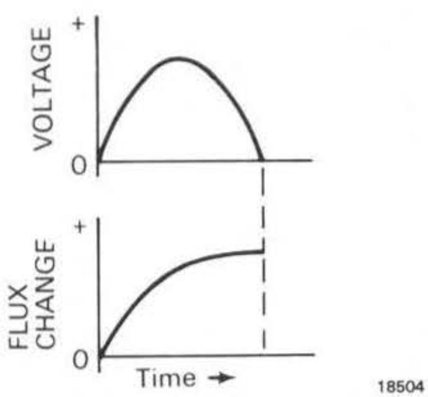


Fig.SE13-10 – Coil Voltage And Flux Change

A typical hysteresis loop, Fig. SE13-11, illustrates the magnetic characteristics of the magamp core.

With core flux density near negative saturation, point A in Fig. SE13-12, the positive input signal is applied. This signal produces a positive flux change to point B. Positive core saturation was not reached, therefore, coil impedance remained high and no voltage appeared across R51. The module input voltage then goes through the negative half cycle, applying the core reset voltage through diode D41 and resistor R41. The reset voltage produces a negative flux change from point C to point D in Fig. SE13-12. With no current flow in the control windings, the magamp continues to operate along this path, and the SCR assembly is not turned on.

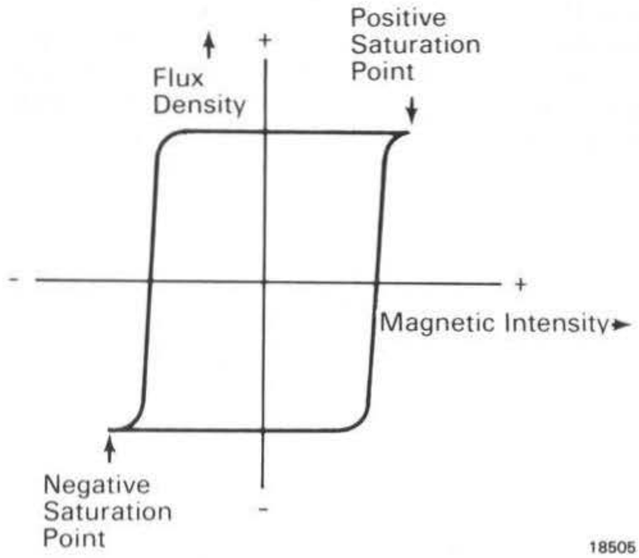


Fig.SE13-11 – Magamp Core Hysteresis Loop

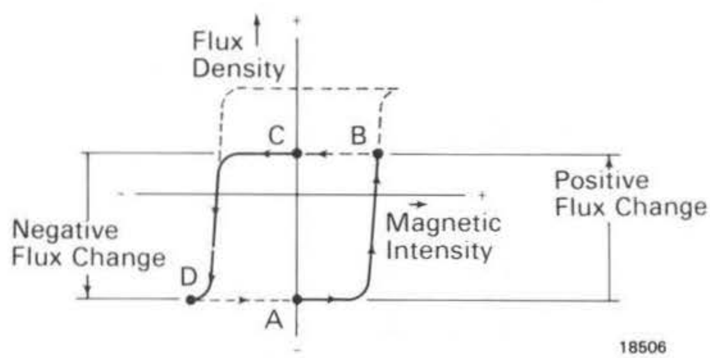


Fig.SE13-12 – Magamp Core Operation - No Control Winding Current

Allowing a positive current flow through the magamp control winding changes the magamp operation. The current flow produces a positive flux change, Fig. SE13-13, from point A to point A^1.

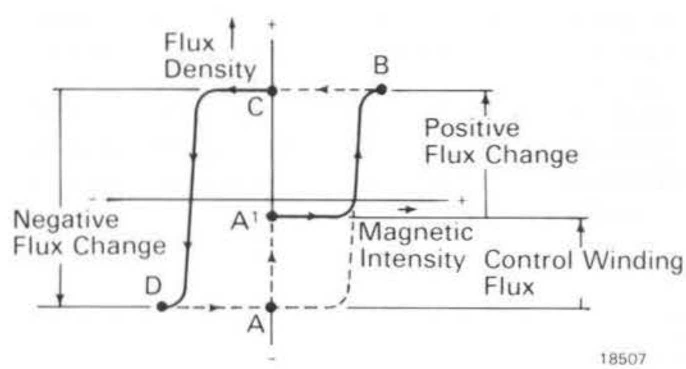


Fig.SE13-13 – Magamp Core Operation - With Control Winding Current

The positive flux change produced by the module input signal now results in core saturation. At the time the core reaches saturation, coil impedance becomes zero and the voltage across it drops to zero, the entire input signal, Fig. SE13-14, is then present across R51, turning on SCR1 (in SE) which produces the SCR assembly gating signal.

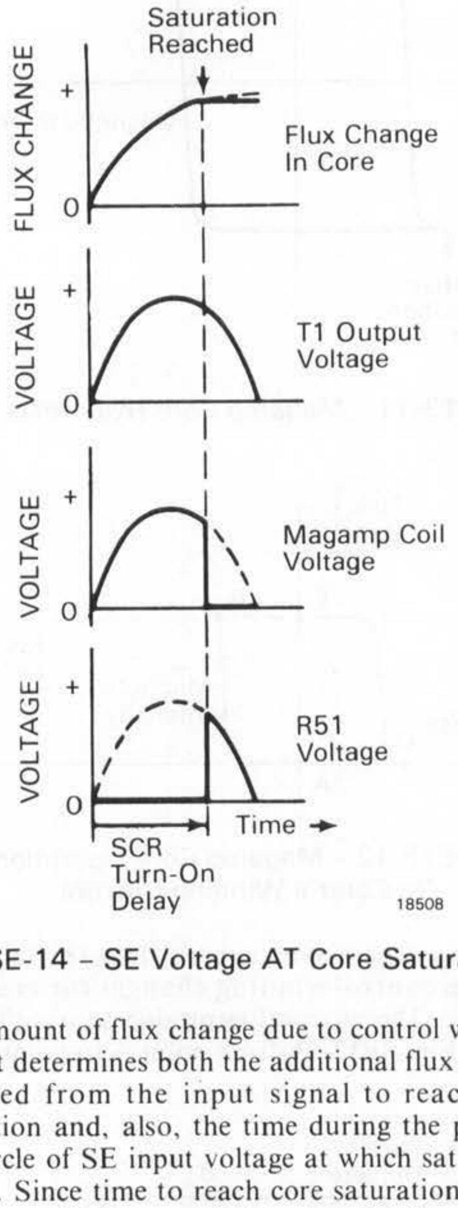


Fig.SE-14 - SE Voltage AT Core Saturation

The amount of flux change due to control winding current determines both the additional flux change required from the input signal to reach core saturation and, also, the time during the positive half cycle of SE input voltage at which saturation occurs. Since time to reach core saturation is also SCR assembly turn-on delay, changing the control winding current also changes this turn-on delay and therefore also changes main generator field excitation current.

Since the core tends to retain the same flux level after the magnetizing force is removed, the reset voltage is required to cause the core to return to some flux density level below positive saturation. At positive saturation, the coil impedance is near zero, and the SCR assembly will continue to be turned on even after the control winding current is removed, unless the reset voltage is provided.

Resistor R71 and capacitor C11 are used to provide a fast rise time for the voltage pulse developed across R61. This fast rise time is desirable to provide a rapid SCR assembly turn-on.

The magamp has three control windings on each core: one connected in series between the sensor bypass (on FP) module and the main generator voltage regulator (GV) module; the second and the third not used.

The current in the winding between the GV and FP modules flows through a transistor in the GV module and a transistor in the FP module. The amount of current flow is dependent on the biasing of these two transistor. The transistor in the FP module is forward biased when the load regulator reference signal is larger than the feedback signal. The transistor in the GV module is forward biased whenever the main generator output voltage is less than the preset maximum level in which the GV module limits.

An increase in current flow through this control winding, as previously described, causes a decrease of the SCR assembly turn-on delay, which increases main generator field excitation. The second winding, connected to the main generator output voltage during braking, is connected such that the current flow through it tends to produce flux lines opposing those produced by the other control winding. An increase in main generator output voltage causes current through this winding to increase. This results in a more stable control during dynamic braking. During braking, the combined effect on the two magamp control windings brings about stable control of the main generator output voltage and current at the low levels required for dynamic braking.

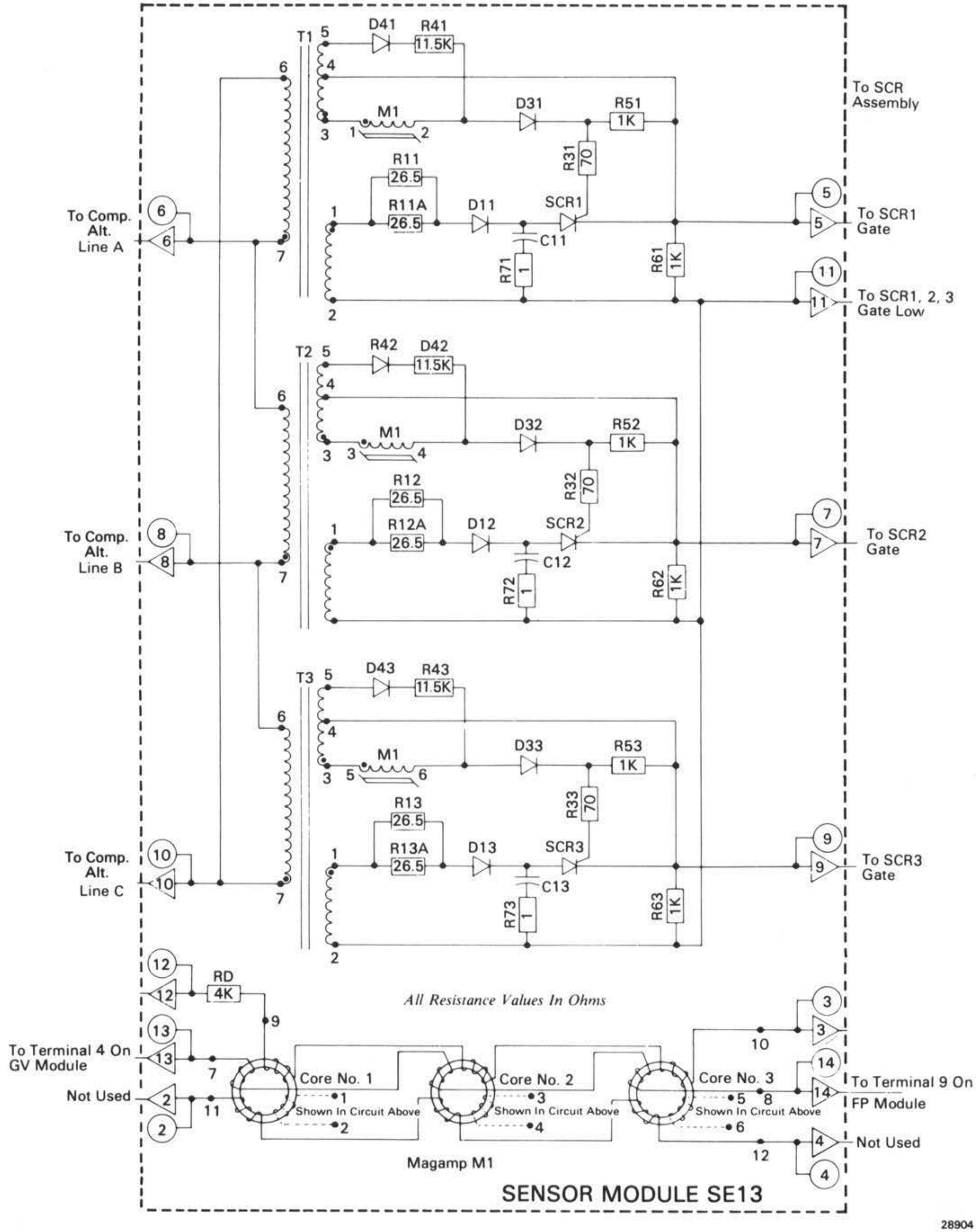


Fig.SE13-15 – Sensor Module SE13 – Simplified Schematic Diagram

VOLTAGE REFERENCE REGULATOR AND THROTTLE RESPONSE MODULE

INTRODUCTION

The voltage reference regulator and throttle response modules TH13 and TH14 contain a voltage 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 response 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 RH11, 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 to 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.

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.

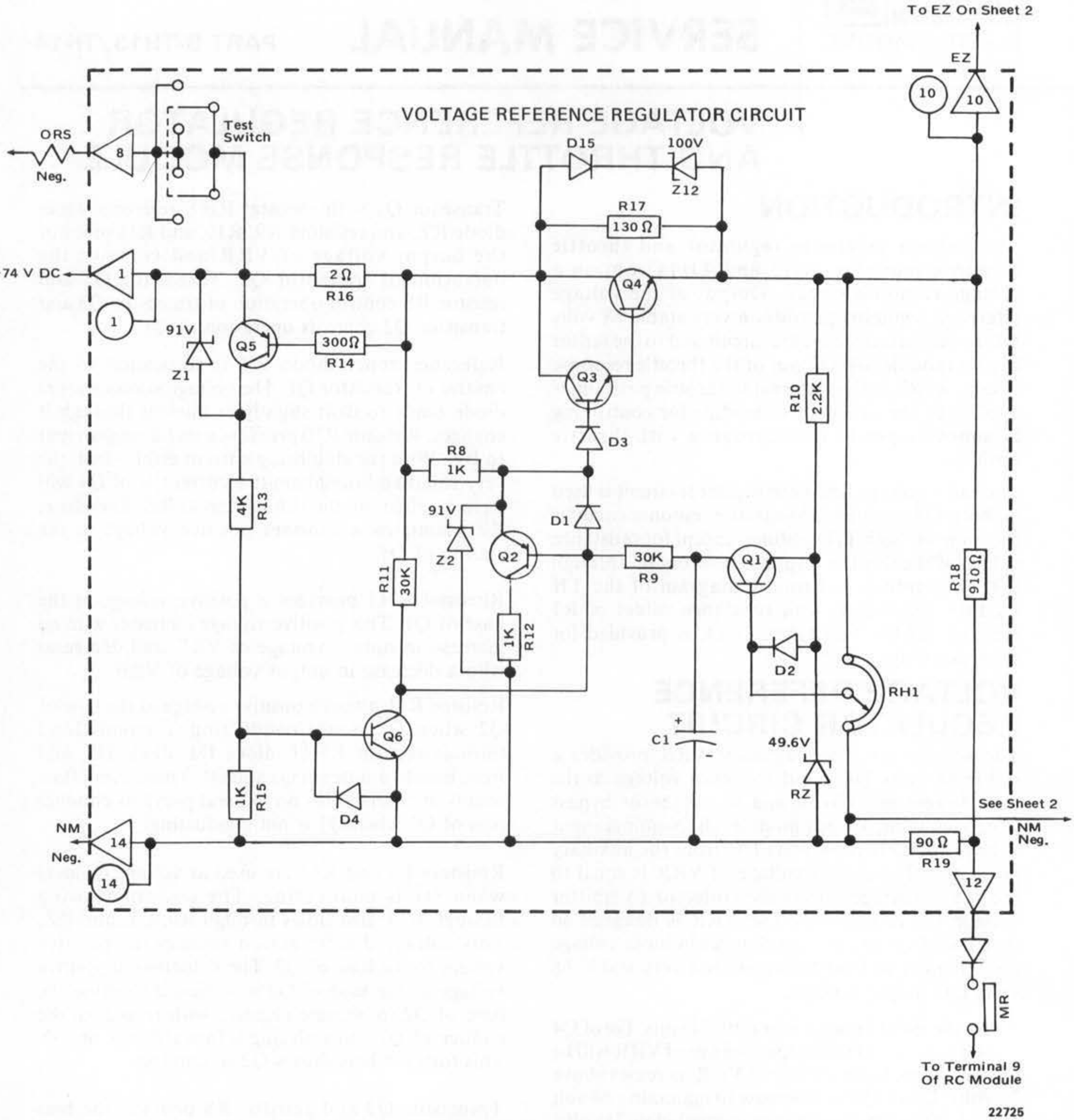
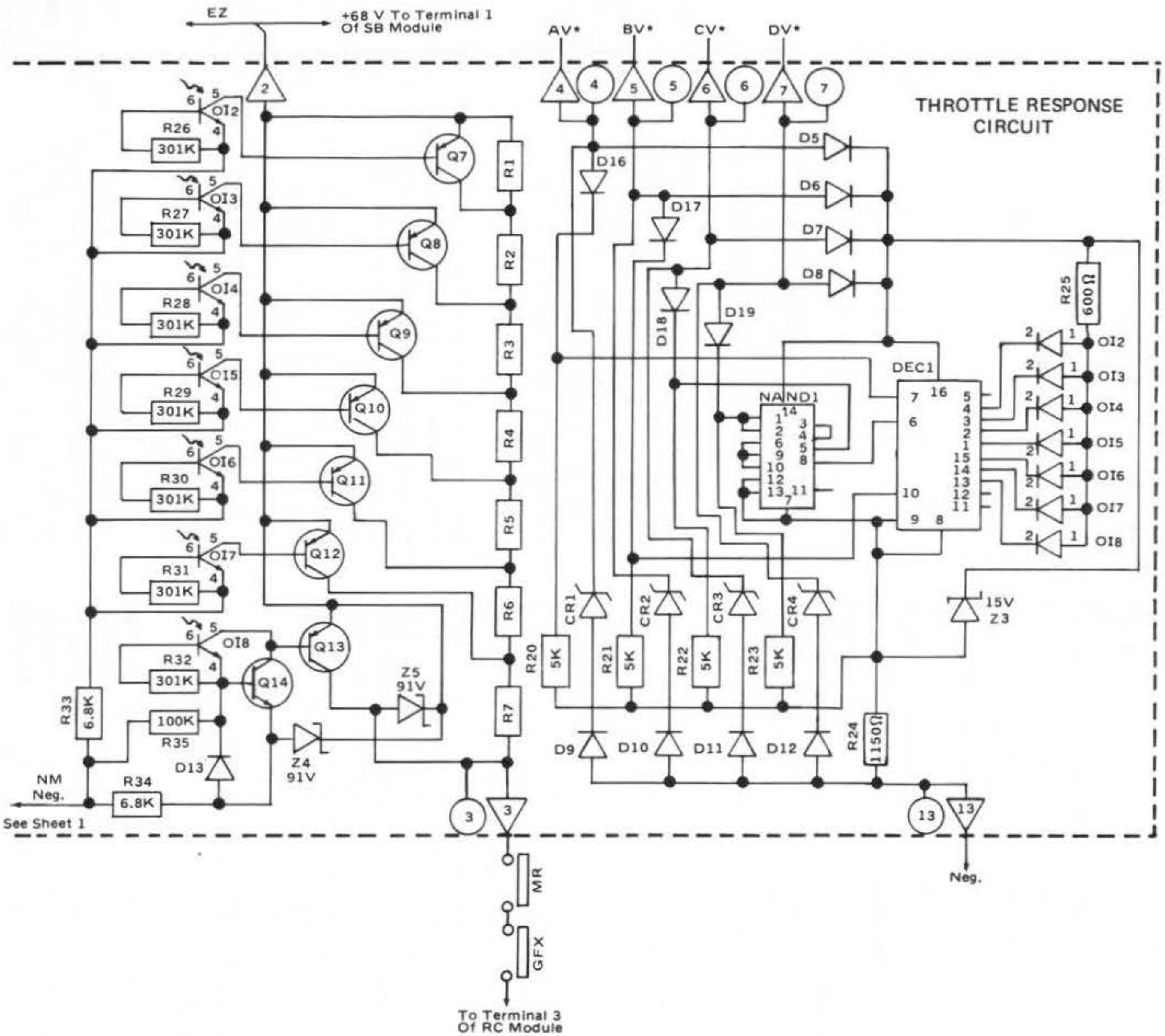


Fig.TH-1 – Voltage Reference Regulator And Throttle Response Module, Simplified Schematic Diagram

(Sheet 1 of 2)



Throttle Response Resistors	Resistance In Ohms	
	TH13	TH14
R1	4248	5180
R2	1058	1155
R3	844	683
R4	354	472
R5	192	336
R6	150	302
R7	103	144

*These terminals are energized with 74V, whenever the specific governor solenoid valve is energized, as determined by throttle position.

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Fig.TH-1 – Voltage Reference Regulator And Throttle Response Module, Simplified Schematic Diagram

(Sheet 2 of 2)

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 Q2 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

Output from the voltage reference regulator portion of the TH module supplies a very stable 68 volts DC to a string of seven resistors connected in series on the throttle response portion of the TH module. This input voltage is modified by the throttle response resistors, as determined by throttle position, and applied to the rate control RC module as a reference for controlling main generator excitation. As throttle position is increased, an increased portion of the resistance from the throttle response resistors is removed, resulting in increased output voltage to the RC module. In throttle position 8, all resistance is removed and the full 68 volts is applied to the RC module.

The relationship of throttle position to throttle response module output voltage is given in Fig. TH-2.

Throttle Position	Governor Solenoids Energized	Approximate Output Voltage TH13 Module	Approximate Output Voltage TH14 Module
STOP	D		
LOW IDLE	AD	0.0	0.0
IDLE	NONE	0.0	0.0
1	NONE	12.5	10.9
2	A	22.5	21.6
3	C	31.2	28.6
4	AC	43.0	35.7
5	BCD	51.2	43.3
6	ABCD	57.3	51.2
7	BC	63.2	61.4
8	ABC	68.0	68.0

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Fig.TH-2 – Relationship Of Throttle Position And Output Voltage Of The Throttle Response Control Circuit

The throttle response circuit consists of two separate sections. The first section provides the logic for determining what position the throttle handle is in. The second section uses the logic to short out the appropriate throttle response resistors, singly or in combination, to control the output voltage to the RC module.

The logic section has four inputs. As the throttle handle is moved, switches in the controller close to energize certain governor speed setting solenoid valves. The four solenoids, AV, BV, CV, and DV determine engine speed, when energized singly, in combination, or none at all. Input terminal 4 of the logic section is connected so that it is energized when the AV solenoid valve is energized. Input terminals 5, 6, and 7 are similarly connected to solenoid valves BV, CV, and DV respectively. Fig. TH2 shows which governor solenoids are energized for each throttle position.

An input or combination of inputs to terminals 4, 5, 6, or 7 represents a binary coded decimal, indicating throttle position. These signals are decoded by the binary coded decimal (BCD) decoder. As shown in Fig. TH-3 only three logic inputs, to the BCD decoder, are necessary to provide one of seven separate outputs representing throttle position.

NOTE

Only throttle positions 2 through 8 are shown as outputs in Fig. TH-3. In throttle position 1 no governor solenoids are energized therefore no input signal is provided to the throttle response circuit. However, the TH module provides a small voltage signal to the RC module equivalent to 68 volts minus the voltage drop provided across the total resistance of all throttle response resistors connected in series.

The three inputs to the BCD decoder are represented as A, B, and C$\overline{D}$. The A input is "on" when governor solenoid AV is energized and the B input is "on" when BV is energized. The C$\overline{D}$ input is "on" when governor solenoid CV is energized but DV is not. This arrangement is possible by feeding the CV and DV inputs to a "NAND" gate integrated circuit. The "NAND" gate output is "on" only when input CV is "on" and the DV input is not. Inputs or a combination of inputs to the BCD decoder and the resulting output is shown in Fig. TH-4.

As shown in Fig. TH-4, for any input or combination of inputs, a single output from the BCD decoder is obtained. This output is used to turn "on" one of the opto-isolators, OI2 thru OI8. Each Opto-isolator consists of a light emitting diode LED and a photosensitive transistor. The LED portion of OI2 is connected to output pin 4 of the BCD decoder. This output is "low" in throttle 2 position. When the output at pin 4 is low, the base of the photosensitive transistor (OI2) is exposed to the light of the LED. This causes collector current to increase. This collector current is applied to the base of Q7 causing Q7 collector current to increase. Increased collector current at this point effectively shorts throttle response resistor R1 out of the circuit. Throttle response module output to the RC module is increased due to the removal of a portion of the throttle response resistance. OI3 thru OI8 are similarly connected to the output of the GCD decoder and the throttle response resistors.

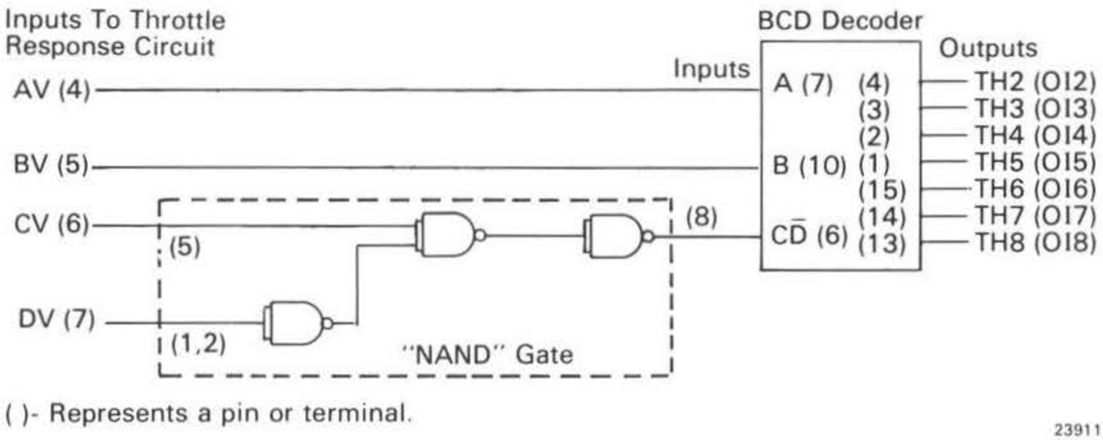

Fig.TH-3 - Simplified Diagram Of Inputs And Outputs Of The BCD Decoder

INPUTS	OUTPUTS						
A B C$\overline{D}$	(OI2) TH2	(OI3) TH3	(OI4) TH4	(OI5) TH5	(OI6) TH6	(OI7) TH7	(OI8) TH8
1 0 0	1	0	0	0	0	0	0
0 0 1	0	1	0	0	0	0	0
1 0 1	0	0	1	0	0	0	0
0 1 0	0	0	0	1	0	0	0
1 1 0	0	0	0	0	1	0	0
0 1 1	0	0	0	0	0	1	0
1 1 1	0	0	0	0	0	0	1

0-Indicates input or output is "off."
1-Indicates input or output in "on."

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Fig.TH-4 - Input To BCD Decoder And Resulting Output

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

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 full parallel across the main generator output. This transition sequence is initiated by the transition module TR12.

This section provides a description of the TR12 module and a step-by-step description of forward transition, simultaneous wheel overspeed correction, and backward transition. A simplified schematic diagram of the TR12 module is provided in Fig. TR-1 for convenient reference. The applicable locomotive wiring diagrams should be used when performing troubleshooting or maintenance of the transition control system.

A signal proportional to main generator output voltage is applied to transformers T1 and T2 on the TR module. Refer to Fig. TR-1. 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 two voltage divider circuits. One voltage divider provides a signal to the base of Q1. The other voltage divider provides a signal to the base of transitor Q3. Therefore, a voltage proportional to main generator output voltage is applied to the base of transitors Q1 and Q3. However, the voltage signal applied to the base of Q3 is larger than the voltage signal applied to the base of Q1.

A signal, from the PF module, proportional to main generator output current is applied to the base of transistor Q6. The absolute maximum value of this signal is less than 50 volts. The emitter of Q6 is connected, through resistor R16, to 74 VDC. Therefore, forward bias is applied to Q6. Turn on of Q6 provides the PF module current feedback signal to the emitter of Q1 and Q3. This signal is larger than the voltage signal applied to the base and results in reverse bias for Q1 and Q3.

As track speed increases the voltage signal increases and the current signal decreases. This results in a decrease of reverse bias on Q1 and Q3. A further increase in speed results in forward bias on Q3. The voltage signal applied to the base of Q3 is higher than that applied to the base of Q1. Therefore, a higher track speed must be attained before forward bias is applied to Q1.

Turn on of Q3 provides forward bias for Q4. Turn on of Q4 provides a feed to the BTR relay on TR12. Pickup of BTR increases forward bias applied to Q3 by recalibrating the voltage divider connected to the base of Q3. This ensures against dropout of BTR until track speed decreases to a lower value than the pickup value. Pickup of BTR also provides a feed to module receptacle 6 which sets up the forward transition sequence.

A further increase in speed results in forward bias on Q1. Turn on of Q1 provides forward bias for Q2. Turn on of Q2 provides a feed to the FTR relay. Pickup of FTR increases forward bias applied to Q1 by recalibrating the voltage divider connected to the base of Q1. This ensures against cycling of FTR during forward transition. Pickup of FTR also provides a feed to FTX at receptacle 7. Pickup of FTX provides a feed to the PR relay which initiates forward transition.

A transition sequence chart is provided in Fig. TR-2. A step-by-step sequence of events during transition is provided in Fig. TR-3.

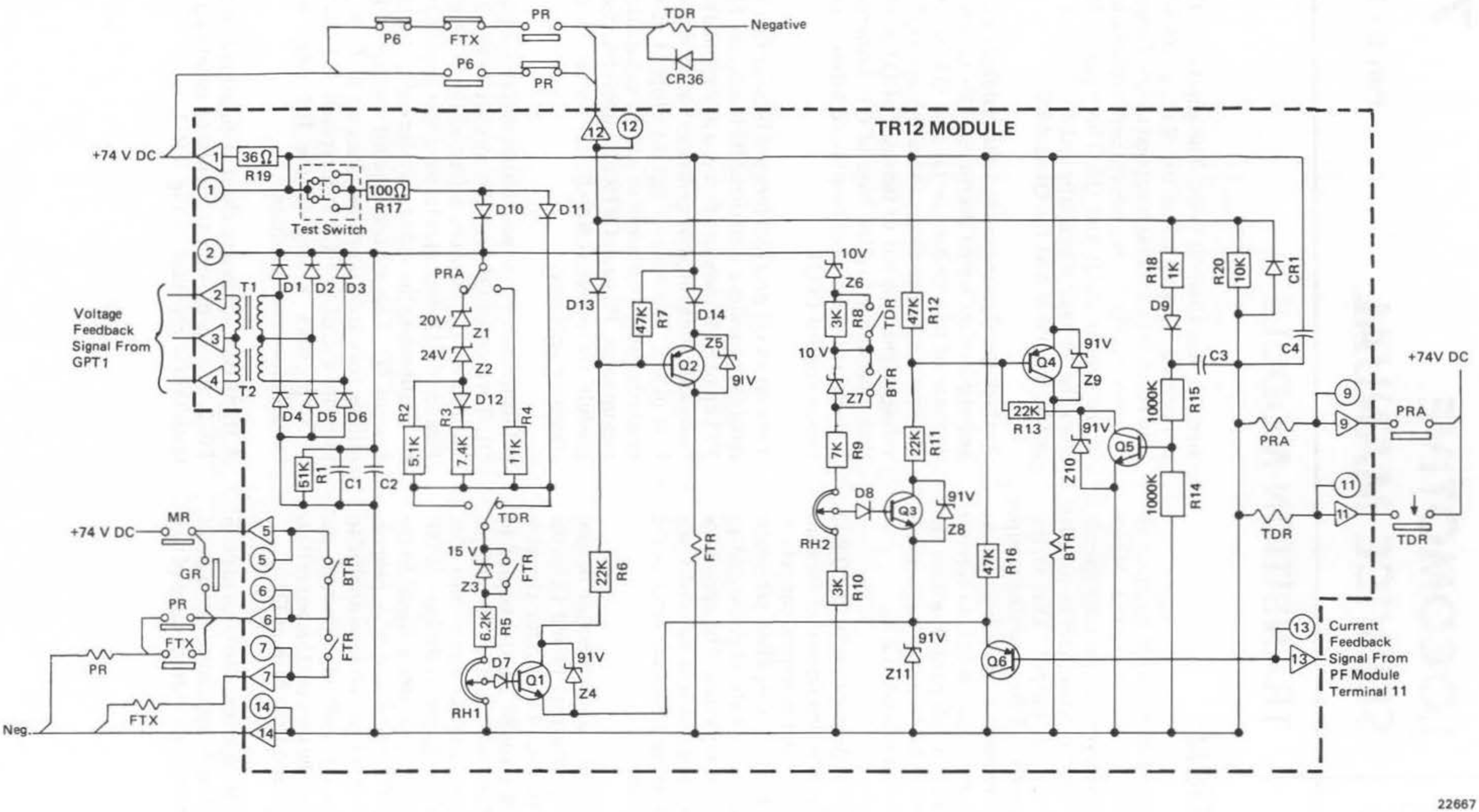


Fig.TR-1 – Transition Module TR12, Simplified Schematic Diagram

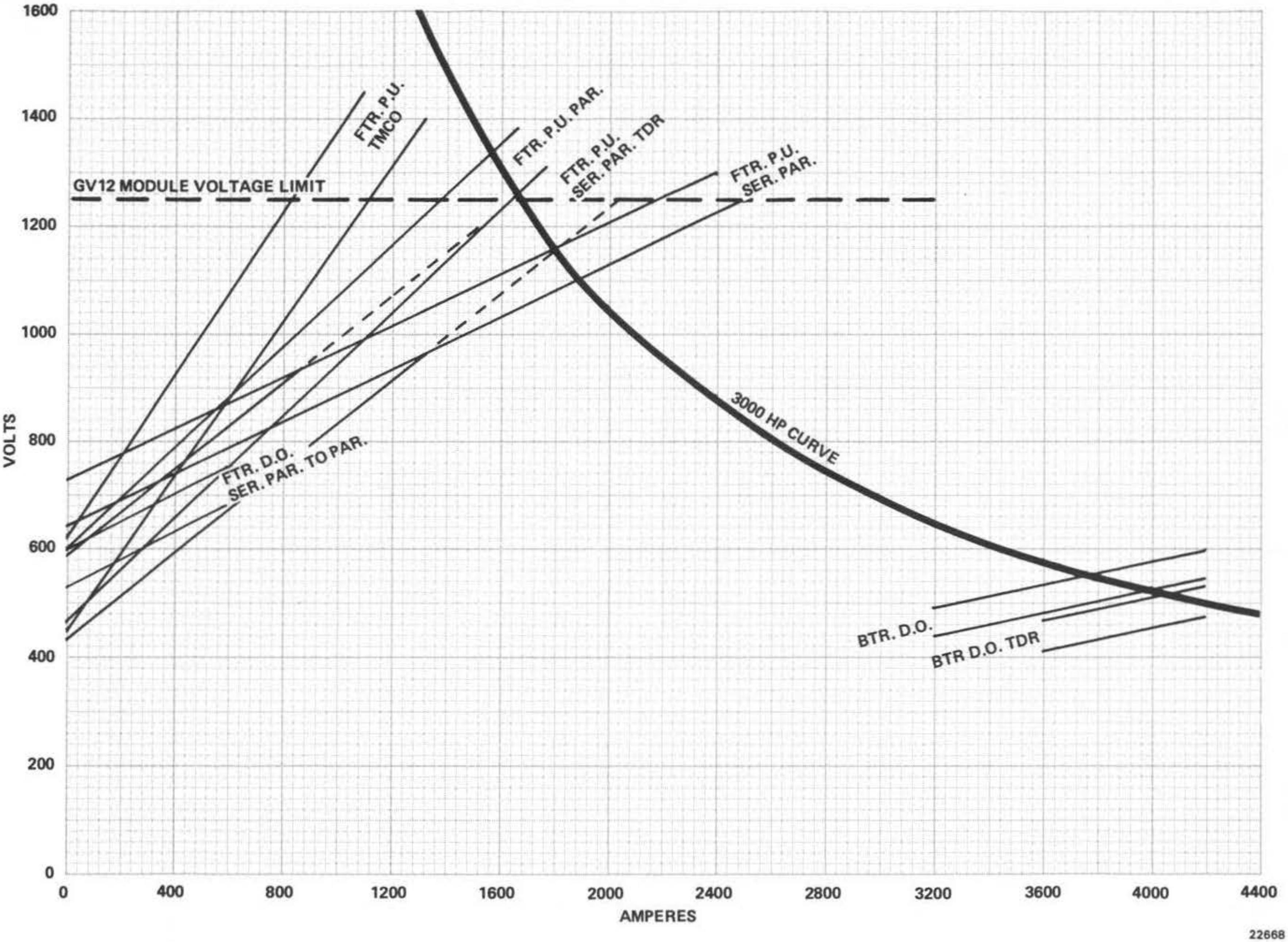


Fig.TR-2 – Transition Sequence Chart

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-3 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 1 of 13)

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 Z6 and Z7, rheostat RH2, and resistors R8, R9, and R10. The base of Q3 is connected, through diode D8, 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 D7, 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 to base of Q6. This signal has a maximum value of +50 VDC, therefore, Q6 is forward biased. Turn on of Q6 applies the main generator output current signal to the emitter of Q1 and Q3. **NOTE** Transistors Q1 and Q3 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 Q3.
8	Increase in track speed results in forward bias on Q3.	Turn on of Q3 provides forward bias for Q4.
9	Forward bias on Q4.	BTR ↑ .
10	BTR ↑ .	Recalibrates the voltage divider that provides forward bias for Q3. 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.	Turn on of Q1 provides forward bias for Q2.

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 2 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
12	Forward bias on Q2.	FTR ↑.
13	FTR ↑.	FTX ↑.
14	FTX ↑.	GFD ↓. Provides holding feed for S14 which prevents drop out of S14 until FTX drops out. PR ↑. Prevents pickup of TDR until FTX drops out. Opens one feed to EQP, but EQP is held in by closed PRA contacts. Contacts provide a feed to WL which results in a wheel slip indication in case of wheel overspeed after forward transition.
15	GFD ↓.	GFC ↓. Inserts resistance in series with main generator field to speed up decay of main generator field.
16	PR ↑ Step 14.	Provides feed to U relay on the WS module. This increases response of wheel slip correction at the higher track speeds. Recalibrates the current feedback signal to terminal 13 of the TR module. Provides feed to the WD relay. Opens main feed to S14, but S14 is held in through S14 and FTX contacts. Sets up circuit for pickup of P1 and P4 after S14 drop out. Provides holding feed to PR, after drop out of FTX, until BTR drops out on backward transition. Sets up circuit for pickup of TDR when FTX drops out. Also sets up circuit to provide forward bias to Q5 on TR module when FTR drops out. Prevents pickup of TDR until FTX drops out.

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 3 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
16 (Cont'd)	PR ↑ .	Sets up circuit for pickup of PRA after P3 picks up. 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.
17	GFC ↓ Step 15.	Disconnects D14 alternator from main generator field. 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.
18	WD ↑ Step 16.	Provides feed between TH module and RC module to prevent discharge of RC module. Opens the circuit between terminal 6 of the RC module and terminal 20 of the WS module. This prevents discharge of the RC module during transition. Ensures against operation of the WS module until forward transition has been completed.
19	Main generator output voltage decreases (Step 15)	Decrease in main generator output removes forward bias from Q1 on TR module.
20	Turn off of Q1.	Removes forward bias from Q2 of TR module.
21	Turn off of Q2.	FTR ↓ .
22	FTR ↓ .	FTX ↓ . Drop out of FTR increases reverse bias on Q1 by recalibrating the voltage divider at the base of Q1. This ensures against pickup of FTR during forward transition.
23	FTX ↓ .	GFD ↑ . This sets up the circuit to the GFC relay and also shorts out the resistance in series with the main generator field. S14 ↓ .

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 4 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
23 (Cont'd)	FTX ↓ .	Drops out main feed to PR, but PR is held in by closed PR contacts. Provides secondary feed to EQP. This prevents drop out of EQP when PRA picks up. Sets up circuit for pickup of WL relay in case of overspeed after transition. TDR ↑ . Provides forward bias to Q5 on TR module. Turn on of Q5 provides forward bias for Q4 which ensures against drop out of BTR during forward transition.
24	TDR ↑ .	Provides feed to TDR relay on TR12 module. Pickup of TDR on TR12 module recalibrates voltage dividers which increases FTR pickup level and decreases BTR drop out level. This ensures against pickup of FTR and drop out of BTR until forward transition has been completed.
25	S14 ↓ .	Disconnects traction motors 1 and 4 from main generator output. P1 ↑ and P4 ↑ . Opens S14 holding contacts.
26	P1 ↑ .	Connects traction motor 1 across main generator output. S25 ↓ and S36 ↓ . Sets up circuit to P2 and P5. Sets up circuit for GFC.
27	P4 ↑ .	Connects traction motor 4 across main generator output. Sets up circuit to P3 and P6. Opens feed to ORS.

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 5 of 13)

Step	Procedure Or Condition	Results Of Procedure Or Condition
28	S25 ↓ Step 26.	Disconnects the WS module WSR relay during parallel motors operation. Disconnects traction motors 2 and 5 from main generator. Ensures against pickup of the B contactor during parallel motor operation. P2 ↑ and P5 ↑ .
29	S36 ↓ Step 26.	Disconnects traction motors 3 and 6 from main generator. Sets up circuit to P3 and P6.
30	P2 ↑ Step 28.	Connects traction motor 2 across main generator. Ensures against pickup of S25 during parallel operation. P3 ↑ and P6 ↑ . Sets up circuit for GFC.
31	P5 ↑ Step 28.	Connects traction motor 5 across main generator. Ensures against pickup of S36 while P5 is energized. Provides holding feed to P2 and P5 through S14 contacts. Provides feed to ORS to move load regulator toward minimum field position which results in smooth reapplication of power after transition.

Fig.TR-3 - Sequence Of Events During Acceleration, Foward Transition, Wheel Overspeed, And Backward Transition (Sheet 6 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
32	P3 ↑ Step 30.	Connects traction motor 3 across main generator. Ensures against pickup of S36 while P3 is energized. GFC ↑ and PRA ↑ . Sets up +74 VDC to WS module.
33	P6 ↑ Step 30.	Connects traction motor 6 across main generator. Provides holding feed to P3 and P6. TDR ↓ . Removes reverse bias from Q2 on TR12 module. This permits FTR to pickup in case of overspeed during parallel motors operation. Removes forward bias from Q5 on TR12 after a short delay. This permits BTR to drop out for backward transition at low track speeds. Sets up circuit for backward transition at low track speeds.

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 7 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
34	GFC ↑ Step 32.	Reconnects D14 alternator to main generator field. GFX ↑ . Drops feed to ORS to allow load regulator to move toward maximum field position.
35	PRA ↑ Step 32.	Provides alternate path to GFD to prevent drop out of GFD in case of overspeed after forward transition. WD ↓ . Provides feed to PRA relay on TR12 module. This recalibrates FTR pickup to desired point for overspeed operation. Sets up circuit to EQP so that EQP will drop out in case of overspeed after transition. Sets up circuit to WL relay so that WL will pick up in case of overspeed after transition.
36	GFX ↑ Step 34.	Maintains feed from TH module to RC module when WD drops out. Disconnects +74 VDC from test circuit input terminal 2 of EL module. Disconnects +74 VDC from test circuit input terminal 22 of WS module. Provides alternate feed to NIR relay. Sets up circuit for dynamic braking.
37	WD ↓ Step 35.	Opens alternate path between TH module and RC module. The path is completed through GFX contacts. Reconnects RC module terminal 6 to WS module terminal 20 for wheel slip correction. Reapplies +74 VDC to WS module terminal 1.
38	TDR ↓ Step 33.	Drops feed to the TDR relay on the TR12 module after a short time delay. This results in recalibrating the voltage dividers that are connected to the base of Q1 and Q3. This allows BTR to drop out to initiate backward transition at low track speeds and allows FTR to pickup in case of wheel overspeed.

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 8 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
	SIMULTANEOUS WHEEL OVERSPEED	
39	A simultaneous wheel overspeed condition resulting from excessive track speed or from a simultaneous wheel slip provides forward bias to Q1 on the TR12 module.	Q1 turn on provides forward bias for Q2.
40	Forward bias to Q2.	FTR ↑.
41	FTR ↑.	FTX ↑.
42	FTX ↑.	EQP ↓.
		WL ↑. This provides a wheel slip indication on the indicator light panel.
43	EQP ↓.	Provides discharge path for RC capacitors.
		GFC ↓.
44	GFC ↓.	Disconnects the D14 alternator from the main generator field.
		GFX ↓. This opens the feed between the TH and RC modules.
		Provides a feed to ORS to drive the load regulator toward minimum field position. This provides for smooth reapplication of power when operation is restored.
		NOTE Reduced excitation 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.

Fig.TR-3 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 9 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
	BACKWARD TRANSITION	
45	Assume that traction motors are connected in parallel across main generator and track speed decreases to a low value.	Main generator voltage decreases and current increases. This results in reverse bias to Q3 on the TR12 module.
46	Reverse bias to Q3.	Removes forward bias from Q4. This results in drop out of BTR.
47	BTR ↓ .	PR ↓ (643). Recalibrates voltage divider connected to base of Q3 on TR12 module.
48	PR ↓ .	Removes the feed from the U relay on the WS module. Opens the recalibration circuit to terminal 13 of the TR12 module. Sets up circuit for pickup of S14. P1 ↓ and P4 ↓ . Drops holding feed to PR. TDR ↑ . Provides forward bias for Q5 on the TR12 module. This results in forward bias to Q4. Turn on of Q4 results in pick up of BTR. Provides reverse bias for Q2 on the TR12 module. This ensures against pickup of FTR during backward transition. Sets up circuit for pickup of GFC after backward transition. PRA ↓ and GFC ↓ . Maintains +74 VDC to WS module after drop out of P3.

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 10 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
49	TDR ↑.	Provides feed to TDR relay on the TR12 module. This recalibrates the bias to Q3 which prevents drop out of BTR during backward transition and sets up circuit for recalibrating the bias to Q1.
50	PRA ↓ Step 48.	Sets up circuit for drop out of GFD on next forward transition. Sets up circuit for pick up of WD on next forward transition. Drops feed from PRA relay on TR12 module. This recalibrates the bias to Q1 which ensures against pickup of FTR until backward transition has been completed.
51	GFC ↓.	Disconnects D14 alternator from main generator field. GFX ↓. Sets up circuit to ORS to drive load regulator toward minimum field position when P4 drops out. This provides for smooth reapplication of power after backward transition.
52	GFX ↓.	Disconnects RC module from TH module. This removes throttle signal from RC module. Connects +74 VDC to test circuit input terminal 2 of the EL module. Connects +74 VDC to test circuit input terminal 22 of WS module. Removes alternate feed from NIR relay. Disables dynamic braking circuit while GFX is deenergized.
53	P1 ↓ Step 48.	Disconnects traction motor 1 from main generator. S14 ↑. Sets up circuit for drop out of P2 and P6.

Fig.TR-3 – Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 11 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
54	P4 ↓ Step 48.	Disconnects traction motor 4 from main generator.
		Sets up circuit for drop out of P3 and P6.
		Provides feed to ORS to drive load regulator toward minimum field position. This results in smooth reapplication of power after backward transition.
55	S14 ↑ Step 53.	Connects traction motors 1 and 4 across main generator.
		P2 ↓ and P5 ↓ .
		Sets up circuit for feed to GFC after backward transition.
56	P2 ↓ .	Disconnects traction motor 2 from main generator.
		S25 ↑ .
57	P5 ↓ Step 55.	Disconnects traction motor 5 from main generator.
		Sets up circuit for feed to S36.
58	S25 ↑ Step 56.	Connects WS module WSR relay for wheel slip detection during series parallel operation.
		Connects traction motors 2 and 5 in series across main generator.
		Sets up circuit for dynamic braking during series parallel operation.
		P3 ↓ and P6 ↓ .
59	P3 ↓ .	Disconnects traction motor 3 from main generator.
		S36 ↑ .
60	P6 ↓ Step 58.	Disconnects traction motor 6 from main generator.
		TDR ↓ . This recalibrates the bias for Q1 and Q3 on the TR12 module.
61	S36 ↑ Step 59.	Connects traction motor 3 and 6 in series across main generator.
		GFC ↑ .

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 12 of 13)

Step	Procedure Or Condition	Result Of Procedure Or Condition
62	GFC ↑.	Connects D14 alternator to main generator field. GFX ↑. Removes feed from ORS to allow load regulator to move toward maximum field position.
63	GFX ↑.	Reconnects output from TH module to RC module. Disconnnects +74 VDC from test circuit input terminal 2 of EL module. Disconnects +74 VDC from test circuit input terminal 22 of WS module. Provides alternate feed to NIR relay. Sets up circuit to enable dynamic braking during series parallel operation. **NOTE** Locomotive is now operating with series-parallel motor connections.

Fig.TR-3 - Sequence Of Events During Acceleration, Forward Transition, Wheel Overspeed, And Backward Transition (Sheet 13 of 13)

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 during series-parallel operation. Therefore, a wheel slip bridge circuit is provided for detecting wheel slip conditions of this nature. The wheel slip bridge circuit on six axle 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 four axle 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 in this section.

The sanding module SA, upon receiving a signal from the WS module, inititates 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.

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 manually to the SA module by operating the MANUAL SAND lever, or may be applied automatically by the emergency sanding switch or the WS module. Sand may be applied to the rails in front of the lead truck by manually closing the LEAD TRUCK SAND switch.

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 trouble-shooting or maintenance.

AUTOMATIC SANDING INITIATED BY SIGNAL FROM THE WS MODULE

The RAB relay on 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. Pickup of RAB applies 74 VDC to terminal 19 of the WS module. Terminal 19 of the WS module is connected, through a diode, to terminal 2 of the SA module. Therefore, pickup of RAB provides 74 VDC to terminal 2 of the SA module.

The signal from terminal 2 of the SA module is applied to a voltage divider consisting of resistor R12, diode D8, capacitor CA4, and resistor R16. The signal available at the junction of R12 and D8 is applied, through diode D7, to the base of transistor Q5. This provides forward bias for Q5. Turn on of Q5 provides a positive potential to the base of Q3. However, R5 and zener diode Z5 provide a positive potential of 16 volts to the emitter of Q3. Therefore, the positive potential at the base of Q3 must be greater than 16 volts in order to provide forward bias to Q3. A timing circuit consisting of R12, R16, and CA4 provides a time delay of approximately 45 milliseconds in turn on of Q3. This short time delay reduces the possibility of unnecessary sanding when operating over rough track.

Turn on of Q3 provides a path for current flow through D3, R4, R6, from collector to emitter of Q3, then through Z5 to negative. Turn on of Q3 also provides a path for current flow through D4, from emitter to collector of Q4, through R15, RH1, R13, collector to emitter of Q5, then through R10 and R9 to negative. Zener diodes Z4 and Z5 limit the voltage at the junction of R15 and RH1 to positive 31 volts with respect to negative.

The voltage developed across R4 provides forward bias for Q2. Turn on of Q2 provides a path for current flow from emitter to collector of Q2, then through R2 and R3 to negative. The voltage developed across R2 and R3 provides forward bias for Q1 and the voltage developed across R3 maintains forward bias on Q3 after Q5 turns off.

Turn on of Q1 provides a path for current flow from collector to emitter of Q1, then through D15 to terminal 3 of directional sanding relay DSR and through D15 and D18 to terminal 9 of DSR. Turn on of Q1 also provides a feed to the sanding light located on the module. If the reverser is set for forward operation, a feed is provided from terminal 9 of DSR to magnet valve 1 sand forward MV1-SF and from terminal 3 of DSR to magnet valve 2 sand forward MV2-SF. If the reverser is set for reverse operation, a feed is provided from terminal 9 of DSR to magnet valve 2 sand rear MV2-SR and from terminal 3 of DSR to magnet valve 1 sand rear MV1-SR.

Forward bias is removed from Q5 when the sanding signal is removed from terminal 2. Turn off of Q5 allows CA3 to charge through D4, Q4, R15, RH1, R13, R11, R10 and R9. The charge on CA3 is applied to the emitter of Q6. The potential on base 1 of Q6 is maintained at 16 volts by Z5. Therefore, the charge on CA3 must be more than 16 volts in order to provide forward bias for Q6. The value of CA3, R15, RH1, R13, R10, and R9 are selected so that forward bias will be applied to Q6 within approximately 3 to 5 seconds after the sanding signal is removed from terminal 2. The charging time of CA3 may be changed by adjusting RH1. Turn on of Q6 allows CA3 to discharge from emitter to base 1 of

Q6, through D6, R10, and R11. Current flow through D6 provides reverse bias to Q3. Turn off of Q3 removes forward bias from Q2. Turn off of Q2 removes forward bias from Q1. Turn off of Q1 removes the feed from the sanding valves. Therefore, the magnet sanding valves will be energized for 3 to 5 seconds after the sanding signal is removed from terminal 2.

AUTOMATIC SANDING INITIATED BY SIGNAL FROM THE EMERGENCY SANDING SWITCH

The emergency sanding switch ESS is an air operated switch which closes during an emergency application of the brakes. Closing of ESS contacts provides a sanding signal to terminal 6 of SA module. This signal passes through diodes D11 and D12 to terminals 12 and 13. From terminals 12 and 13, the signal is applied to magnet sanding valves MV1-SR and MV2-SF. The signal is also applied to terminals 10 and 11. From terminals 10 and 11 the signal passes through diodes D19 and D20 to MV1-SF and MV2-SR. Therefore, an emergency application of the brakes provides a sanding signal to all magnet sanding valves. The sanding valves are de-energized as soon as the emergency sanding switch ESS opens. The emergency sanding signal applied to terminal 6 may be trainlined so that the emergency sanding signal will be applied to terminal 6 of SA modules in all other locomotives in the consist.

MANUAL SANDING

When the MANUAL SAND lever is operated, the sanding signal is applied to terminal 3 of the SA module. From terminal 3, the signal passes through diode D17 to terminal 3 of the DSR relay and through diodes D17 and D18 to terminal 9 of the DSR relay. The signal from terminal 3 also passes through diode D16 to terminal 6 of the DSR relay. If the reverser is set for forward operation, the signal passes from DSR terminal 9 to 7, 3 to 1, and 6 to 4. The signal at DSR terminal 7 provides a feed to the MV1-SF. The signal at DSR terminal 1 provides a feed to MV2-SF, and through D19 to MV1-SF. The signal at DSR terminal 4 provides a feed to MV2-SF and through D19 to MV1-SF. If the reverser is set for reverse operation, the signal passes from DSR terminal 9 to 8, 3 to 2, and 6 to 5. The signal at DSR terminal 8 provides a feed to MV2-SR. The signal at DSR terminal 2 provides a feed to MV1-SR and through D20 to MV2-SR. The signal at DSR terminal 5 provides a feed to MV1-SR and through D20 to MV2-SR. Redundant circuits are used during manual sand operation to increase reliability. The signal from terminal 3 of SA module is applied through D10 to terminal 7. Terminal 7 may be connected to a manual sand light to indicate that the manual sand signal is applied to the SA module. The signal applied to terminal 3 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.

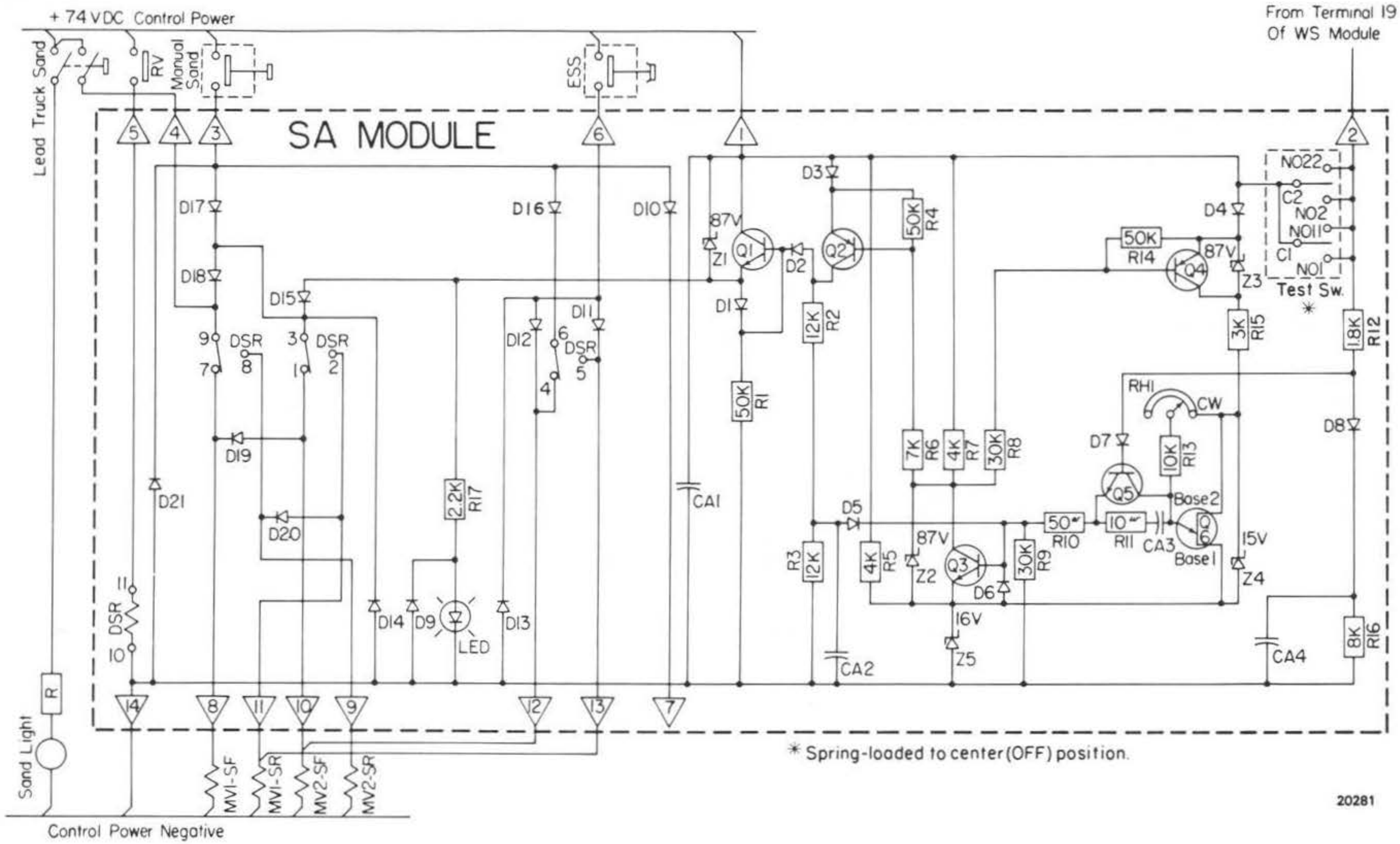


Fig. 7-SA1 - SA Module, Simplified Schematic Diagram

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. 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. 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, bridge rectifier consisting of D5, D6, D7, and D8, 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 D5, D6, D7, and D8. Zener diode Z1 regulates the DC voltage at 50 volts and capacitor C4 filters the output.

Minor differences in wheel diameter and wheel slip transductor magnetizing current cause the wheel slip transductors to provide a small and essential steady signal between terminal 8 and terminal 21 of the WS module during normal operation. This small signal is blocked by zener didoes Z4 and Z5. Zener diodes Z4 and Z5 block all signals below 16 volts. This blocking action helps prevent small noise signals from inducing wheel slip corrective action. A signal is applied to transformer T1 when the input signal between terminal 8 and terminal 21 rises above 16 volts. The output signal from T1 is rectified and filtered, then 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 available at the wiper arm of RH1 is applied, through capacitor C3, to diodes D17 and D18. A small steady state signal is not sufficient to cause conduction of D17 and D18, 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 and 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.

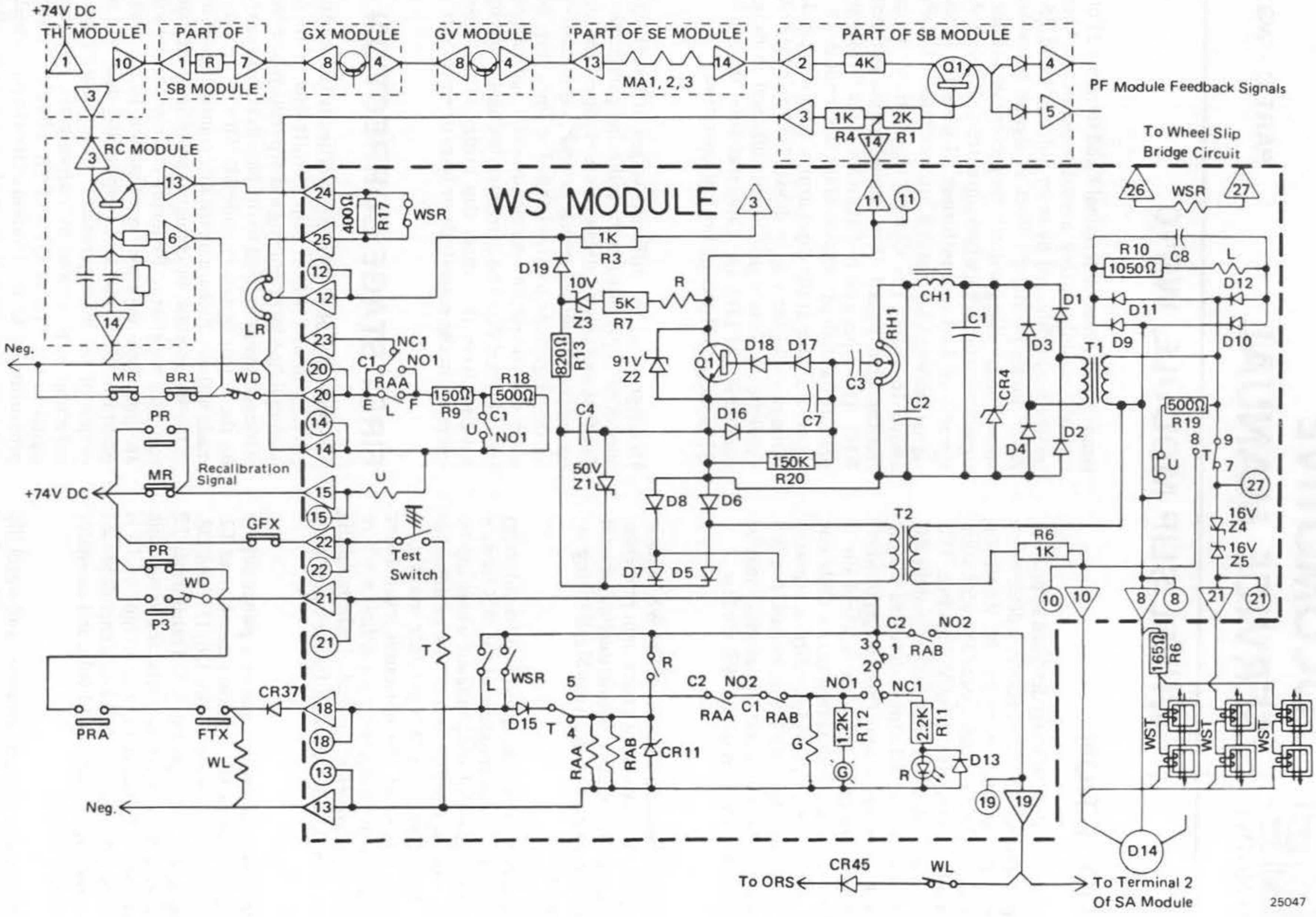


Fig.WS-1 – Wheel Slip Module, Simplified Schematic Diagram

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 D19 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, ORS is energized, 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 ORS and to the SA module which results in application of sand to the rails and drives the load regulator toward minimum field position. Discharging the rate control capacitors and energizing ORS 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. Dropout of RAB also removes the feed from ORS.

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 except a feed is not provided to ORS. 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 a slip persists, the three stages of correction are repeated. The wheel 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

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 when operating under power with series-parallel motor connections and 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 pickup of the WSR relay during simultaneous wheel slip of all wheels on the front truck or on the rear truck.

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 and opens the circuit between terminal 19 of the WS module and ORS. 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. The recalibration signal is provided by pick up of the PR relay, Fig. WS-2.

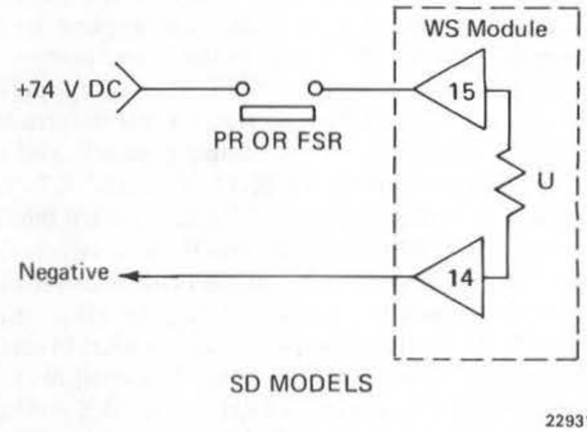


Fig.WS-2 - Application Of Recalibration Signal To WS Module

SIMULTANEOUS WHEEL OVERSPEED CORRECTION

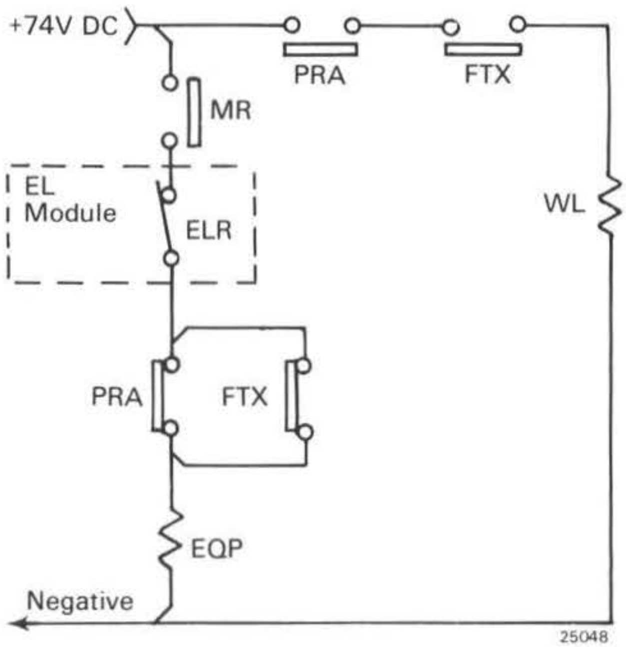
A signal is applied to the WL relay and EQP drops out in case a wheel overspeed condition occurs, Fig. WS-3. Wheel overspeed may result from excessive track speed or from a simultaneous wheel slip condition.

Wheel overspeed is detected by the transition module TR. 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 drops the feed to EQP.

Pickup of WL provides a feed to the wheel slip light WS. 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.

TEST CIRCUIT FUNCTION

With the isolation switch in RUN postion and the throttle opened, the GFX opens the positive feed to terminal 22 of the WS module which prevents pickup of the test relay T in case the test switch is closed when operating under power. This prevents application of high (Run 8) voltage from the D14 alternator to transformer T1.



WS-3 - Wheel Overspeed Correction Circuit

When the locomotive is isolated or throttle placed in IDLE position, the GFX relay drops out to allow application of positive feed to terminal 22 of the WS module. Closing the test switch with positive voltage applied to terminal 22 results in pickup of test relay T.

Pickup of the T relay 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 position. Pickup of the T relay also provides a feed to the red test light on the WS module.

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. 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 test 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.

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.

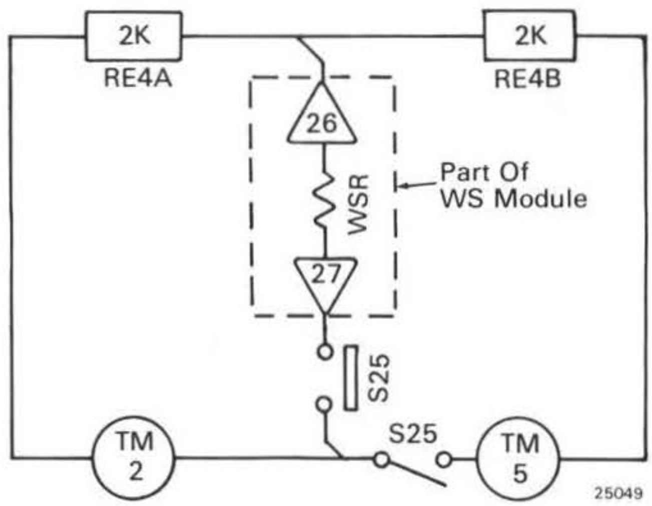


Fig.WSBC-1 - Wheel Slip Bridge Circuit, Simplified Schematic Diagram

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 module is very small and essentially constant during normal operation.

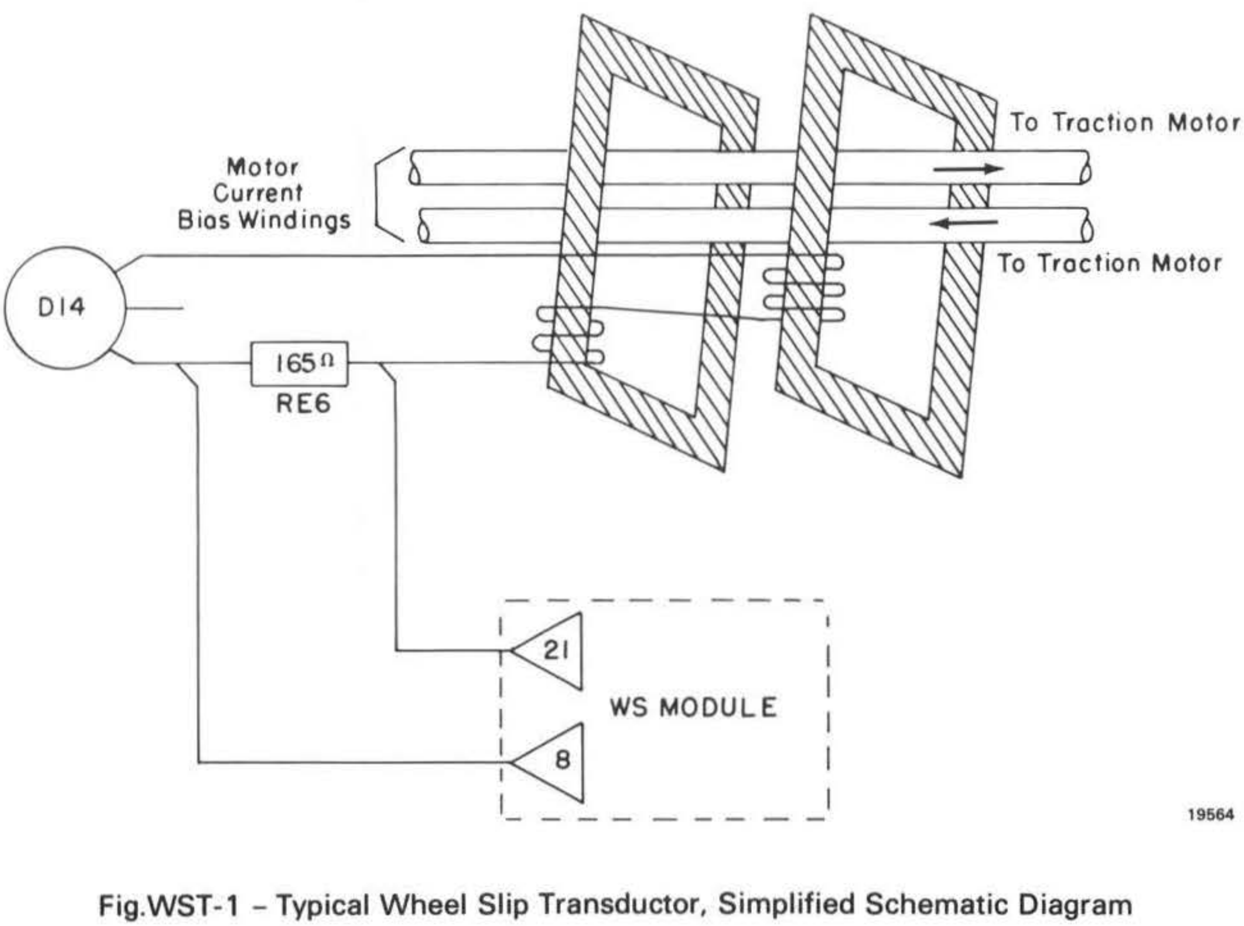


Fig.WST-1 – Typical Wheel Slip Transductor, Simplified Schematic Diagram

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 motor current bias windings. Therefore, the wheel slip tranductors 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 model 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.

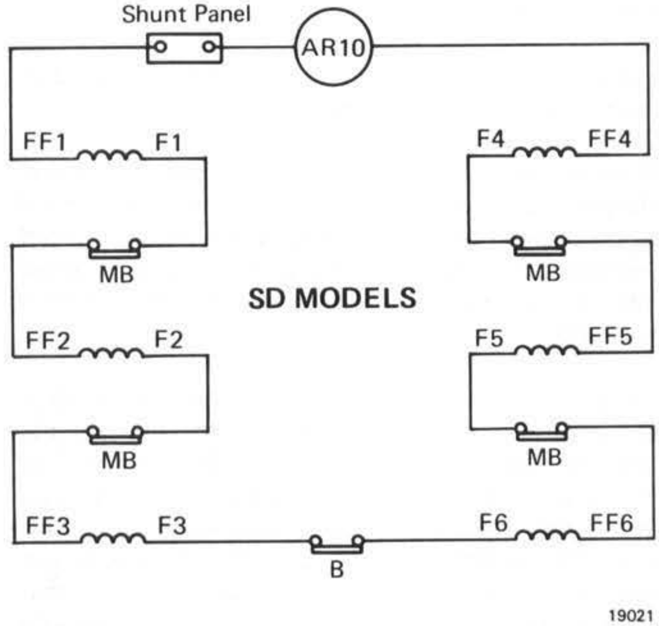


Fig.7D-1 – Motor Field Connections During Dynamic Braking, Simplified Schematic Diagram

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 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. On units equipped with basic dynamic brakes, the DR module provides protection against an open circuit in the dynamic braking grids. Refer to description of the DR module for a detailed description of this regulating action.

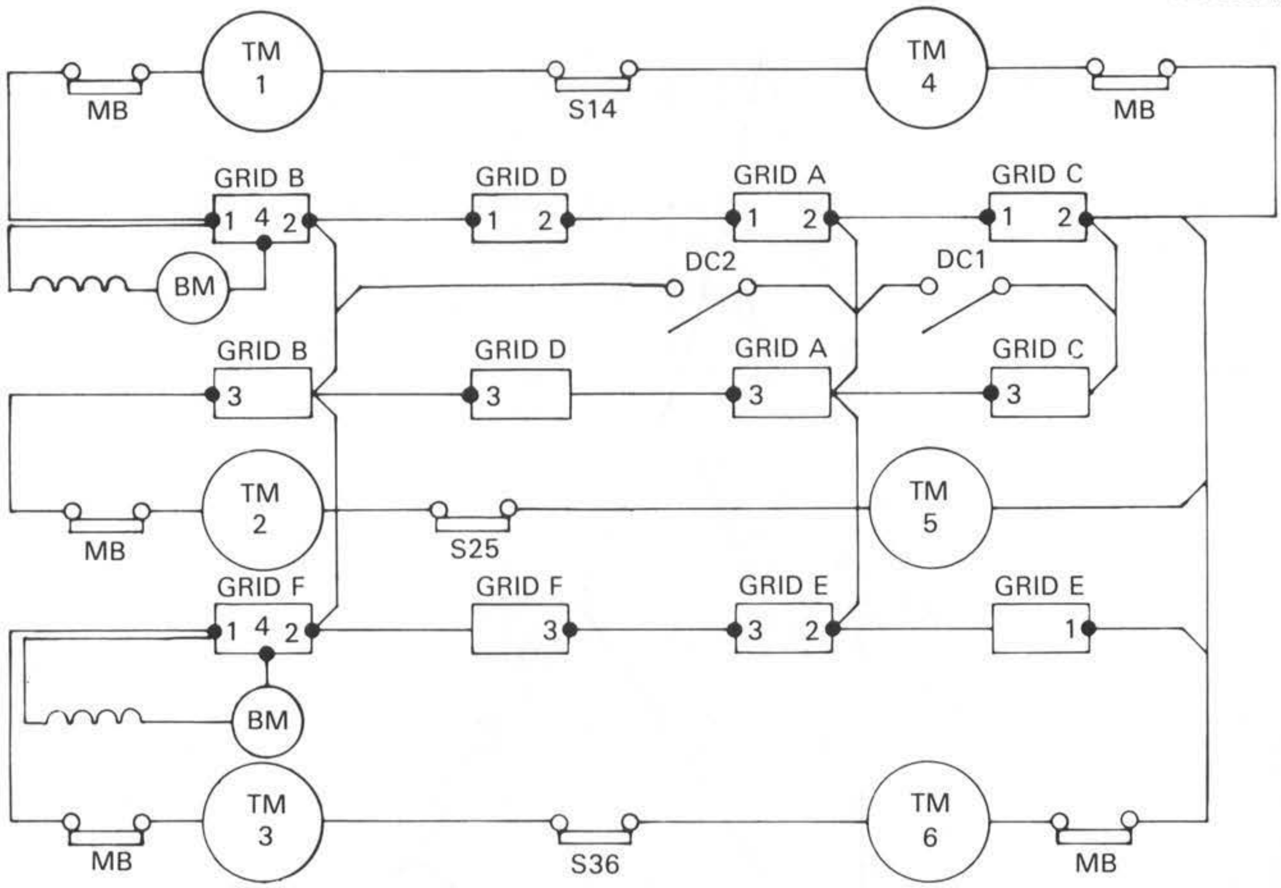
The braking grids are cooled by an exhaust blower to prevent overheating. The blower motor is connected across a portion of one braking grid. The blower, located above the grids, draws outside air through a grill, circulates it around the grids, and exhausts to atmosphere. The DG module provides protection 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 protection action.

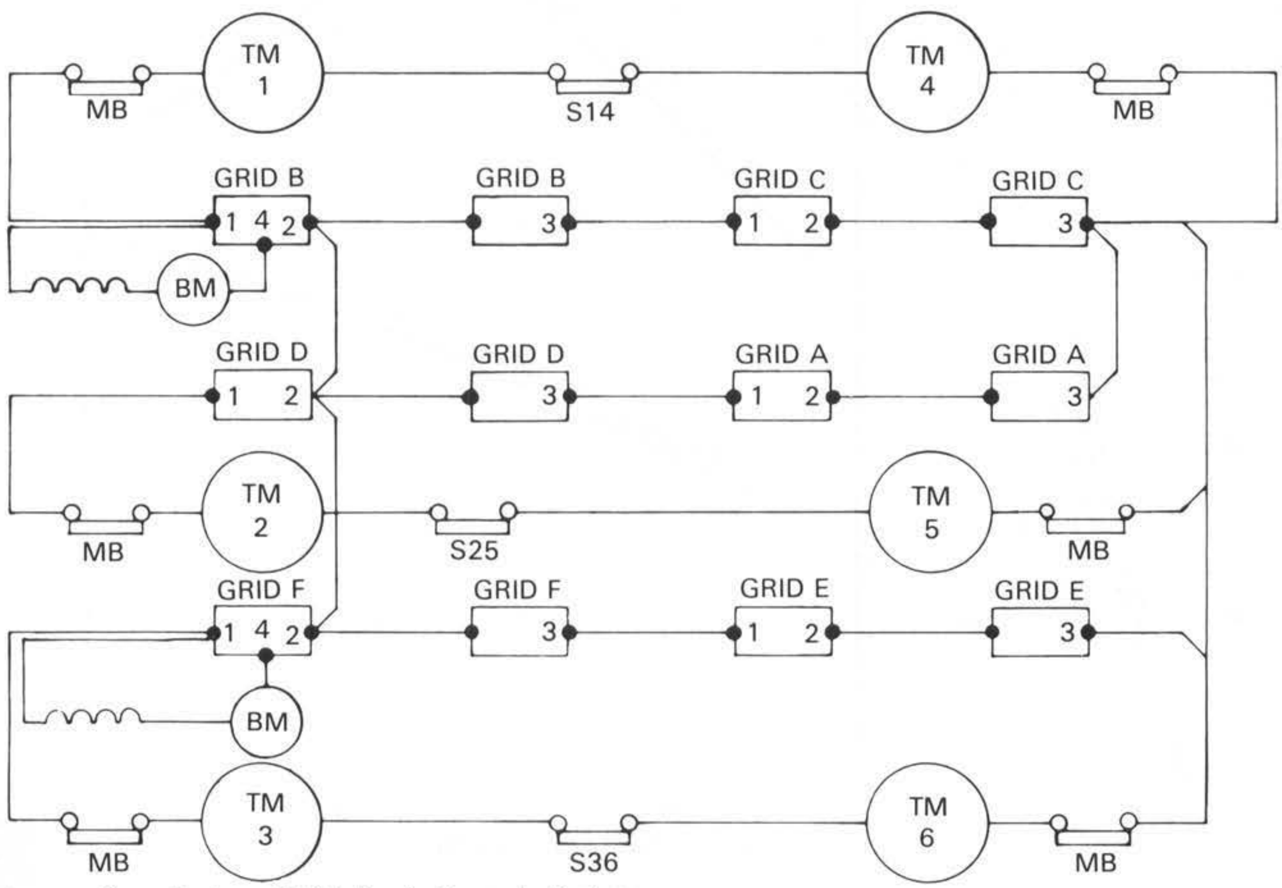
If a braking grid opens, on units equipped with extended range dynamic brakes, the open circuit protection relay OCP detects an unbalance and operates to drop the feed to brake relay B. Dropping this feed disables the dynamic braking system. This prevents opening of the grid shorting contactors while carrying high current and it also protects the traction motors from excessively high voltages. After pickup, the OCP relay actuates the OCL relay which latches in mechanically 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 the 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) trainlined 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 signal. 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.



Locomotives Equipped With Extended Range Dynamic Brakes



Locomotives Equipped With Basic Dynamic Brakes

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Fig. 7D-2 – Motor Armature Connections During Dynamic Braking Simplified Schematic Diagram

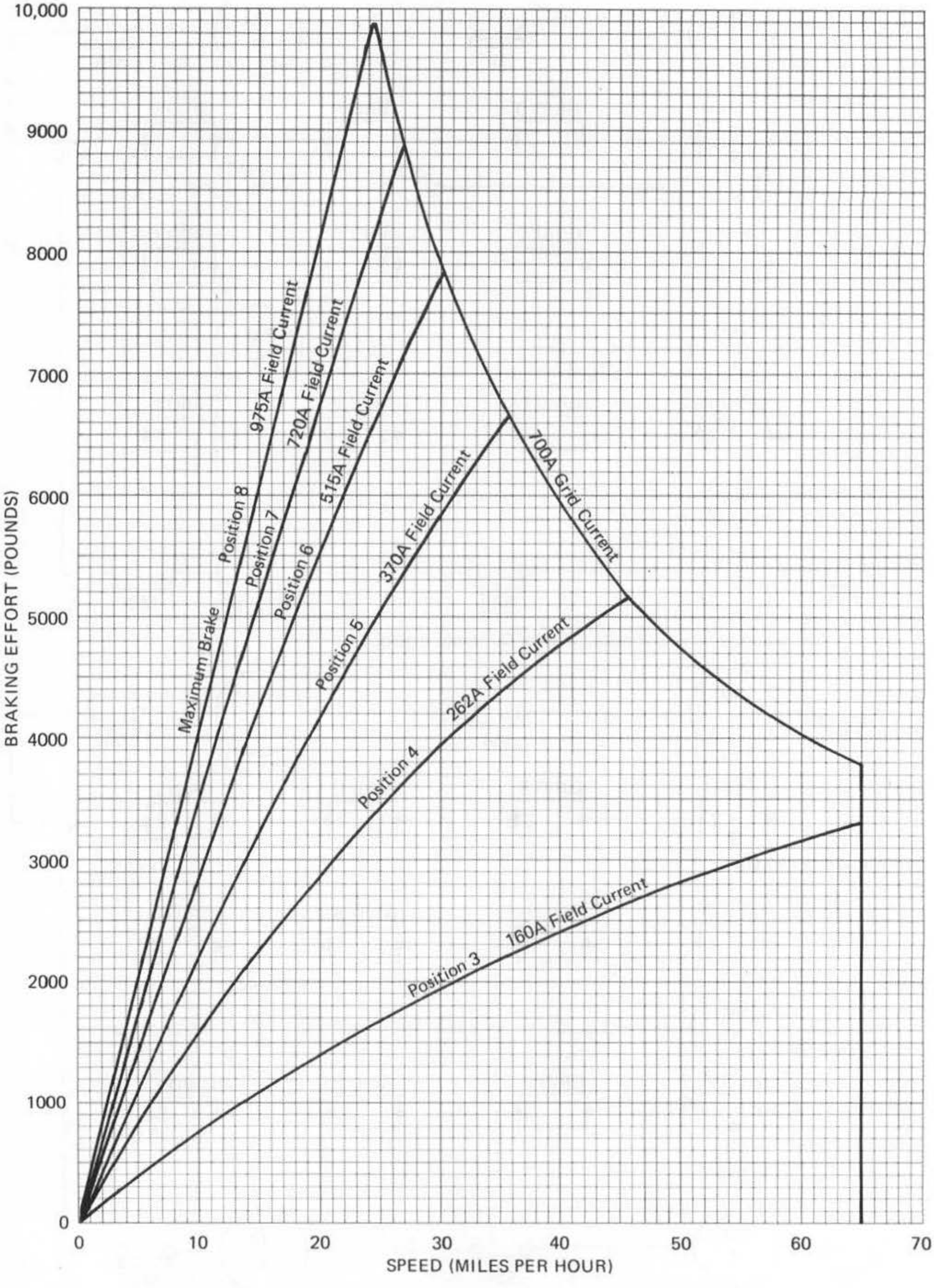

Fig. 7D-3 – Braking Effort Curves With Basic Dynamic Brakes

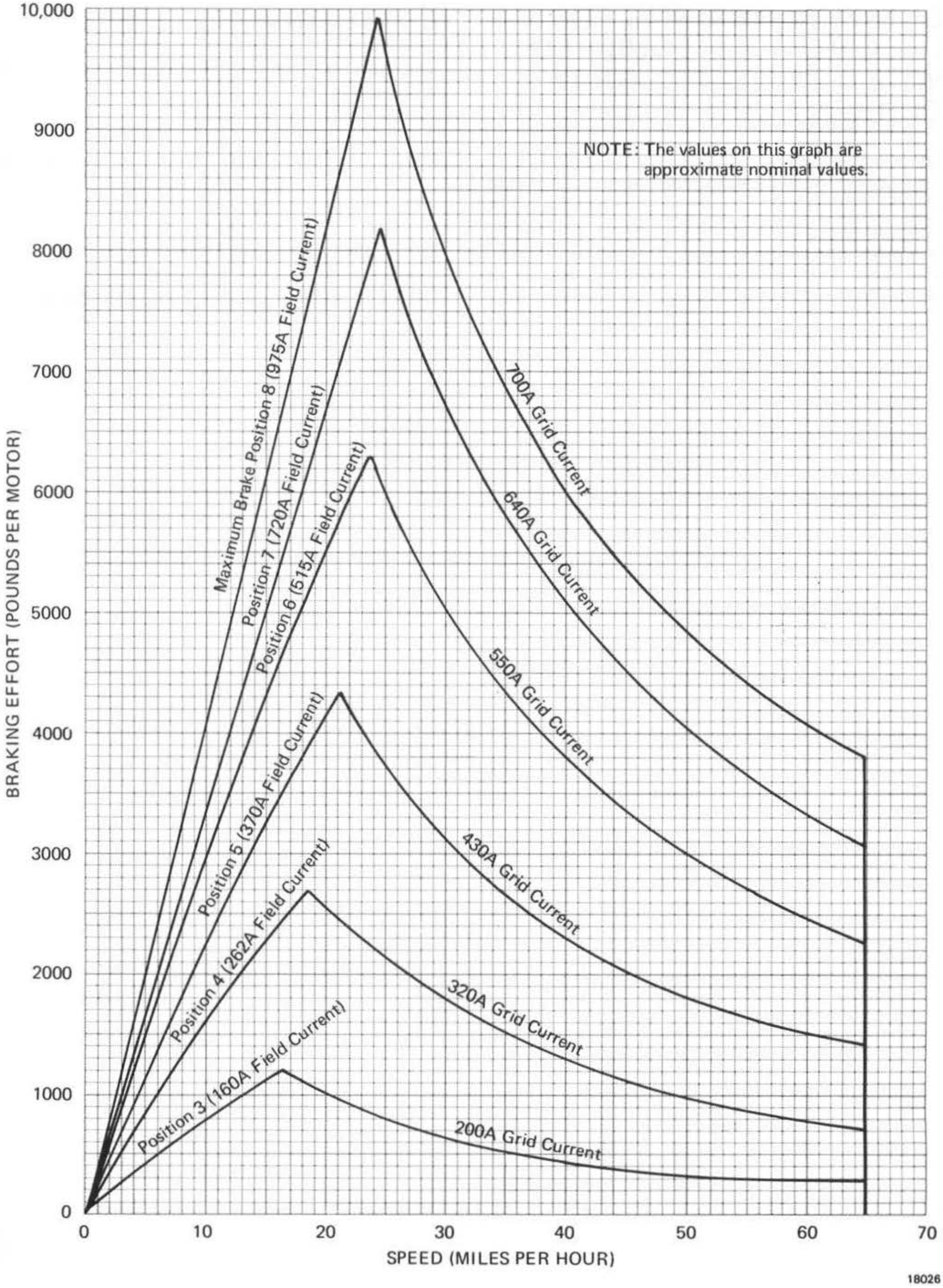

Fig. 7D-4 – Braking Effort Curves When Equipped With Trainline Grid Current Control (Special)

DYNAMIC BRAKING FOR LOCOMOTIVES EQUIPPED WITH TRAINLINED GRID CURRENT CONTROL

On locomotives equipped with trainlined 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 trainlined grid current control.

CONTENTS

The contents of Section 7 Part D are arranged in the following order.

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 while operating in the extended range dynamic braking mode.

Full time trainlined grid current control is offered as an optional extra feature. On units equipped with full time trainlined grid current control, braking grid current is limited to a value proportional to braking lever position throughout the dynamic braking range.

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 and 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 at all track speeds 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 and shorting DP1A contacts between terminal 6 on the DR module and terminal 8 on the RC 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 applied 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 curent 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 0 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 0 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^2R 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:

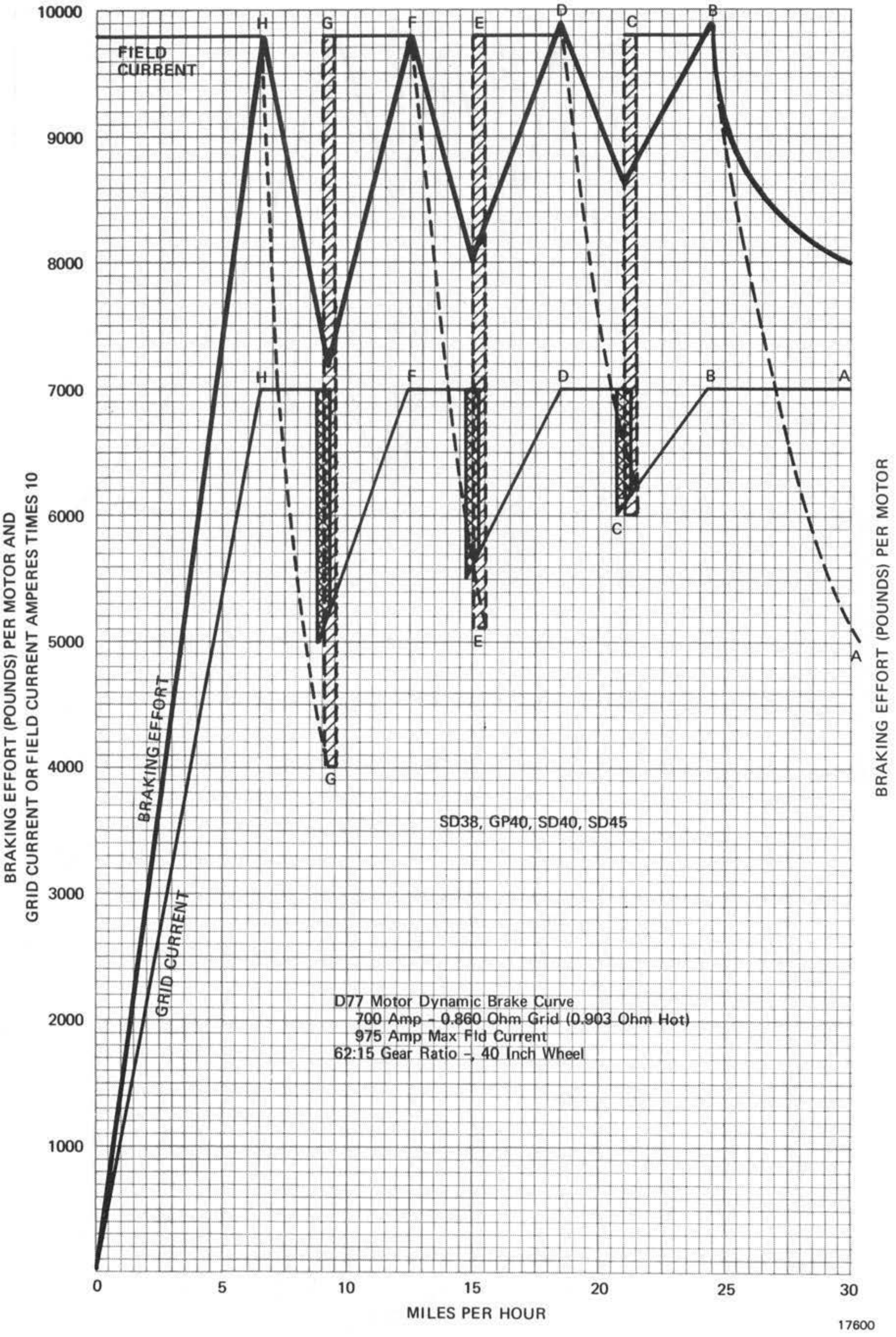

Fig.DE-1 - Braking Effort, Grid Current And Field Current Curves For Extended Range Dynamic Brakes With 0.86 Ohm Grids

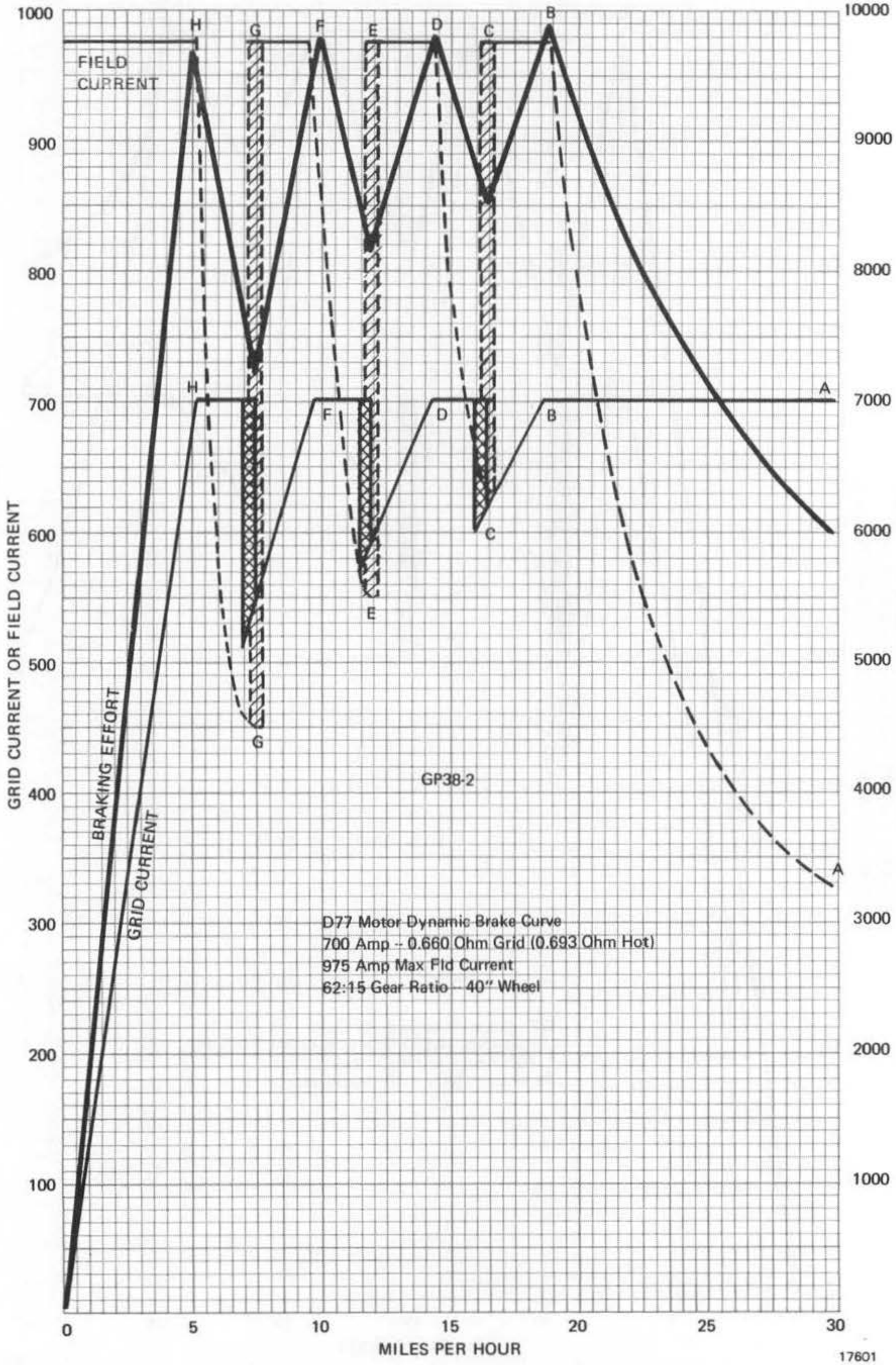

Fig.DE-2 – Braking Effort, Grid Current And Field Current Curves For Extended Range Dynamic Brakes With 0.66 Ohm Grids

Horsepower is equal to retarding force times miles per hour divided by 375.

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, dropout of DC1, 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 in 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 and dropout of DC1 shorts out a second and 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 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 and third 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. As the DE module senses the decrease in current, it again initiates pickup of grid shorting contactor DC1 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 DC1 picks up.

Pickup of DC1 again shorts out the first 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 first portion of the braking grid, combined with the second and third portion, 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 constant 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 ouput of T3. Refer to sheet 2 of 2, Fig. DE-4.

Fig.DE-3 - Operation Of The DE Module (Sheet 1 of 8)

Step	Procedure Or Condition	Result Of Procedure Or Condition
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.
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 (2C - 2NO) through A-B of DC1 and DP2 (2C - 2NO). Provides feed to DC1 (4C - 4NO) through DP2 (4C - 4NC). 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 first braking grid section.
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-B). These contacts also remove charging current from C4 and C5. Shorts out first section of dynamic braking grid (main contacts). Provides feed to DC1A and DC1B (C-D). These contacts also provide a feed to light emitting diode DC1 on the DE module.

Fig.DE-3 - Operation Of The DE Module (Sheet 2 of 8)

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 second and third sections 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 8 are repeated except substitute DP2 for DP1.	
23	DP2 picked up.	Provides holding feed to DP2 (1NC - 1NO) through forward biased Q10. Interrupts feed to DC1 (4C-4NC) through DP1 (4C-4NO) opening circuit to first section of braking grid. Provides feed to DC2 (4C-4NO). DC2 picks up after a short inherent time delay. Provides charging path for C4 and C5 (3C-3NO) through A-B of DC2.
24	Charge placed on C4 and C5.	Places forward bias on Q6 when charge on C4 and C5 rises above breakdown value of zener diode Z8.
25	Forward bias on Q6.	Provides feed to TD relay and places reverse bias on Q12.

Fig.DE-3 - Operation Of The DE Module (Sheet 3 of 8)

Step	Procedure Or Condition	Result Of Procedure Or Condition
26	DC2 picked up (Step 23).	Removes charging current from C4 and C5. Shorts out second and third sections of dynamic braking grid (main contacts). Provides feed to DC2A and DC2B (E-F) through DC1 (A-B). These contacts also provide a feed to light emitting diode DC2 on the DE module.
27	TD relay energized (Step 25).	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 DC2 (2). Provides a fast charging path for the RC capacitors on the RC module for fast recovery of grid current (1).
28	Reverse bias on Q12 (Step 25).	Provides open circuit to base of Q8. This prevents a feed to DP3 when DC2B picks up. This forces a short time delay between pickup of DC2 and DC1.
29	Open circuit to base of Q8.	Drops main feed to DP2. DP2 remains picked up by holding feed.
30	Dynamic braking grids shorted out (Step 26).	Grid current increases due to reduced resistance in braking grid circuit. Grid current increase results in maintaining high braking effort.
31	DC2A picked up (Step 26).	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.
32	DC2B picked up (Step 26).	Sets up circuit to DP3 and provides a holding circuit to DP1 to ensure that DP1 remains picked up until DC2B drops out.
33	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.
34	Procedures and conditions of Steps 3 through 8 are repeated except substitute DP3 for DP1.	
35	DP3 picked up.	Provides holding feed to DP3 (1NC - 1NO) through forward biased Q10. Places forward bias on Q13 and provides charging path for C4 and C5 (2C - 2NO) through A-B of DC1 and DP1 (2C - 2NC). Provides feed to DC1 (4C - 4NO) through DP1 (4C - 4NC). DC1 again picks up after a short inherent time delay.

Fig.DE-3 – Operation Of The DE Module (Sheet 4 of 8)

Step	Procedure Or Condition	Result Of Procedure Or Condition
36	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 first braking grid section.
37	Charge placed on C4 and C5 (Step 35).	Places forward bias on Q6 when charge on C4 and C5 rises above breakdown value of zener diode Z8.
38	Forward bias on Q6.	Provides feed to TD relay and places reverse bias on Q12.
39	DC1 picked up (Step 35).	Removes forward bias from Q13 which opens fast discharge path for RC capacitors on the RC module (A-B). These contacts also remove charging current from C4 and C5.
		Shorts out first section of dynamic braking grid (main contacts).
		Provides feed to DC3A (C-D) through DC2 (C-D). These contacts also provide a feed to light emitting diode DC3 on the DE module.
40	TD relay energized (Step 38).	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).
41	Reverse bias on Q12.	Provides open circuit to base of Q8.
42	Open circuit to base of Q8.	Drops main feed to DP3. DP3 remains picked up by holding feed.
43	Dynamic braking grid shorted out (Step 39).	Grid current increases due to reduced resistance in braking grid circuit. Grid current increase results in maintaining high braking effort.
44	DC3A picked up (Step 39).	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.

Fig.DE-3 - Operation Of The DE Module (Sheet 5 of 8)

Step	Procedure Or Condition	Result Of Procedure Or Condition
	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.
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 27 volts. DC1 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.

Fig.DE-3 - Operation Of The DE Module (Sheet 6 of 8)

Step	Procedure Or Condition	Result Of Procedure Or Condition
12	Forward bias on Q10.	Provides holding circuit for DP2.
13	DC1 drops out after a short inherent time delay (Step 10).	Removes short circuit from first 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 27 volts. Removes feed from DC3A causing DC3A to drop out. Light emitting diode DC3 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 Q2 until grid current signal increases.
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.
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 DC1; c. In Step 9 feed is not maintained to DP2; d. In Step 13, short circuit is removed from second and third braking grids and added back to first braking grid. e. Substitute DC2A and DC2B for DC3A, DC2 light emitting diode for DC3 light emitting diode.	

Fig.DE-3 - Operation Of The DE Module (Sheet 7 of 8)

Step	Procedure Or Condition	Result Of Procedure Or Condition
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. In Step 9, feed is not maintained to DP1 and DP2; c. In Step 12, feed is not provided to DP2; d. Substitute DC1A and DC1B for DC3A, DC1 light emitting diode for DC3 light emitting diode.	
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 8 of 8)

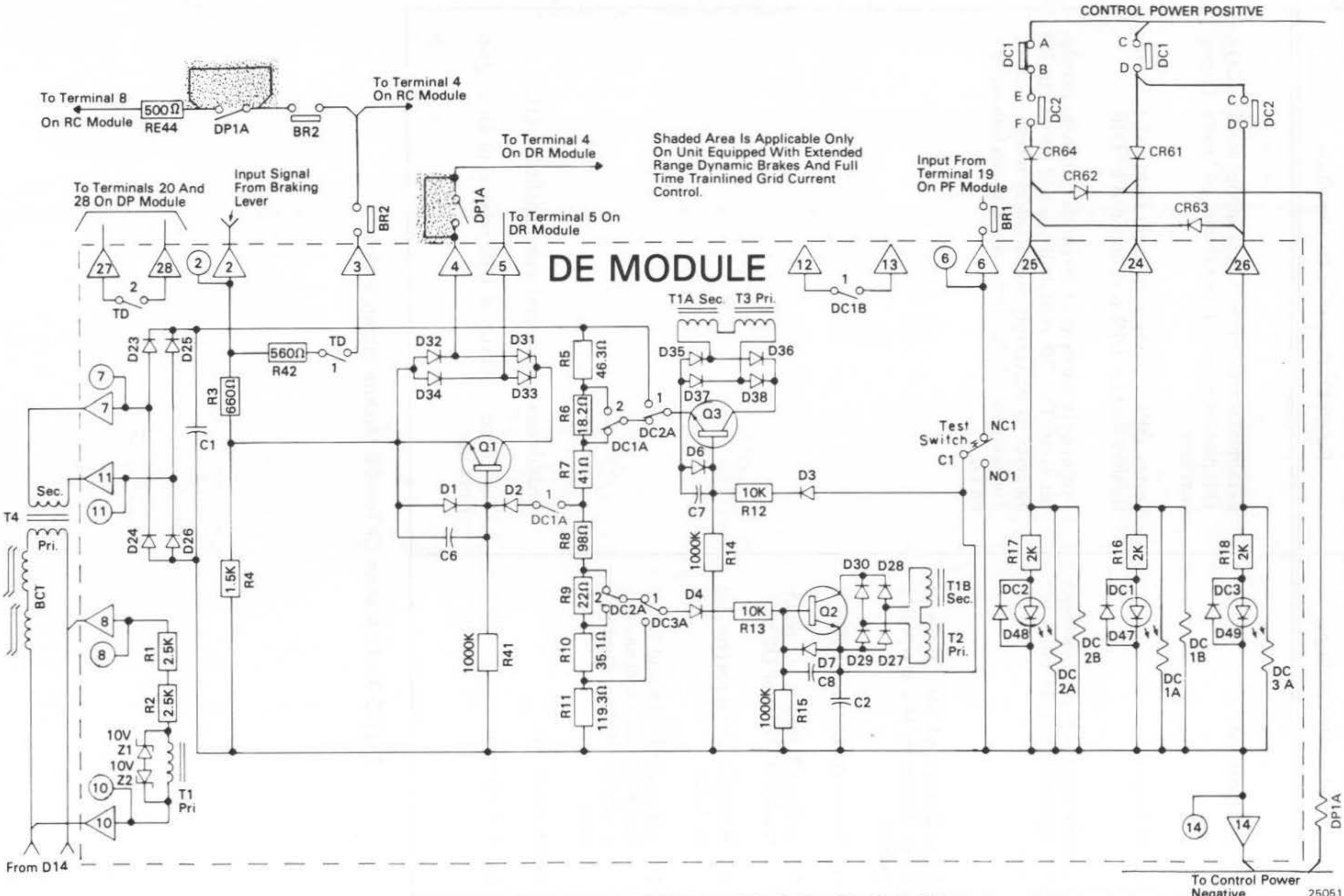

Fig.DE-4 - Extended Range Dynamic Brake Module DE, Simplified Schematic Diagram (Sheet 1 Of 2)

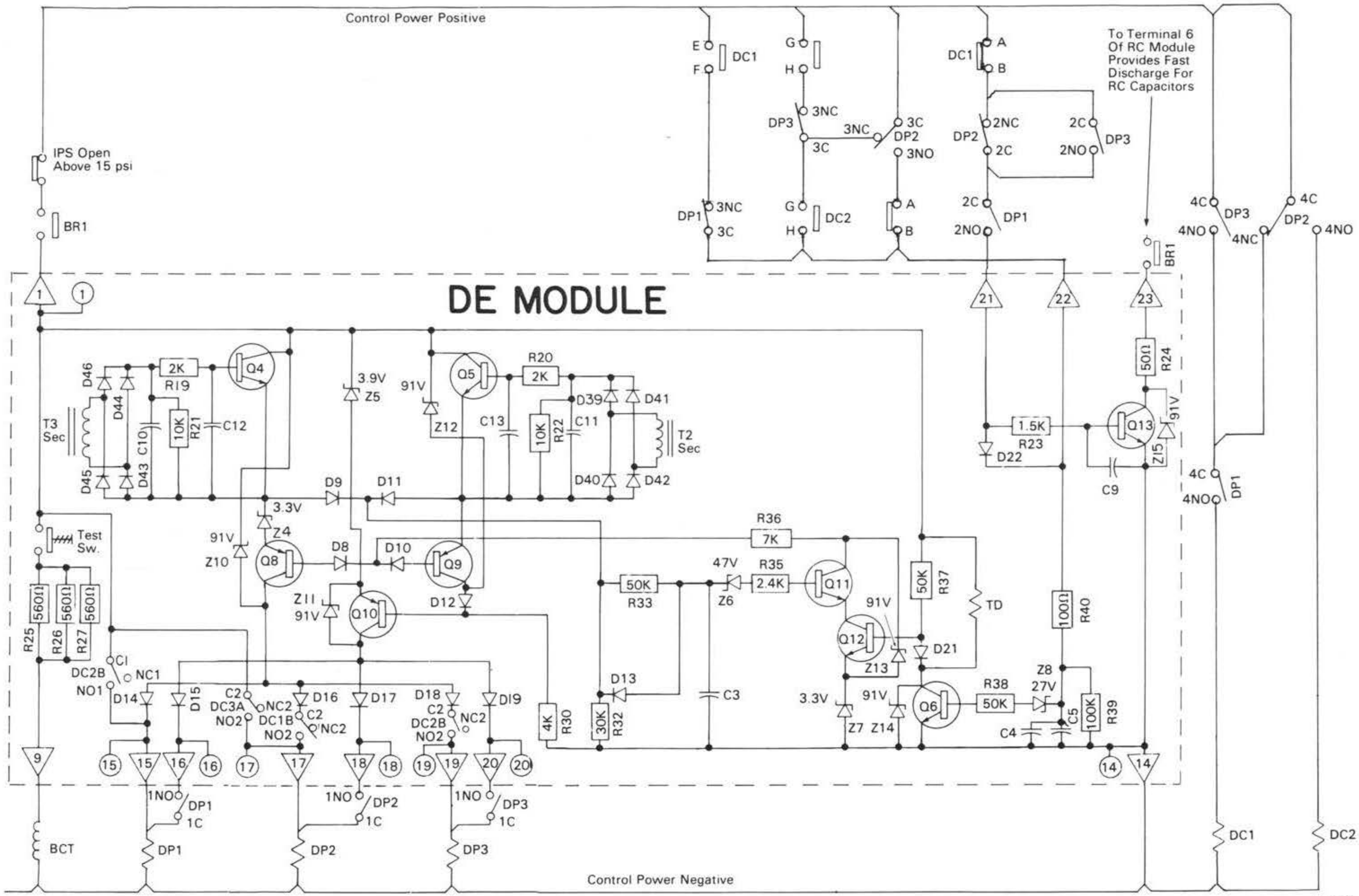

Fig.DE-4 – Extended Range Dynamic Brake Module DE, Simplified Schematic Diagram (Sheet 2 Of 2)

DYNAMIC BRAKE GRID PROTECTION MODULE (SPECIAL ORDER)

INTRODUCTION

The dynamic brake grid protection module DG12 provides protection for the braking grids by dropping the feed to the braking relay B in case of failure in the grid blower motor circuit during dynamic brake operation. During self load tests, on units equipped, DG12 provides protection by dropping the feed to the field contactor GFC, should a failure occur in the grid blower motor circuit during test operations. The DG12 module contains a detector stage and an output stage. The detector stage monitors the grid blower circuit and turns on the output stage if a fault is detected. Turn on of the output stage results in drop out of the generator field contactor GFC or brake relay B. Dropout of the GFC removes excitation from the main generator field. Dropout of brake relay B results in disconnecting the dynamic brake grids.

OPERATION

Solid state devices used in both the detector and output stages, Figs. DG-1 and DG-2, require plus and minus 15 volts for operation. Zener diodes Z3, and Z4 provide the proper operating voltage, derived from the locomotive 74 volt system.

The detector stage, Fig. DG-1, contains a magsense amplifier with three control windings A1, A2, and A3 a bias winding A4, an oscillator winding A5, and a center tapped output winding A6. The detector stage also contains a solid state comparator and an output transistor.

The oscillator winding A5 provides pulses (about 35 per second) to output winding A6. Polarity of the pulses is determined by the operating point established by the bias winding A4 and the control windings A1, A2, and A3. Magnitude of the pulses increases as the operating point moves away from O μa point.

Bias winding A4 is a negative sense winding which sets the normal operating point, when no current is flowing in control windings A1, A2, and A3, to the left of the O μa point. The pulses at the bottom of output winding A6 (magsense terminal A), Fig. DG-1, are negative and the pulses at the top of A6 (Terminal F) are positive when the operating point is to the left of the O μa point.

The positive pulses at the top of output winding A6 (terminal F) result in a high terminal 4 of the comparator. This provides forward bias for Qb. Turn on of Qb provides a low at the base of Qc. Turn off of Qc removes the forward bias from Q2 of the output stage, Fig. DG-2. Turn off of Q2 results in placing 5 and 6 of OP1 at common potential so that there is no output at 12 of OP1. The +4.3 VDC bias at 5 and 9 of OP2 results in negative saturation at 2 and 12 of OP2. This negative signal is blocked by diodes D5 and D6. Transistor Q1 is turned off. When Q1 is off, the DGR relay on the DG module is de-energized. With DGR de-energized, 74 volts from terminal 5 is connected to terminal 4, causing the DGX relay to pick up. When DGX is picked up, normal dynamic braking or load testing is possible.

During the period between pulses, the output at terminal F of output winding A6 goes to common. This removes forward bias from Qb, Fig. DG-1. Turn off of Qb results in forward bias for Qc. Turn on of Qc provides forward bias for Q2, Fig. DG-2. Turn on of Q2 results in a high at 5 of inverting average amplifier OP1. Therefore, the positive output at 12 of OP1 is the average of the positive pulses applied to the base of Qc. The positive pulses at the base of Qc are directly related to the time that Qb is turned off.

Negative sense bias winding A4 sets the operating point to the left of the O μa point. The external "set point" raise and lower circuits are adjusted so that Qb, Fig. DG-1, is turned on most of the time when operating to the left of the O μa point. Therefore, the output at 12 of OP1, Fig. DG-2, is small when operating to the left of the O μa point and decreases as the operating point moves further to the left.

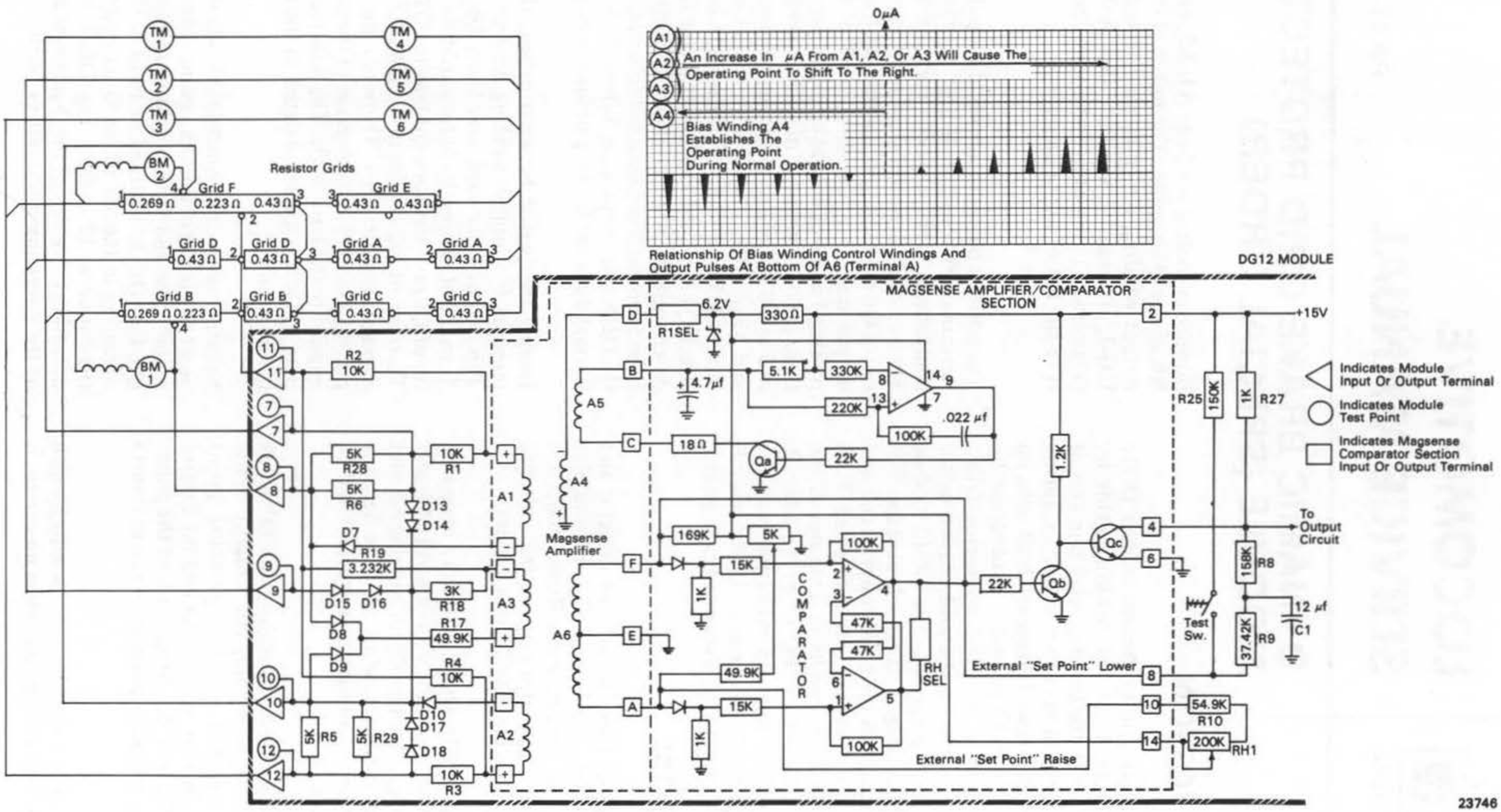

Fig.DG-1 – DG12 Detector Stage, Simplified Schematic Diagram

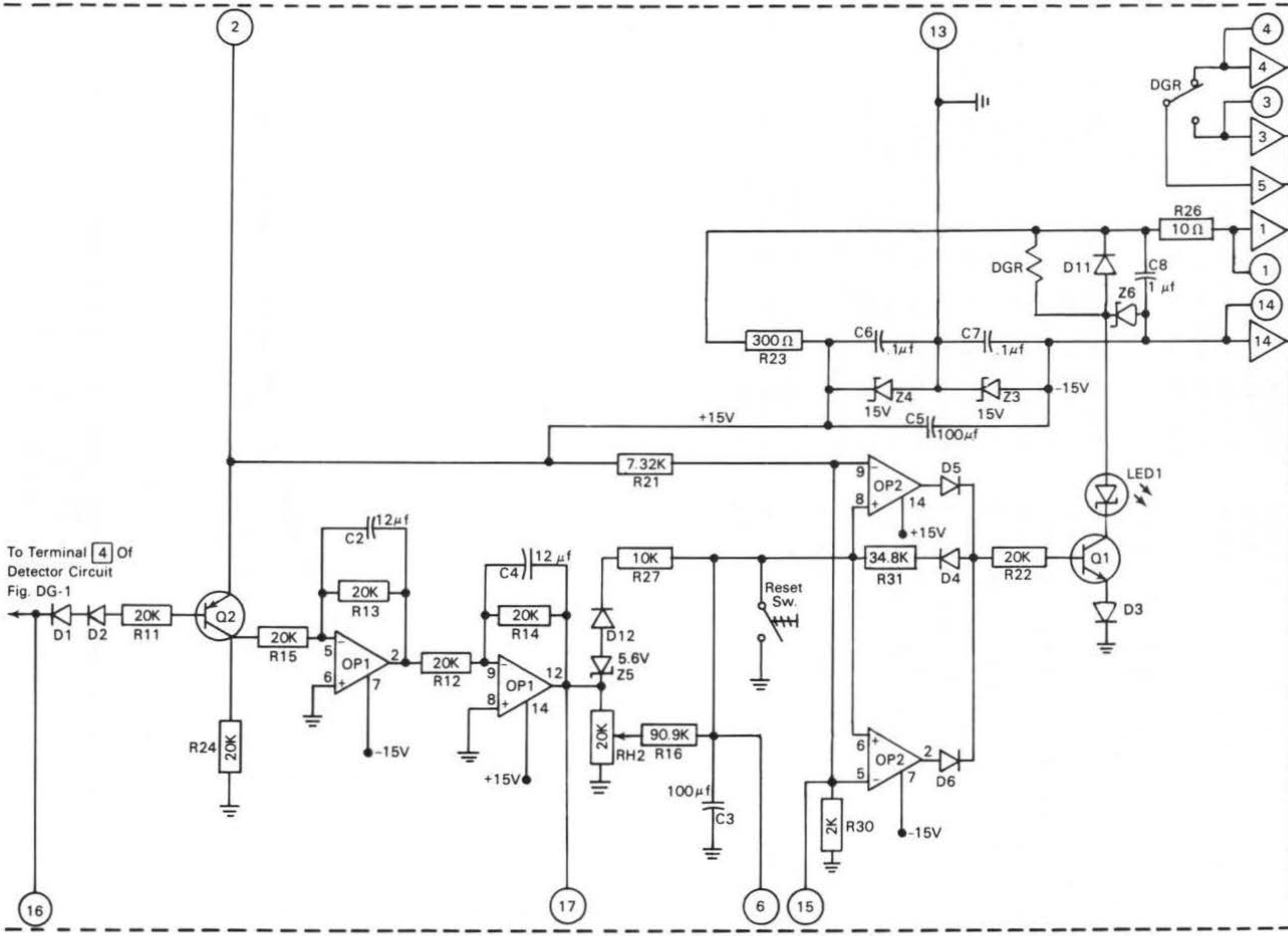

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Fig.DG-2 – DG12 Output Stage, Simplified Schematic Diagram

The output at 12 of OP1 is applied through RH2 and R16 to capacitor C3. The charge on C3 is applied to 6 and 8 of OP2 where it is compared with the +4.3 VDC bias applied to 5 and 9 of OP2. The charge on C3 is less than +4.3 VDC when operating at the left of the O μa point. This negative signal provides reverse bias for Q1. When Q1 is off the DGX relay is picked up, allowing normal dynamic braking or load testing.

Control windings A1, A2, and A3, Fig. DG-1, are connected in bridge circuits to detect an open or short circuit in grid blower motors 1 and 2. Diodes D7, D8, D9, and D10 are used to block negative sense currents to these windings. However, positive sense currents will flow through one or more of these windings if an open or short circuit occurs in the blower circuits, causing an unbalanced bridge. Positive sense currents shift the operating point of the magsense amplifier to the right of the point established by bias winding A4 and the external "set point" circuits.

A positive sense current of 500 microamperes through A1, A2, or A3 results in a potential of about +5 VDC at 12 of OP1. This results in positive saturation at 2 and 12 of OP2. This positive signal provides forward bias of Q1. Turn on of Q1 results in turn on of LED1 and pick up of the DGR relay. When DGR picks up the DGX relay drops out to prevent dynamic braking and self load testing. DGR pickup also causes the GRID BLOWER light on the annunciator module to come on. The positive saturation signal at 2 and 12 of OP2 is fed back through D4 and D3 to 6 and 8 of OP2. This results in maintaining positive saturation at 2 and 12 of OP2 until the reset switch is closed.

A positive sense current of 1200 microamperes through A1, A2, or A3 results in about +12 VDC at 12 of OP1. The charge on C3 will rise above +4.3 VDC within one second. This results in positive saturation at 2 and 12 of OP2. This positive signal results in turn on of LED1 and pickup of DGR. A positive sense current of less than 430 microamperes through A1, A2, or A3 will not result in pickup of DGR. The relationship of positive sense currents through A1, A2, or A3 at the time of DGR pickup is shown in Fig. DG-3.

A simplified schematic diagram showing the bridge circuit for detecting an open in grid blower No. 1 circuit is provided in Fig. DG-4.

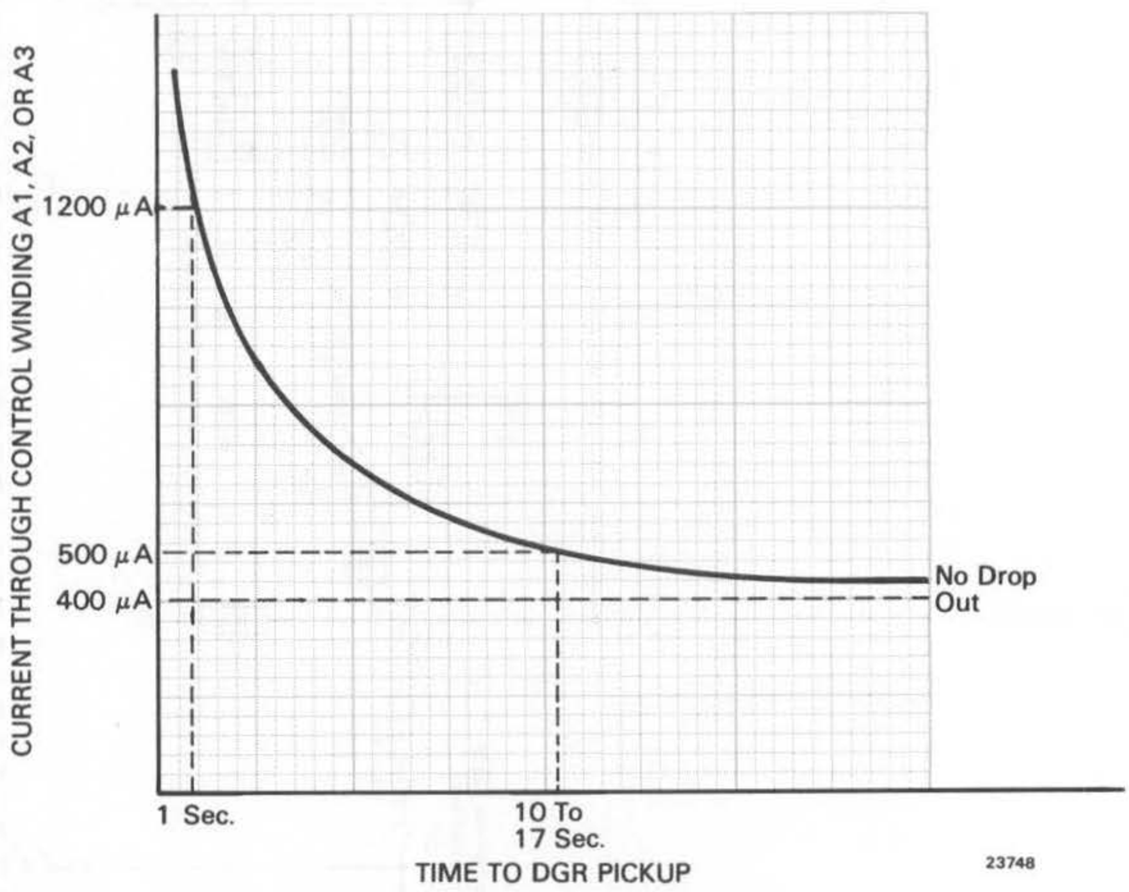


Fig.DG-3 – Relationship Of Positive Sense Current Through A1, A2, Or A3, And Time For DGR Pickup

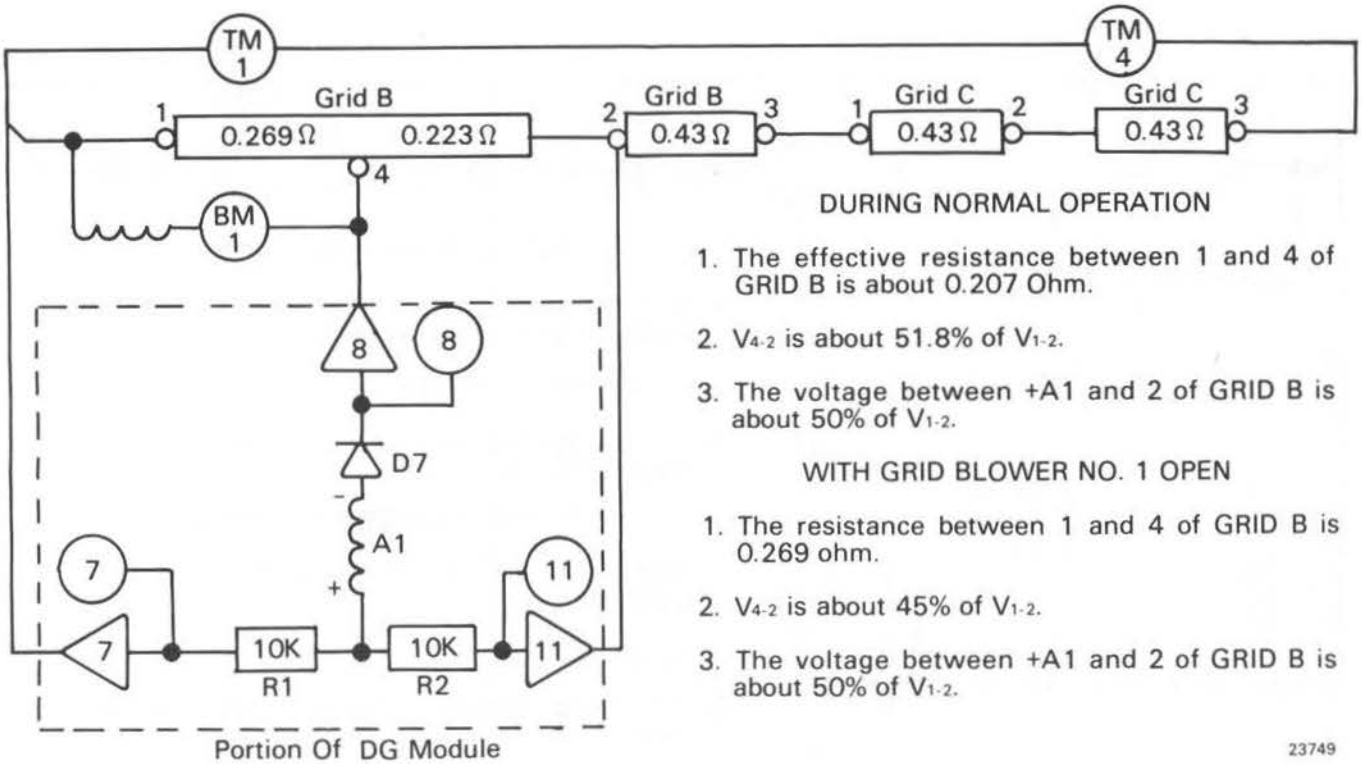


Fig.DG-4 - Grid Blower No. 1 Open Circuit Detection
Simplified Schematic Diagram

During normal operation, diode D7 is reverse biased to prevent negative sense current through winding A1. An open in grid blower No. 1 circuit provides forward bias for D7 and allows a positive sense current through winding A1. A positive sense current of more than 430 microamperes results in DGR pickup. A simplified schematic diagram of grid blower No. 2 open circuit detection is provided in Fig. DG-5. Diode D10 blocks negative sense current through winding A2, but passes positive sense current if an open occurs in grid blower No. 2 circuit.

A simplifed schematic diagram showing the bridge circuit for detecting a short circuit in grid blower No. 1 circuit is provided in Fig. DG-6. During normal operation, diode D8 is reverse biased to prevent negative sense current through winding A3. A short circuit in grid blower No. 1 provides forward bias for D8 and allows positive sense current to flow through winding A3. A positive sense current of more than 430 microamperes results in DGR pickup. A simplified schematic diagram of grid blower No. 2 short circuit detection is provided in Fig. DG-7. Diode D9 blocks negative sense current through winding A3, but passes positive sense current if a short circuit occurs in grid blower No. 2 circuit.

TEST CIRCUIT

A combination test and reset switch is provided in the DG module. When the switch is placed in the TEST position, 15 VDC is applied to the magsense comparator/amplifier section, to simulate a grid blower motor circuit fault. During this functional test the GRID BLOWER light on the annunciator AN module should come on. In addition, LED1 on the DG module should come on and stay on when the switch is released from the TEST position.

A fault detected by the DG module results in positive saturation at 2 and 12 of OP2, Fig. DG-2, and turn on of Q1. The positive saturation signal at 2 and 12 of OP2 is fed back through D4 and D3 to 6 and 8 of OP2. This results in maintaining positive saturation at 2 and 12 of OP2 until the test/reset switch is placed in the RESET position. In this position, the positive saturation signal is discharged to common, returning the DG circuit to normal. Once reset, LED1 on the DG module should go out and DGX should pickup. The GRID BLOWER light on the AN module will remain on until AN is reset.

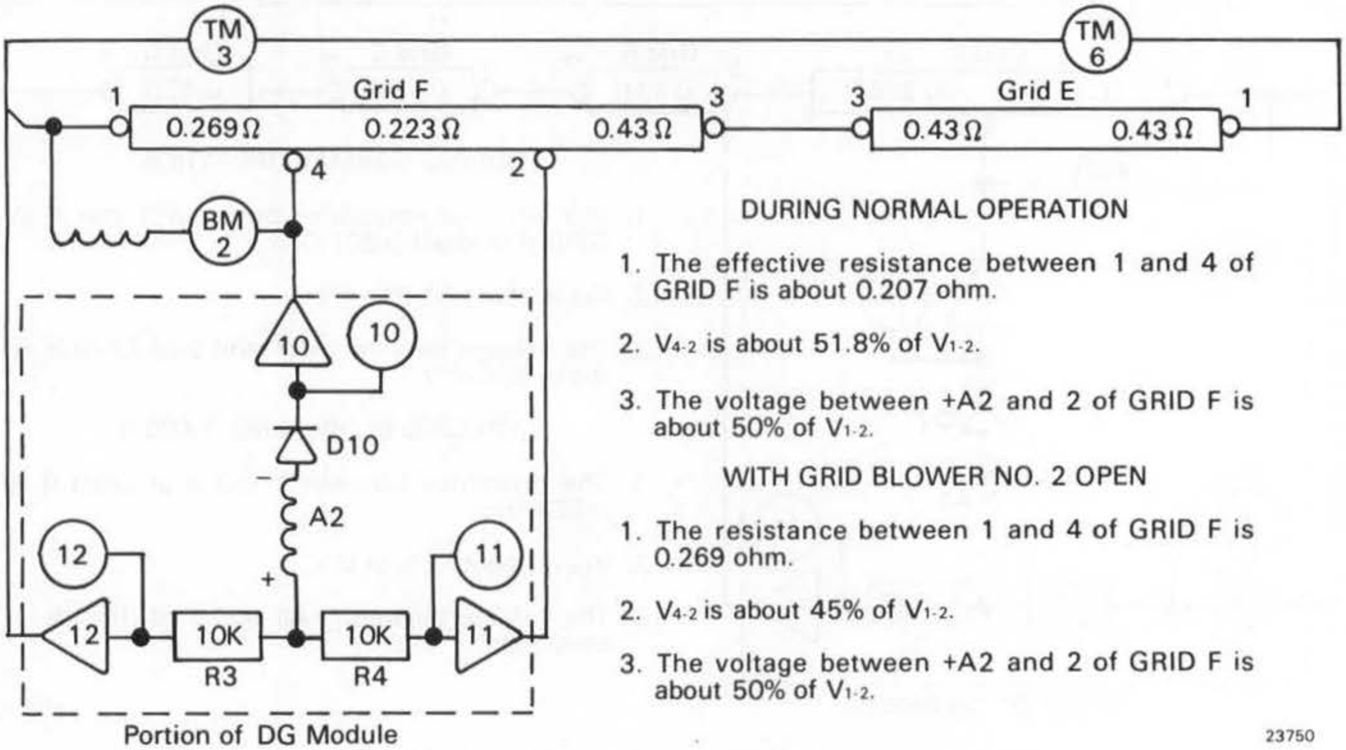
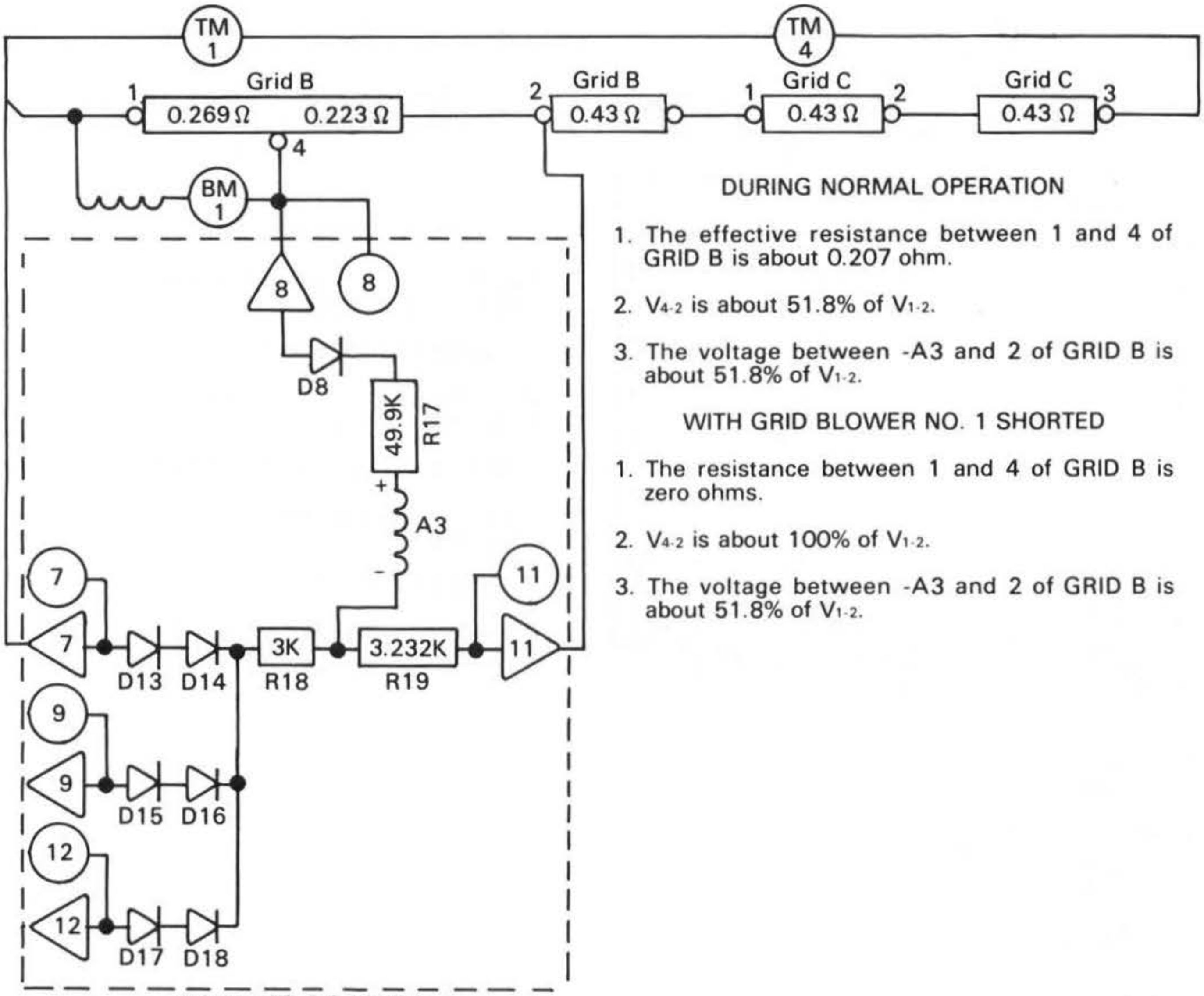


Fig.DG-5 – Grid Blower No. 2 Open Circuit Detection, Simplified Schematic Diagram



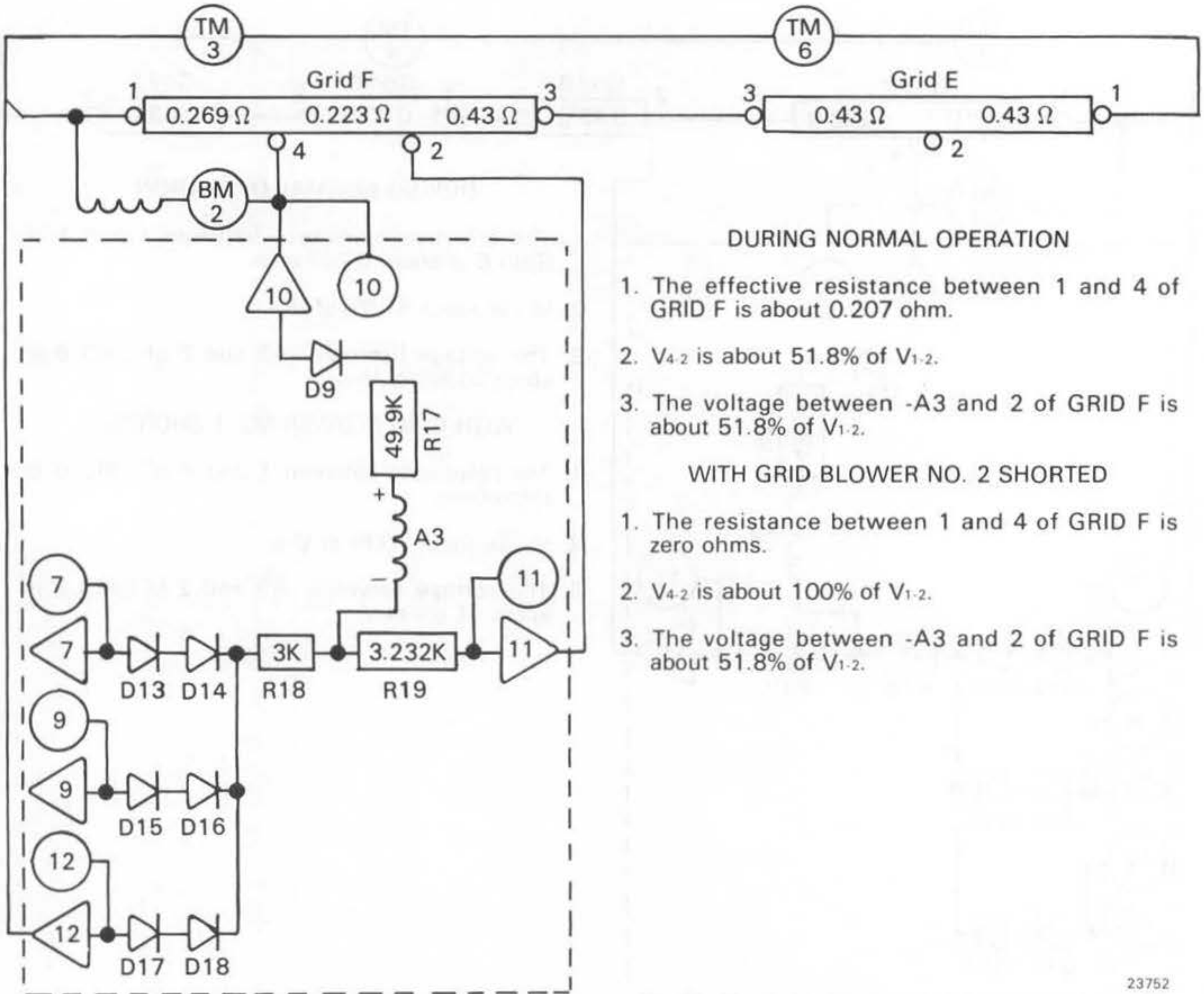
DURING NORMAL OPERATION

1. The effective resistance between 1 and 4 of GRID B is about 0.207 ohm.
2. V_{4-2} is about 51.8% of V_{1-2}.
3. The voltage between -A3 and 2 of GRID B is about 51.8% of V_{1-2}.

WITH GRID BLOWER NO. 1 SHORTED

1. The resistance between 1 and 4 of GRID B is zero ohms.
2. V_{4-2} is about 100% of V_{1-2}.
3. The voltage between -A3 and 2 of GRID B is about 51.8% of V_{1-2}.

Fig.DG-6 – Grid Blower No. 1 Short Circuit Detection, Simplified Schematic Diagram



DURING NORMAL OPERATION

1. The effective resistance between 1 and 4 of GRID F is about 0.207 ohm.
2. V_{4-2} is about 51.8% of V_{1-2}.
3. The voltage between -A3 and 2 of GRID F is about 51.8% of V_{1-2}.

WITH GRID BLOWER NO. 2 SHORTED

1. The resistance between 1 and 4 of GRID F is zero ohms.
2. V_{4-2} is about 100% of V_{1-2}.
3. The voltage between -A3 and 2 of GRID F is about 51.8% of V_{1-2}.

Fig.DG-7 - Grid Blower No. 2 Short Circuit Detection, Simplified Schematic Diagram

DYNAMIC BRAKE PROTECTION MODULE, DP

INTRODUCTION

The dynamic brake protection module DP provides protection for the traction motor fields and also provides back up protection for the dynamic braking resistor grids in case the dynamic braking regulator module DR fails to limit braking grid current to a safe value. The DP module provides protection for the main generator and the dynamic braking grids if an open grid circuit occurs on locomotives equipped with basic dynamic brakes. The DP module operates to remove excitation from the main generator field in case motor field current or dynamic braking grid current rises above a safe value and in case of an open grid circuit.

Simplified schematic diagrams of the DP module, as connected on locomotives equipped with basic dynamic brakes, are provided in Fig. DP-1 and Fig. DP-2. Simplified schematic diagrams of the DP module, as connected on locomotives equipped with extended range dynamic brakes, are provided in Fig. DP-3 and Fig. DP-4. The applicable locomotive wiring diagrams should be used when performing troubleshooting or maintenance.

MOTOR FIELD PROTECTION CIRCUIT

The motor field protection circuit, Fig. DP-1 and DP-2, 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 protects 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 the time delay circuit consisting of R21, R22, C5, and C6.

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 outpout 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.

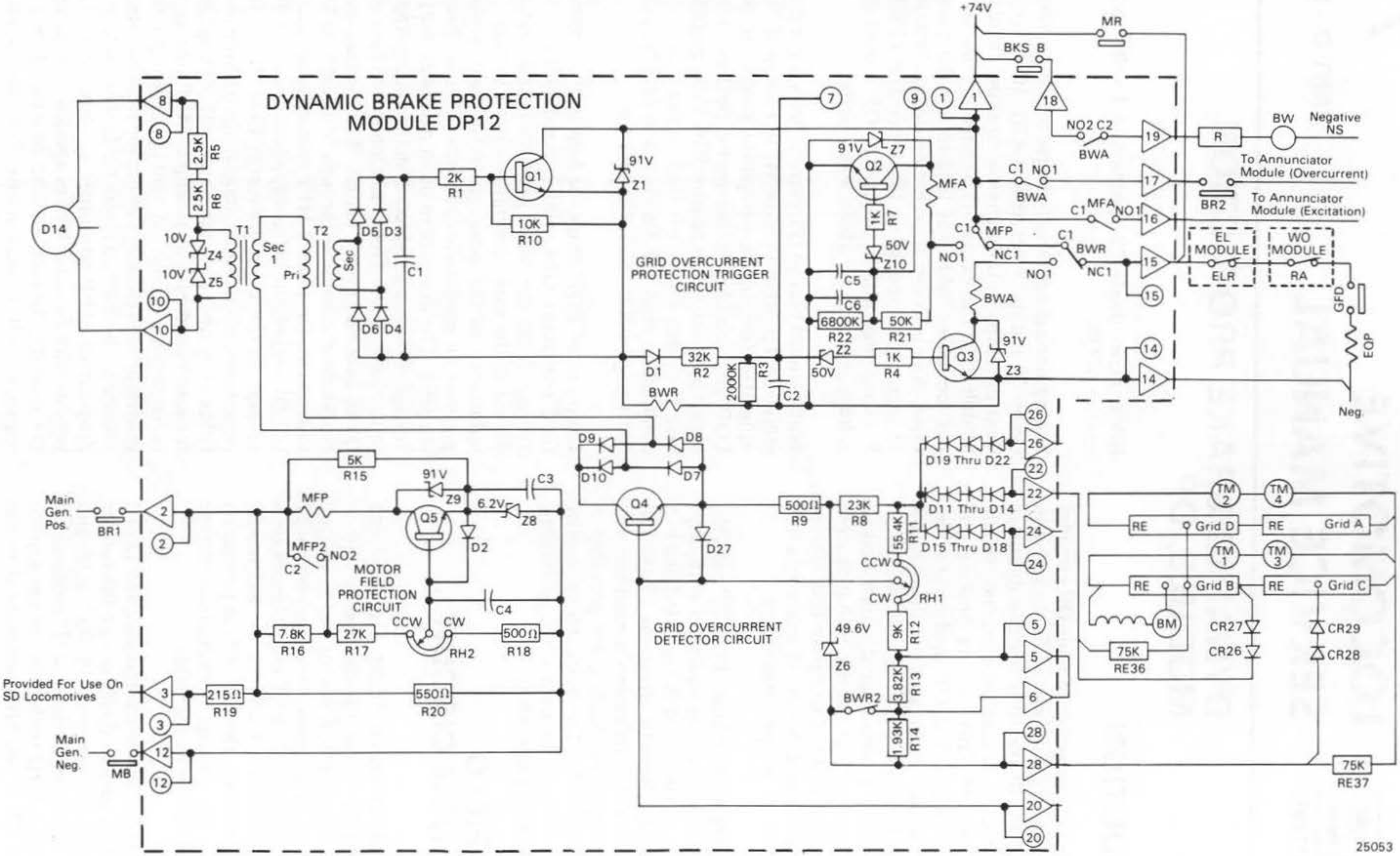


Fig.DP-1 – Dynamic Brake Protection Module DP, Simplified Schematic Diagram
(Four-Axle Locomotives With Basic Dynamic Brakes)

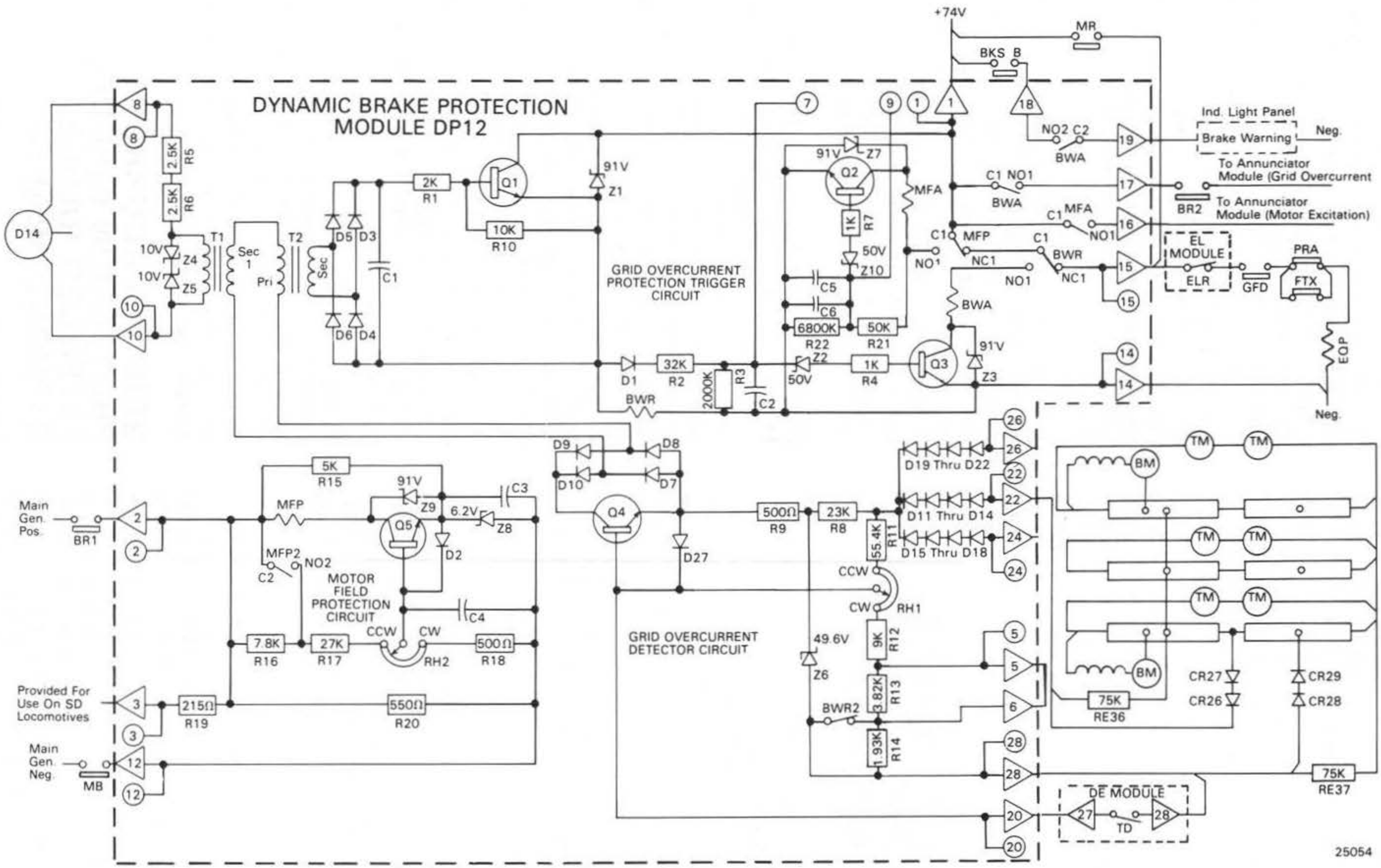


Fig.DP-2 - Dynamic Brake Protection Module DP, Simplified Schematic Diagram
(Six-Axle Locomotives With Basic Dynamic Brakes)

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 provided to the R21, R22, C5, C6 time delay circuit provides a short time delay in turn on of Q2. This prevents turn on of Q2 due to non-repetitive voltage spikes or short time transients. Forward bias is applied to Q2 when the charge on C5 and C6 rises above 50 volts. Turn on of Q2 results in pickup of MFA. Pickup of MFA provides a feed to the annunciator module.

GRID OVERCURRENT PROTECTION CIRCUIT, BASIC DYNAMIC BRAKES

The grid overcurrent protection circuit consists of a detector circuit and a trigger circuit. The detector circuit monitors a signal which is proportional to dynamic braking grid current and provides a signal to the trigger circuit if grid current rises above a safe value. The trigger circuit operates to remove excitation from the main generator field if a grid overcurrent condition is detected. A simplified schematic diagram of the grid overcurrent protection circuit for four-axle locomotives with basic dynamic brakes is provided in Fig. DP-1. Refer to Fig. DP-2 for overcurrent protection circuit for six-axle locomotives with basic dynamic brakes.

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 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.

GRID OVERCURRENT PROTECTION CIRCUIT, EXTENDED RANGE DYNAMIC BRAKES

Two grid current signals are provided to the grid overcurrent detector circuit of the DP module when the locomotive is equipped with four axles and extended range dynamic brakes, Fig. DP-3. A signal proportional to grid current from terminal 1 to terminal 2 of grid B is applied to receptacle 22. A signal proportional to grid current from terminal 3 to terminal 2 of grid B is applied to receptacle 24. Diodes D11 through D14 and D15 through D18 form a highest detector so that the larger of these two signals is applied to the grid overcurrent detector circuit. If an overcurrent condition is detected, the action is the same as for a locomotive equipped with basic dynamic brakes.

Three grid current signals are provided to the grid overcurrent detector circuit of the DP module when the locomotive is equipped with six axles and extended range dynamic brakes, Fig. DP-4. A signal proportional to grid current from terminal 1 to terminal 2 of grid B is applied to receptacle 22. A signal proportional to grid current from terminal 3 to terminal 2 of grid B is applied to receptacle 24. A signal proportional to grid current from terminal 1 to terminal 2 of grid F is applied to receptacle 26. Diodes D11 through D14, D15 through D18, and D19 through D22 form a highest detector circuit so that the largest of these three signals is applied to the grid overcurrent detector circuit. If an overcurrent condition is detected, the action is the same as for locomotives equipped with basic 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 during extended range dynamic brake operation 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 pick up and for a short time after pick up 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.

DYNAMIC BRAKING GRID OPEN CIRCUIT PROTECTION

On four-axle locomotives equipped with basic dynamic brakes, Fig. DP-1, the voltage between receptacles 22 and 28 will increase if an open develops in grids A or C or in grids B and D between RE36 and RE37. On six-axle locomotives equipped with basic dynamic brakes, Fig. DP-2, the voltage between receptacles 22 and 28 will increase if an open develops in grids A, C, or E or if an open develops in grids B, D, or F between RE36 and RE37. The DP module senses an increase in voltage between receptacles 22 and 28 as the grid current signal and operates to limit this voltage to a safe value.

On locomotives equipped with extended range dynamic brakes, Fig. DP-3 and DP-4, an open circuit protection relay OCP is connected across a bridge circuit consisting of the dynamic braking grids and a pair of traction motors. The bridge is balanced during normal operation. Pick up of the grid shorting contactors unbalances the bridge, but this unbalance is not sufficient to cause pickup of OCP. However, an open in one or more of the dynamic braking grids results in an unbalance sufficient to pick up OCP.

Pick up of OCP drops the feed from braking contactor B and provides a feed to the open circuit protection indicator on the annunciator module and the open circuit latching relay OCL. After pickup, the OCL relay mechanically latches in and should not be reset until the braking grid circuit has been checked and repaired. Dropout of the B contactor removes excitation from the main generator and disables the dynamic braking system.

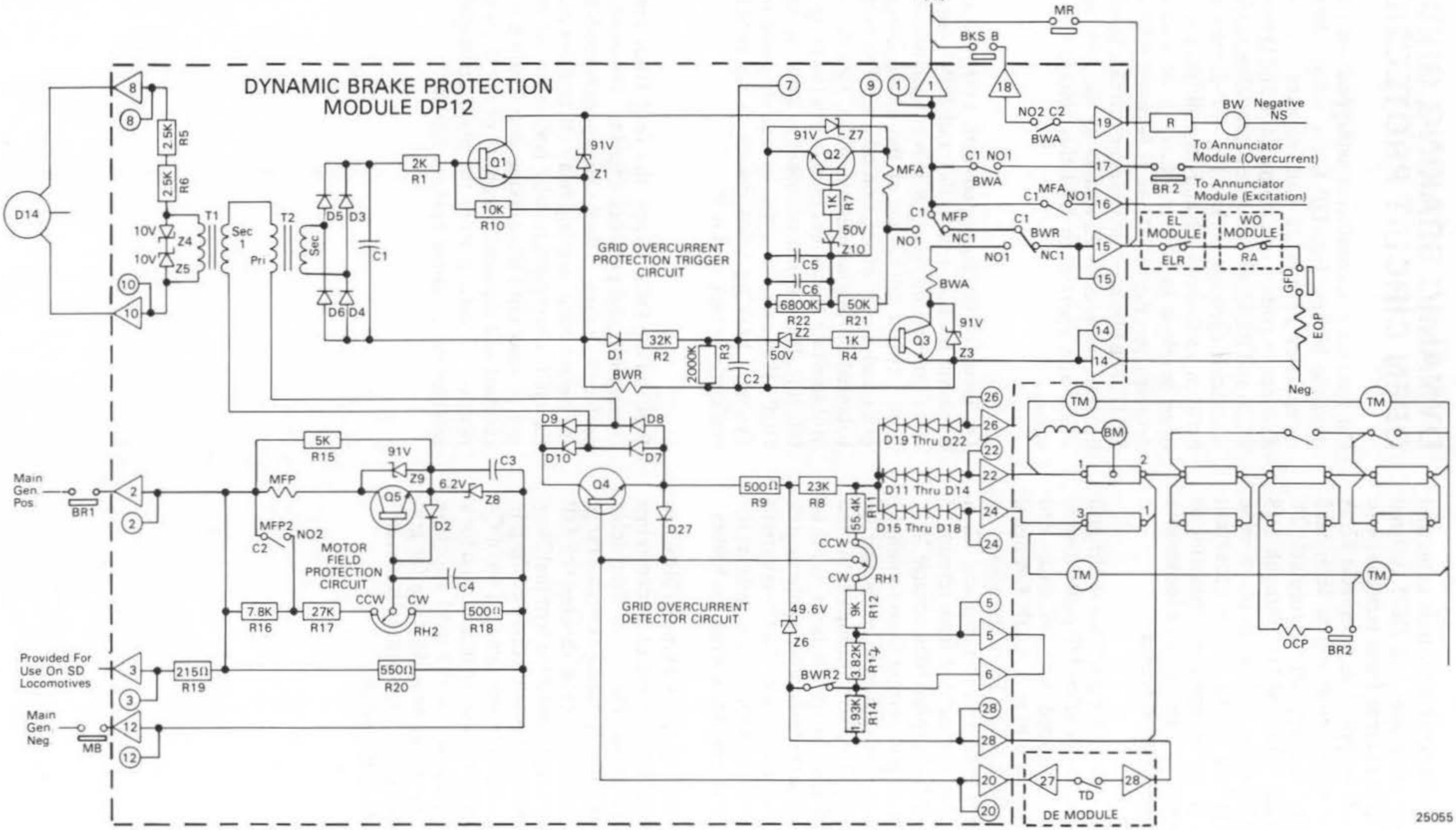


Fig.DP-3 – Dynamic Brake Protection Module DP, Simplified Schematic Diagram
(Four-Axle Locomotives With Extended Range Dynamic Brakes)

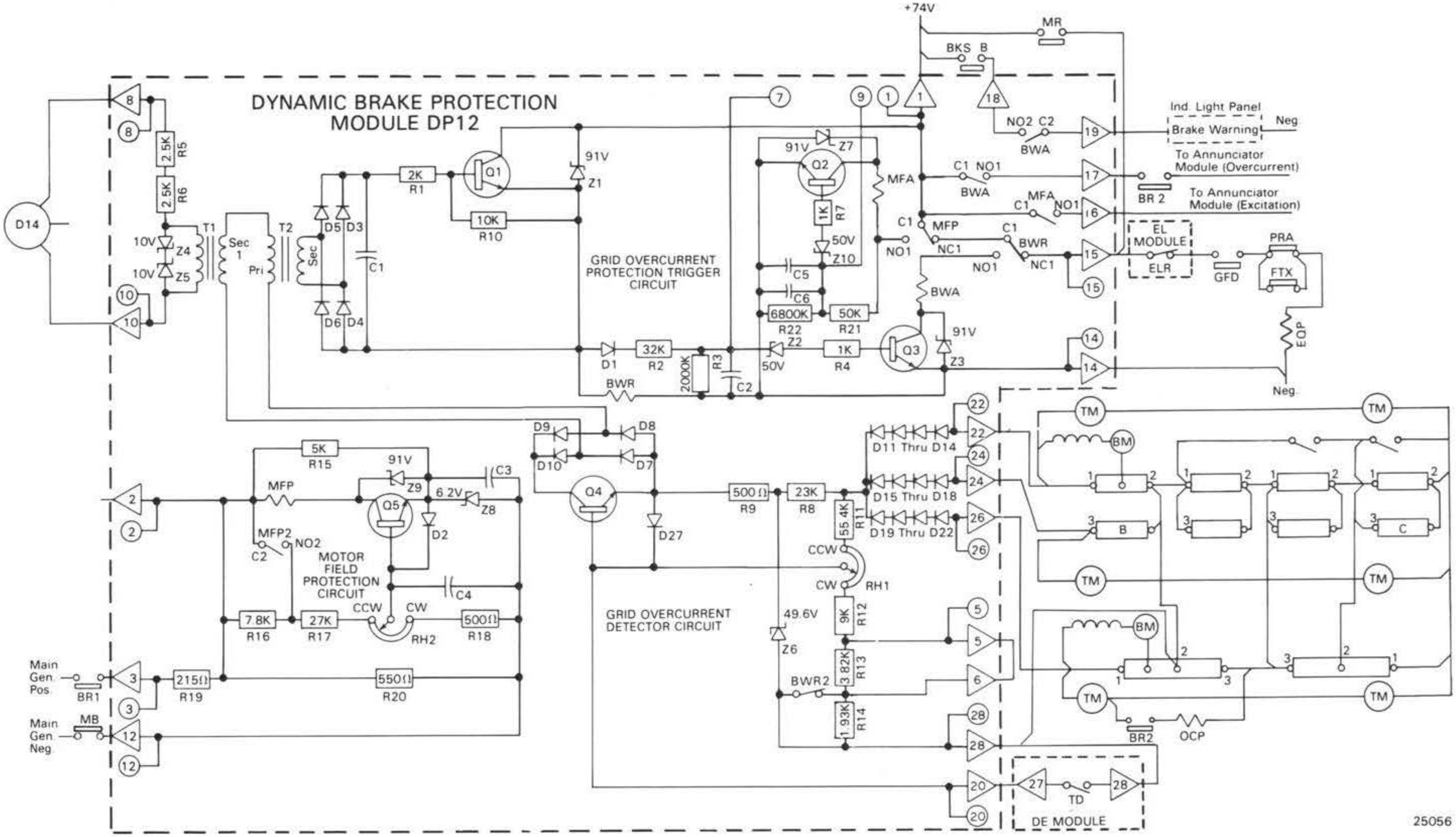


Fig.DP-4 – Dynamic Brake Protection Module DP, Simplified Schematic Diagram
(Six-Axle Locomotives With Extended Range Dynamic Brakes)

DYNAMIC BRAKE REGULATOR MODULE, DR13

INTRODUCTION

Dynamic brake regulator module DR13 is designed to protect the dynamic braking grids by limiting braking grid current to a maximum value of 700 amperes. DR13 may also be used to limit dynamic braking grid current to a value proportional to braking lever position. This limiting action is accomplished by reducing excitation to the main generator field. Excitation to the main generator field is reduced, as necessary to limit braking grid current to the desired value, by discharging the rate control capacitors on the RC module through a solid state circuit on the DR module.

The DR module may be used on locomotives equipped with any one of the following dynamic braking systems.

1. Basic Dynamic Brakes.
2. Basic Dynamic Brakes With Trainlined Grid Current Control.
3. Extended Range Dynamic Brakes.
4. Extended Range Dynamic Brakes With Full Time Trainlined Grid Current Control.

A description of the DR13 module as used with each of the four dynamic braking systems is provided in the following paragraphs.

BASIC DYNAMIC BRAKES

Voltage signals proportional to current through grids B and D on four axle locomotives equipped with basic dynamic brakes, Fig. DR-1, or voltage signals proportional to current grids B, D, and F on six axle locomotives equipped with basic dynamic brakes, Fig. DR-2, are applied to a highest detector CRDB. The larger of these signals is applied between receptacles 2 and 13 of the DR module.

The signal applied between terminals 13 and 2 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 Z9. The zener diodes provide a constant reference signal to the emitter of 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 64 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 turn 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.

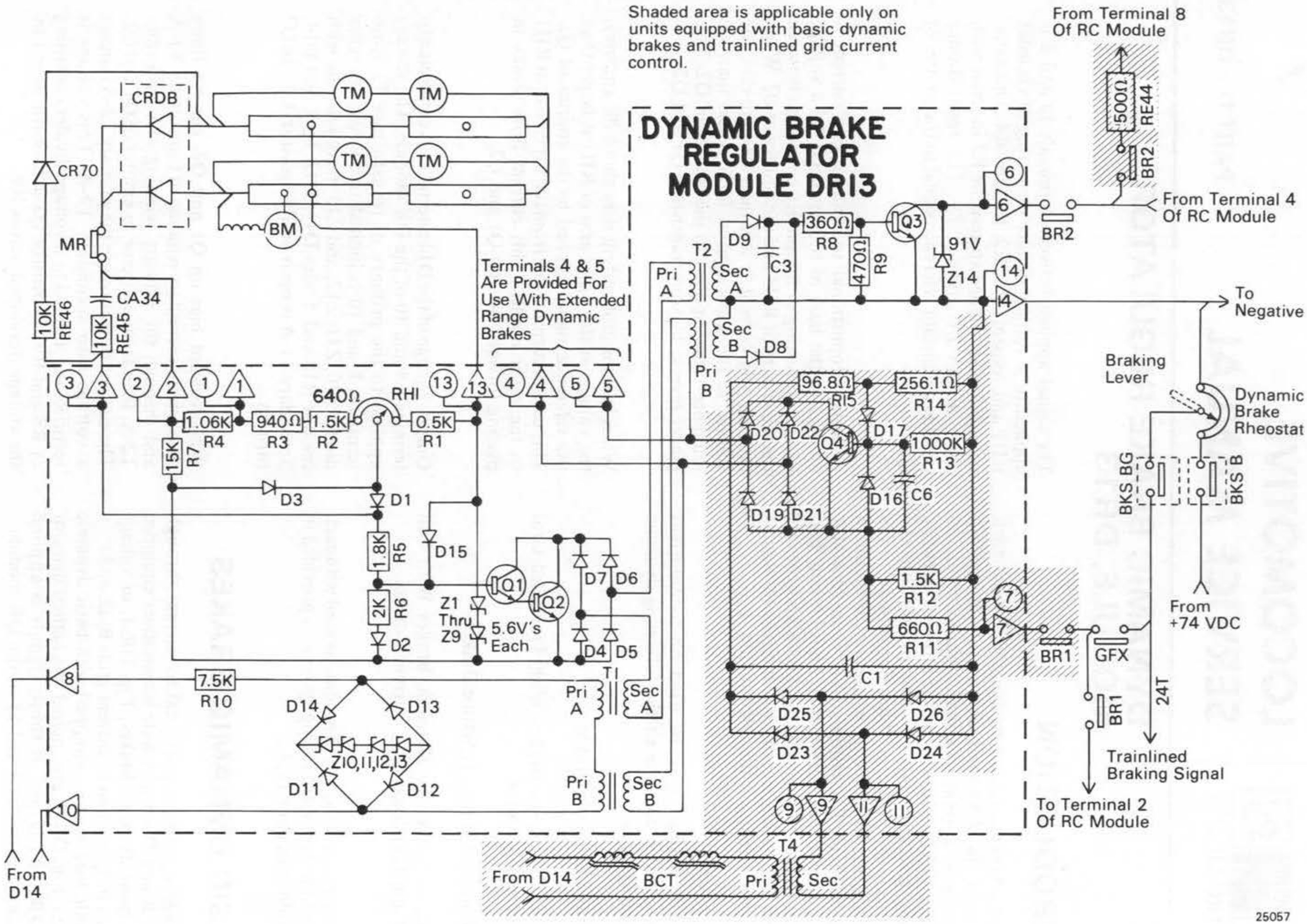


Fig.DR-1 - Dynamic Brake Regulator Module DR, Simplified Schematic Diagram
(Four-Axle Locomotives With Basic Dynamic Brakes)

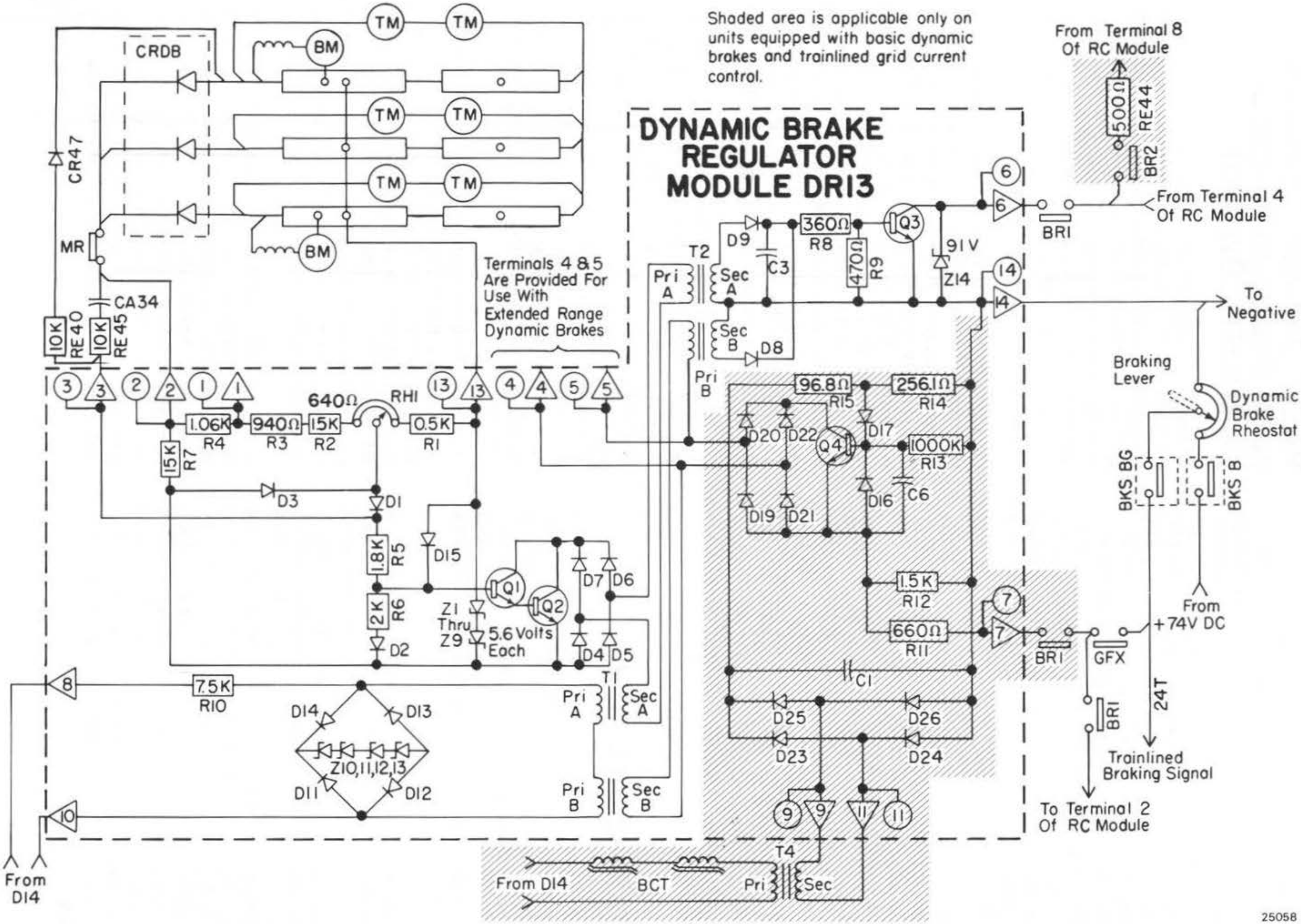


Fig.DR-2 - Dynamic Brake Regulator Module DR, Simplified Schematic Diagram
(Six-Axle Locomotives With Basic Dynamic Brakes)

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 BR2 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.

ANTICIPATION CIRCUIT

An additional function of the DR module is to produce smooth braking by providing a slow buildup of the braking effort. Grid current buildup is controlled through the operation of the "anticipatory" circuit, made up of capacitor CA34 and resitor RE45, which is connected to DR module terminal 3.

Current flows through CA34 only when there is a change in voltage at the positive grid terminal. The amount of current flow is proportional to the rate of voltage increase (expressed in volts per second). A sudden increase in grid current causes a current flow through CA34, RE45, and through DR module resistors R5 and R6. This current flow and resulting voltage drop across R6 forward biases and turns on Q1 and Q2. The DR then operates to discharge the rate control capacitors on the RC module which decreases main generator field excitation and results in a decrease in braking grid current. On special order, additional capacitors may be applied in parallel with CA34 to obtain slower braking current buildup.

BASIC DYNAMIC BRAKES WITH TRAINLINED GRID CURRENT CONTROL

Dynamic braking grid current is limited to a value proportional to braking lever position on units equipped for basic dynamic brakes with trainlined grid current control. A description of this system is provided in the following paragraphs. The description provided for basic dynamic brakes is applicable to this system, but is used only as a backup protection.

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 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

EXTENDED RANGE DYNAMIC BRAKES

Voltage signals proportional to current from terminal 1 to terminal 2 and from terminal 3 to terminal 2 of grid B on four-axle locomotives equipped with extended range dynamic brakes, Fig. DR-3, or voltage signals proportional to current from terminal 1 to terminal 2 of grid B, from terminal 3 to terminal 2 of grid B, and from terminal 1 to terminal 2 of grid F on six-axle locomotives equipped with extended range dynamic brakes, Fig. DR-4, are applied to a highest detector CRDB. The larger of these signals is applied between receptacles 2 and 13 of the DR module.

The signal applied between terminals 13 and 2 is used to limit dynamic braking grid current to a maximum value of 700 amperes. Refer to description of basic dynamic brakes for this limiting action and for operation of the anticipation circuit consisting of RE45 and CA34.

The DR module limits maximum dynamic braking grid current to 700 amperes on units equipped with basic dynamic brakes and on units equipped with extended range dynamic brakes. However, when operating units equipped with extended range dynamic brakes below approximately 24 miles per hour on units with 0.86 ohm braking grids, the DR module in conjunction with the DE module limits braking grid current to a value proportional to the braking lever position.

A signal proportional to dynamic braking grid current is applied to the DE module. Another signal, the braking lever signal, which is proportional to braking lever position is also applied to the DE module. A comparison circuit on the DE module compares the dynamic braking grid current signal to the braking lever signal. A solid state switch on the DE module turns on if the braking grid 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. The DP1A relay picks up when using dynamic brakes below approximately 24 miles per hour on units with 0.86 ohm grids. Therefore, turn on of the solid state switch on the DE module results in connecting terminal 4 to terminal 5 on the DR module and permits current flow through transformer T1-B secondary and T2-B primary on the DR module.

The output of T2-B secondary is rectified and applied to a voltage divider consisting of R8 and R9. The voltage developed across R9 provides forward bias for Q3 on the DR module. 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 current 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 when operating below approximately 24 miles per hour on units with 0.86 ohm grids, or 19 miles per hour on units with 0.66 ohm grids, is the same as that provided in the description of basic dynamic brakes with trainlined grid current control.

EXTENDED RANGE DYNAMIC BRAKES WITH FULL TIME TRAINLINED GRID CURRENT CONTROL

The description provided for extended range dynamic brakes is applicable to this braking system, with one exception.

With the extended range dynamic braking system, the maximum value of dynamic braking grid current is limited to a value proportional to braking lever signal when operating below approximately 24 miles per hour on units with 0.86 ohm grids. With the extended range dynamic braking system with full time trainlined grid current control, the maximum value of dynamic braking grid current is limited to a value proportional to braking lever signal at all track speeds. This is accomplished by using a conductor to bypass the DP1A contacts between terminal 4 of the DR module and terminal 4 of the DE module. Use a second conductor to bypass the DP1A contacts between RE44 and BR2 contacts.

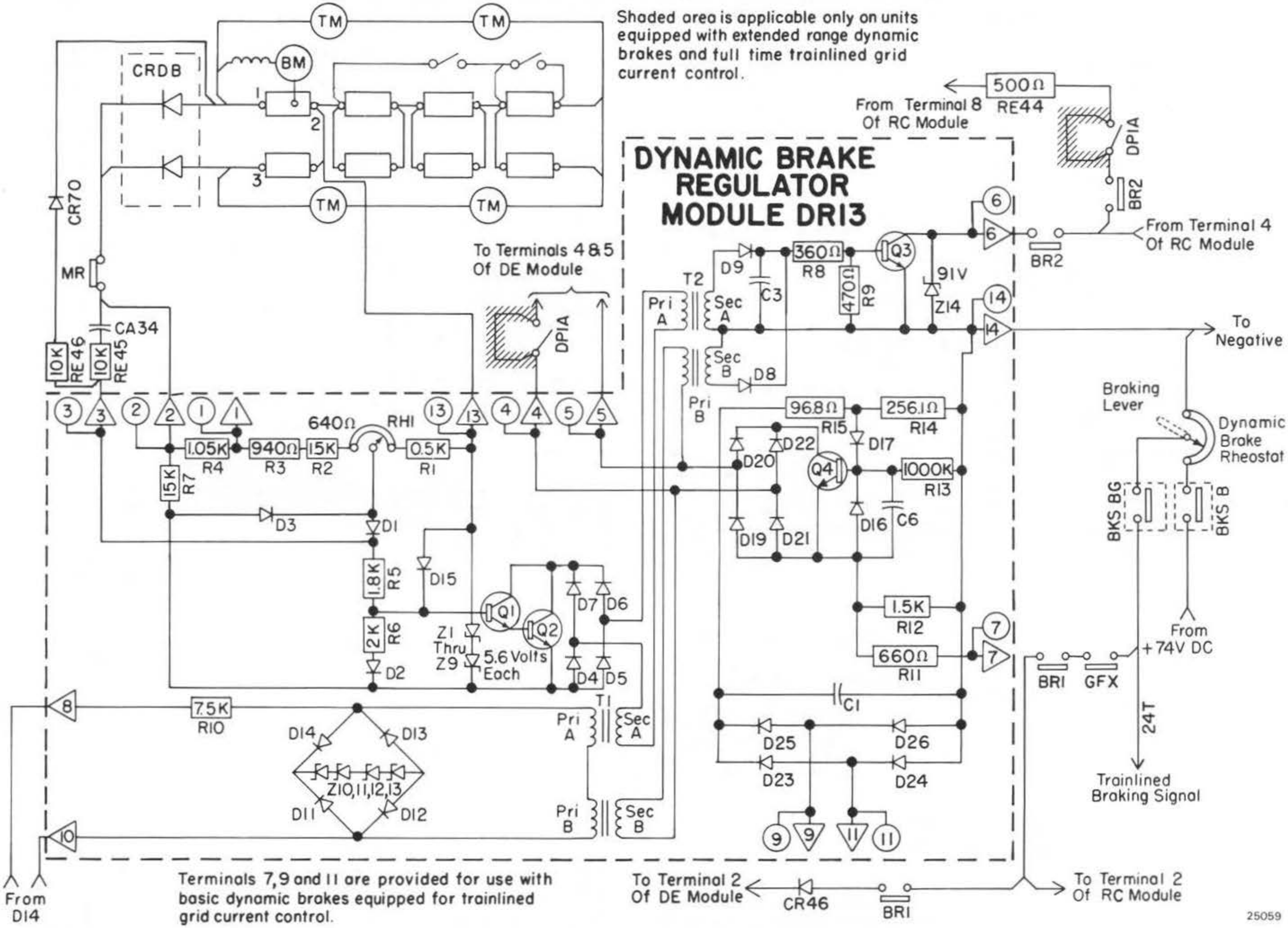


Fig.DR-3 – Dynamic Brake Regulator Module DR, Simplified Schematic Diagram
(Four Axle Locomotives With Extended Range Dynamic Brakes)

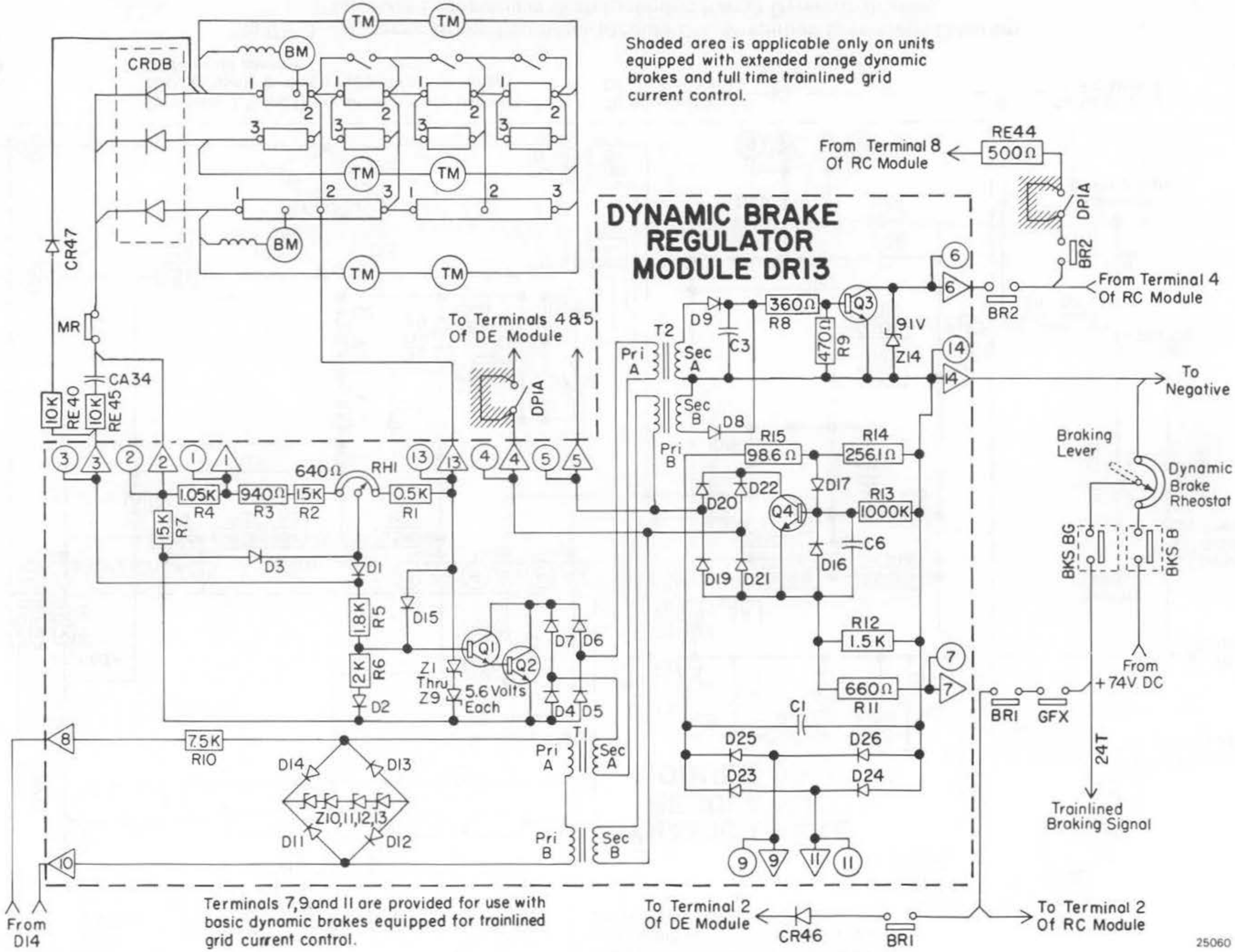


Fig.DR-4 - Dynamic Brake Regulator Module DR, Simplified Schematic Diagram (Six-Axle Locomotives With Extended Range Dynamic Brakes)

TWO SPEED DYNAMIC BRAKE REGULATOR MODULE DR20

INTRODUCTION

The dynamic brake regulator module DR20 is used on locomotives equipped to operate at idle engine speed when operating at lower levels of field current (below 800 amperes) and grid current (below 575 amperes). The traction motor cooling air is sufficient at these lower values of field current and grid current. Additional traction motor cooling air is required if field current rises above about 800 amperes or if grid current rises above about 575 amperes. The increased cooling is provided by automatically increasing the engine to throttle 4 speed.

A signal proportional to braking grid current is applied to receptacles 5, 6, and 7 of the DR module, Fig. DR-1. The signal from receptacles 5, 6, and 7 is applied to the grid current feedback circuit. The grid current feedback signal I_G FB output from the grid current feedback circuit has a ratio of 100 A/V. This I_G FB signal is applied to the grid current regulation and RC module discharge comparator where it is compared with the grid current reference voltage I_G Ref. If the I_G FB signal rises above the I_G Ref signal, the grid current regulation and RC discharge comparator provides forward bias for opto-isolator OI-1. Turn on of OI-1 results in discharging the RC module capacitors as necessary to limit I_G FB to I_G Ref value.

The I_G FB 100 A/V signal is also applied to a comparator where it is compared with a +5.75 VDC bias signal. If grid current rises above 575 amperes, a signal will be applied to the engine speed control amplifier and time delay drop out circuit. This circuit provides a governor control enable signal to the governor solenoid drive circuit. A +74 VDC signal 21T from receptacle 3 is applied through the governor solenoid drive circuit to receptacle 2, then to governor solenoids A and C which increases the engine to throttle 4 speed. The time delay circuit is used to keep the engine at throttle 4 speed for at least 60 seconds after grid current decreases below 575 amperes.

The dynamic brake control signal (24T signal) is applied to receptacle 12. The signal from receptacle 12 is applied to the 24T trainline voltage reference function generator to obtain a V24T Ref signal. Traction motor field current is proportional to the V24T Ref signal. The V24T Ref signal is applied to a comparator where it is compared with a +5.75 VDC bias signal. If field current rises above 800 amperes, a signal will be applied to the engine speed control amplifier and time delay drop out circuit. This circuit provides a governor control enable signal to the governor solenoid drive circuit. A +74 VDC signal 21T from receptacle 3 is applied through the governor solenoid drive circuit to receptacle 2, then to governor solenoids A and C which increases the engine to throttle 4 speed. Therefore, an increase of field current above 800 amperes or an increase of grid current above 575 amperes results in throttle 4 engine speed.

The throttle 4 engine speed signal from the governor solenoid drive circuit is applied to the grid logic circuit where it is used to increase the grid current limit from 600 amperes to 700 amperes. The throttle 4 engine speed signal is also applied to the traction motor field current limit circuit where it is used to remove the 825 ampere field current limit. Field current is then limited by action of the PF and SB modules or the FP module.

The load regulator is in maximum field position during dynamic brake operation. Therefore, the output at RC module terminal 13 is the load regulator reference signal which is compared with the main generator feedback signal. Therefore, during dynamic brake operation the traction motor field current feedback signal I_F FB is equal to the output signal at RC module terminal 13. This I_F FB signal is applied to receptacle 4. The signal from receptacle 4 is applied to the traction motor field current limit circuit. This circuit limits traction motor field current to 825 amperes when operating at idle engine speed. If field current tends to rise above 825 amperes, forward bias is applied to OI-1 which results in discharging the RC module capacitors as necessary to limit field current to 825 amperes. This 825 ampere limit is removed when operating at throttle 4 engine speed.

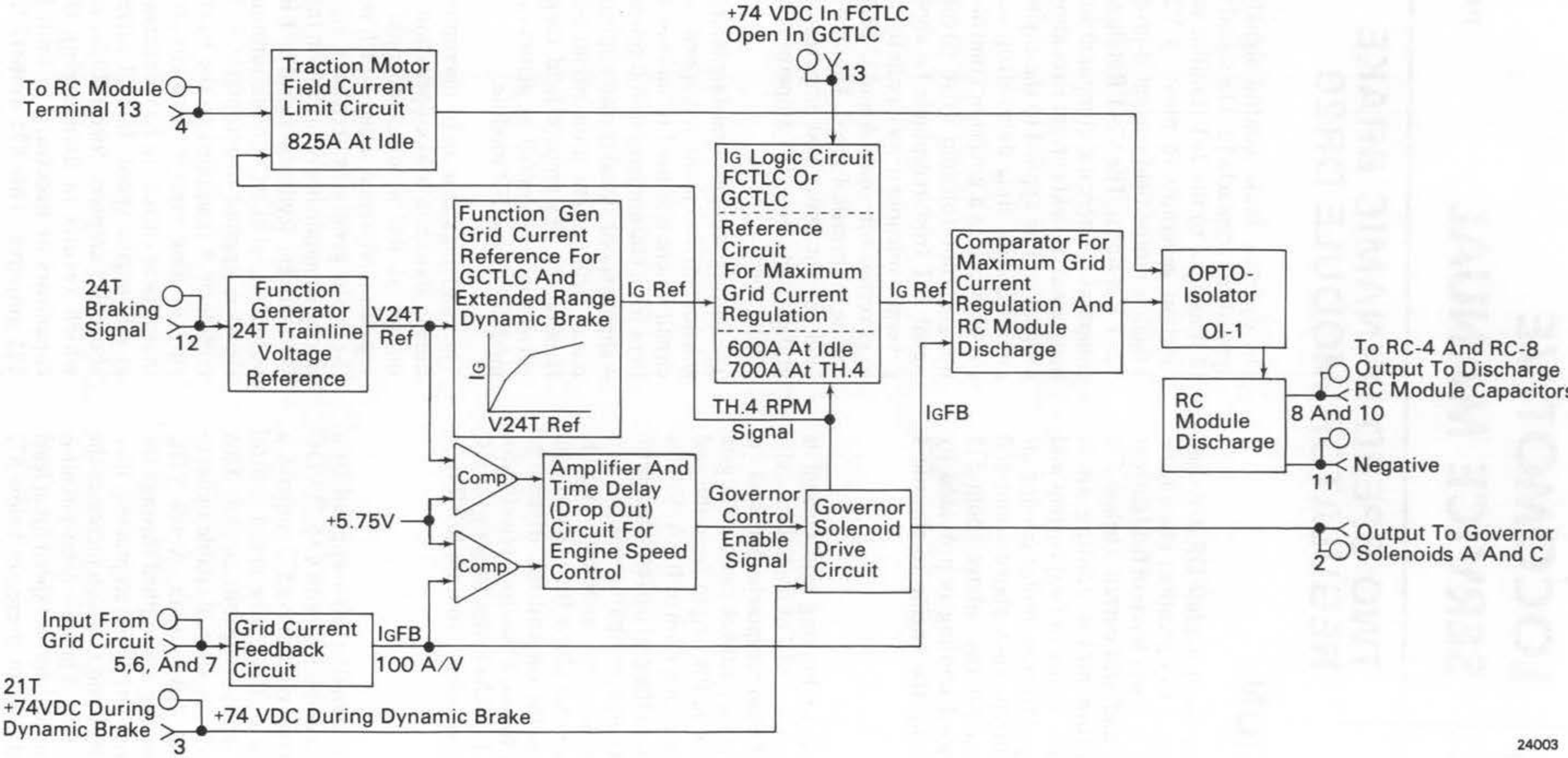


Fig.DR-1 – Dynamic Brake Regulator Module DR20,
Simplified Schematic Diagram

On units equipped with grid current trainlined control (receptacle 13 left open), the V24T Ref signal is applied to a function generator to obtain a grid current reference signal I_G Ref 100 A/V. This signal is applied to the grid current logic circuit where the I_G Ref signal is compared with a bias signal of +6 VDC when operating at idle engine speed. The bias signal is recalibrated to +7 VDC when operating at throttle 4 engine speed. If I_G Ref tends to rise above the bias signal, a signal is applied to the grid current regulation and RC module discharge comparator. This results in turn on of OI-1 which discharges the rate control capacitors as necessary to limit I_G Ref to a value equal to the bias signal. Therefore, when operating with GCTLC, grid current is controlled at a value proportional to the V24T Ref signal and is limited to 600 amperes at idle engine speed or to 700 amperes at throttle 4 engine speed.

OPERATION

±15 VDC POWER SUPPLY

The solid state components of the DR module require a ±15 VDC power source. A schematic diagram of the ±15 VDC power supply is provided in Fig. DR-2.

The 74 VDC control voltage is applied between receptacles 1 positive and 14 negative. The ±74 VDC voltage from receptacle 1 is applied through R1 and C1 to negative at receptacle 14. This resistor and capacitor prevents interchange of noise or short term spikes between the control voltage and the ±15 VDC power supply.

The filtered voltage across C1 is applied through R2, Z1, and Z2 to negative so that 15 VDC is developed across Z1 and across Z2. The junction of Z1 and Z2 is the common point of the ±15 VDC and the -15 VDC. Therefore, test point 19 is +15 VDC above common and receptacle 14 is -15 VDC below common. Capacitors are used to provide filtering and to improve regulation of the ±15 VDC power supply.

REFERENCE VOLTAGE CIRCUIT

Bias voltages of +5.75 VDC and +10 VDC are used at various points on the DR module. These bias voltages are obtained by using a differential amplifier and a voltage divider, Fig. DR-3. The stabilized +68 VDC from receptacle 10 of the throttle response module is applied to receptacle 9. The +68 VDC from receptacle 9 and the -15 VDC from the ±15 VDC power supply are applied to differential amplifier OP3. The gain of OP3 is designed to provide +10 VDC at OP3-2. This +10 VDC is applied through a voltage divider consisting of R7, R8, and R9 to common. The +5.75 VDC bias voltage is obtained at the junction of R7 and R8.

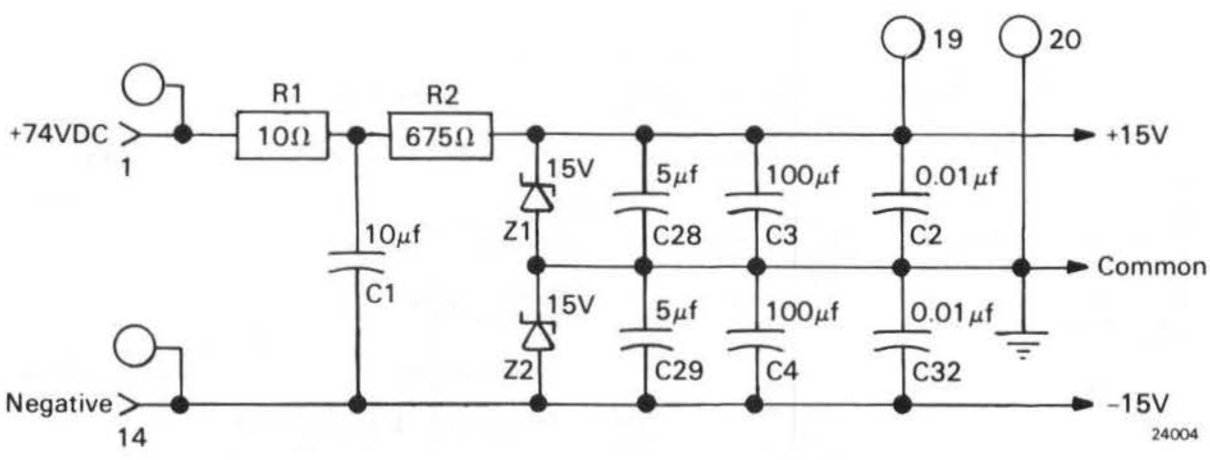


Fig.DR-2 - Power Supply, Simplified Schematic Diagram

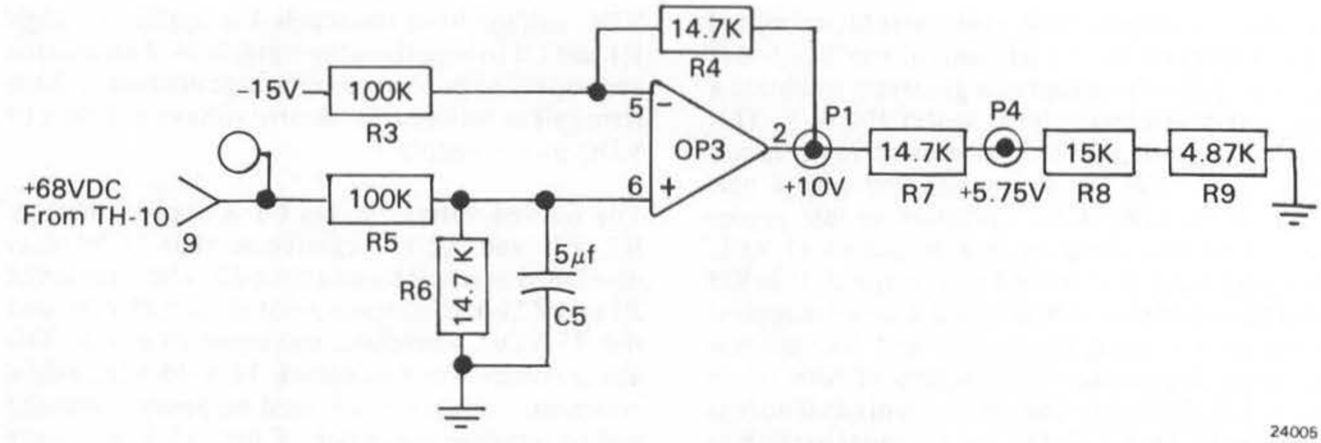


Fig.DR-3 - Reference Voltage Circuit, Simplified Schematic Diagram

GRID CURRENT FEEDBACK CIRCUIT

A voltage divider RE7, Fig. DR-4, is connected across a section of one dynamic braking grid. A small portion of the voltage developed across the voltage divider is applied to the DR module. The voltage developed across the voltage divider is proportional to grid current. Therefore, the signal applied to the DR module is also proportional to grid current.

The signal is applied to receptacles 6 positive and 5 negative. The positive signal is also applied through a capacitor to receptacle 7. The capacitor between positive and receptacle 7 results in a time delay in build up from minimum to maximum grid current. A 33 μF capacitor is used for 10 second anticipation or a 100 μF capacitor is used for 16 second anticipation. The 47 μF capacitor between positive and negative is used to stabilize or provide a short term average of the grid current signal.

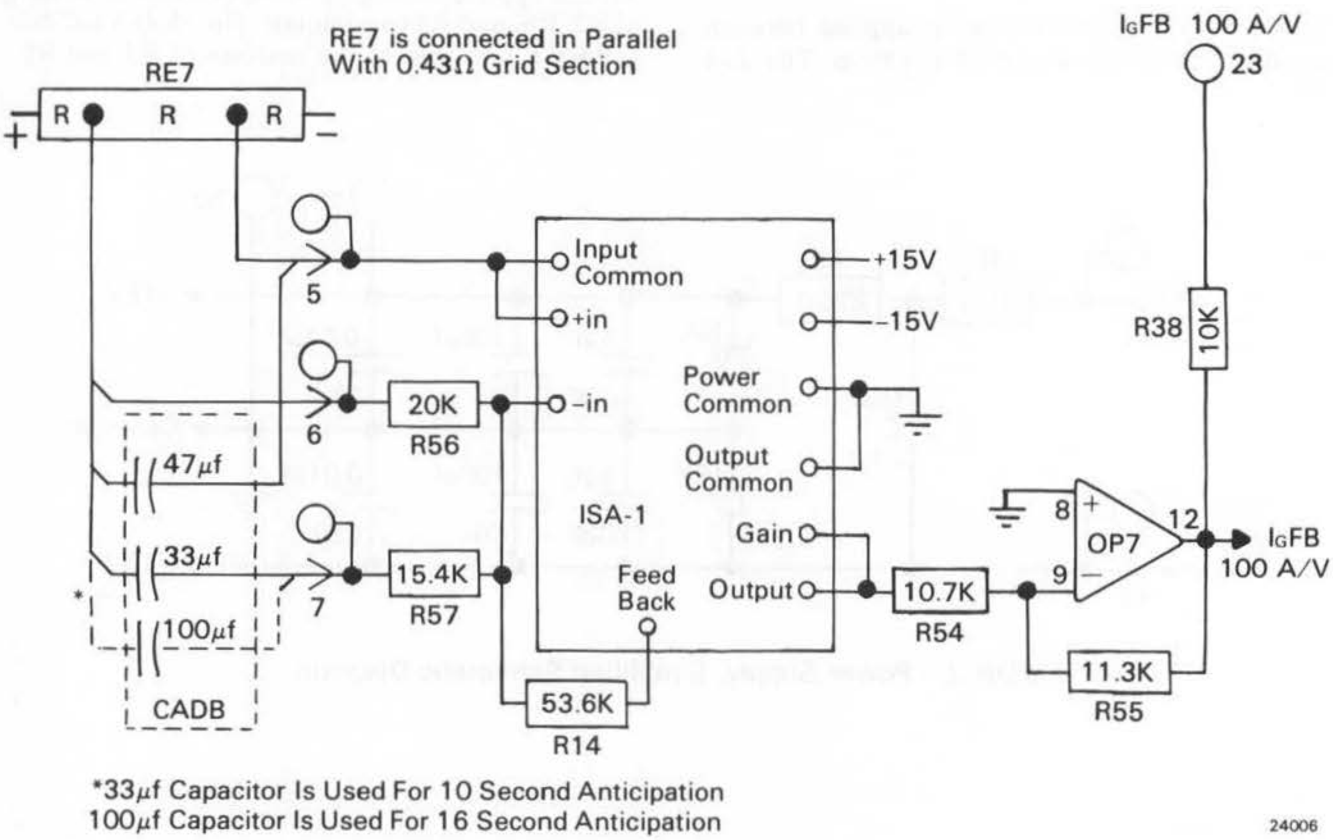


Fig.DR-4 - Grid Current Feedback Signal Circuit, Simplified Schematic Diagram

The negative signal from receptacle 5 is applied to the non-inverting and input common terminals of isolation amplifier ISA-1. The positive signal from receptacle 6 is applied through resistor R56 to the inverting terminal of ISA-1. The positive signal is also applied through a capacitor to receptacle 7 then through R57 to the inverting terminal of ISA-1. The initial gain of ISA-1, prior to charging the capacitor in series with R57, is R14/R57 or about 3.48. This gain decreases as the capacitor charges. The stabilized gain, after the capacitor is fully charged, is R14/R56 or about 2.68.

The negative output signal from ISA-1 is applied to inverting amplifier OP7. The gain of ISA-1 and OP7 is designed to provide a grid current feedback signal I_G FB having a ratio of 100A/V when operating under stabilized conditions. Therefore, grid current is equal to the signal at test point 23 times 100A.

ENGINE SPEED CONTROL CIRCUIT

Traction motor field current is proportional to the braking signal (24T signal). Therefore, the field current reference signal is obtained by applying the positive 24T signal to receptacle 12, Fig. DR-5. The positive signal from receptacle 12 is applied to differential amplifier OP1 to obtain a 24T reference signal at OP1-2. The negative signal from OP1-2 is applied to inverting amplifier OP3 to obtain the traction motor field current reference signal I_F Ref at OP3-12.

The I_F Ref signal is applied to OP4B-8 where it is compared with a +5.75 VDC bias signal at OP4B-9. The +5.75 VDC bias signal is larger than the I_F Ref signal for all values of field current less than 800 amperes. This results in negative saturation at OP4B-12. However, if field current rises above 800 amperes, the I_F Ref signal at OP4B-8 will be larger than the +5.75 VDC bias signal at OP4B-9. This results in positive saturation at OP4B-12.

The grid current feedback signal I_G FB 100A/V from Fig. DR-4 is applied to OP4A-6, Fig. DR-5, where it is compared with a +5.75 VDC bias signal at OP4A-5. The +5.75 VDC bias signal is larger than the I_G FB signal for all values of grid current less than 575 amperes. This results in negative saturation at OP4A-2. However, if grid current rises above 575 amperes, the I_G FB signal at OP4A-6 will be larger than the +5.75 VDC bias signal at OP4A-5. This results in positive saturation at OP4A-2. Therefore, a grid current more than 575 amperes or a field current more than 800 amperes results in positive saturation at P6.

The positive saturation signal at P6 is applied through R32 to C18. The charge on C18 at OP5-8 is compared with a +5.75 VDC bias signal at OP5-9. The output at OP5-12 switches to positive saturation when the charge on C18 rises above +5.75 VDC.

The positive saturation signal from OP5-12 is applied through R34, Fig. DR-5, to the base of Q3, Fig. DR-6. Turn on of Q3 results in current flow from +74 VDC at receptacle 3 through R39, R36, R35, then through Q3 common. The voltage developed across R36 provides forward bias for Q4. Turn on of Q4 provides forward bias for Q5. Turn on of Q5 results in a positive signal at receptacle 2. The positive signal at receptacle 2 is applied to governor solenoids A and C. Energizing governor solenoids A and C results in throttle 4 engine speed. Therefore, a grid current above 575 amperes or a field current above 800 amperes results in increasing engine speed from idle to throttle 4 engine speed.

The positive signal at the output of Q5 is also applied through R47 and Z7 to -15 VDC. A +15 VDC signal is available at the junction of R47 and Z7 whenever the positive signal is applied to governor solenoids A and C. This +15 VDC signal is applied to Fig. DR-7 and is used for recalibrating the grid current and field current limits.

GRID CURRENT AND FIELD CURRENT LIMIT

The positive dynamic braking signal (24T signal) is applied to receptacle 12, Fig. DR-7. The signal from receptacle 12 is applied to differential amplifier OP1A to provide a negative V24T Ref signal at OP1A-2. The negative V24T Ref signal from OP1A-2 is applied to a function generator consisting of OP1B, Q1, Q2, and associated resistors. The output at P3 (OP1B-12) is the grid current reference signal I_G Ref during grid current trainline control operation. The gain of OP1A and OP1B is designed to provide an I_G Ref signal ratio of 100 A/V at P3.

During grid current trainline control GCTLC operation (no signal applied to receptacle 13) the I_G Ref signal from P3 is applied to OP2A-6. A +6 VDC bias is applied to OP8B-8 and a +7 VDC bias is applied to OP2B-8. A least detector is formed by OP2A, OP2B, OP8B, D11, D12, and D3. The output of this least detector at point "A" is equal to the least signal applied to OP2A-6, OP2B-8, or OP8B-8.

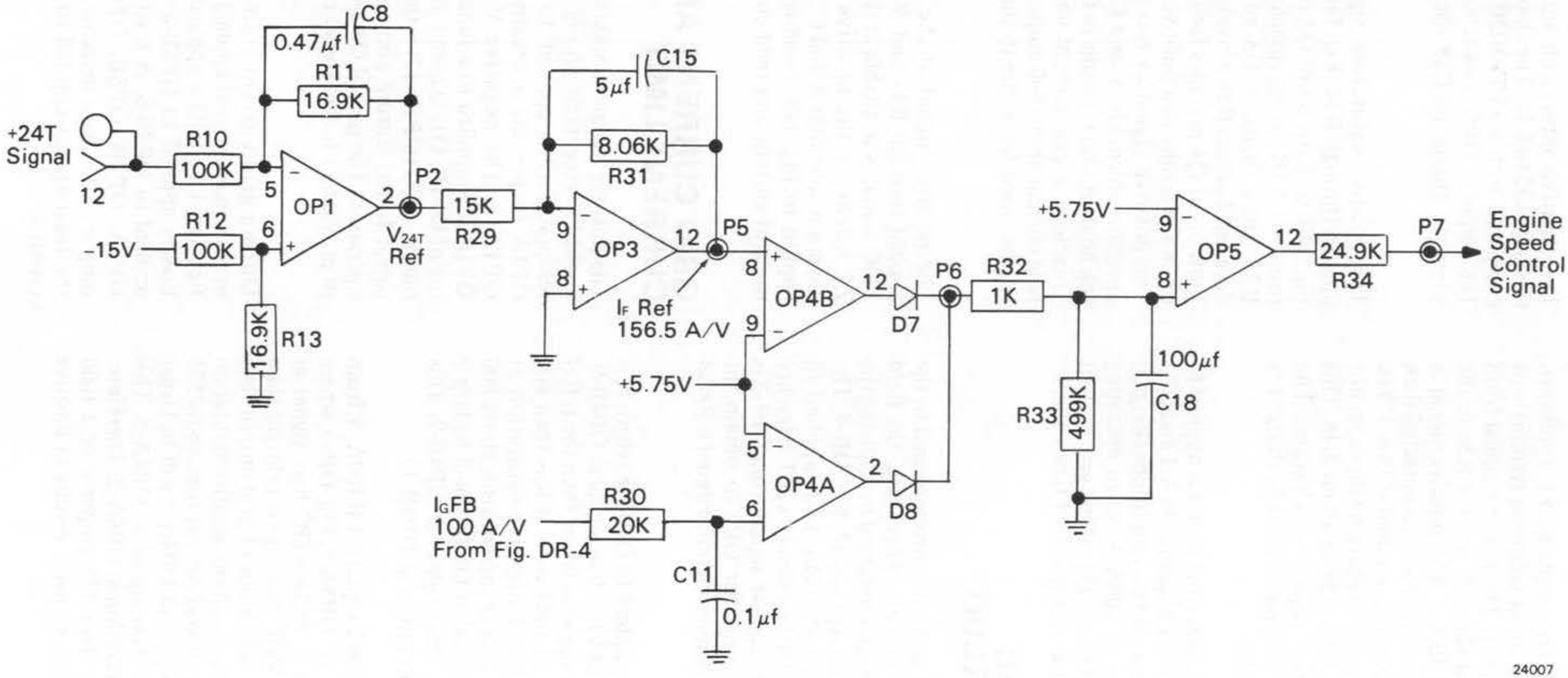


Fig.DR-5 – Engine Speed Control Signal Circuit, Simplified Schematic Diagram

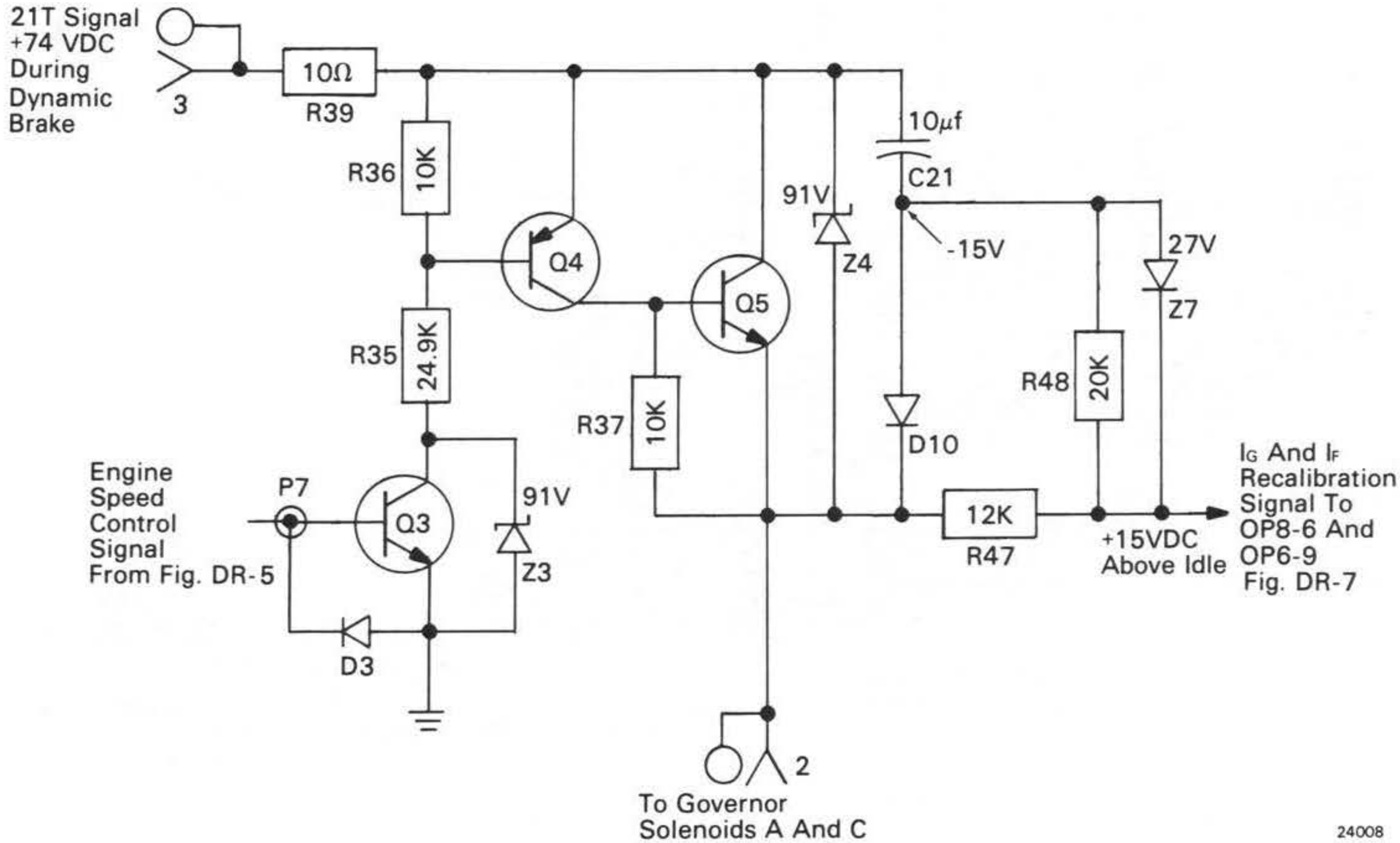


Fig.DR-6 – Engine Speed Control And Recalibration Signal Circuit, Simplified Schematic Diagram

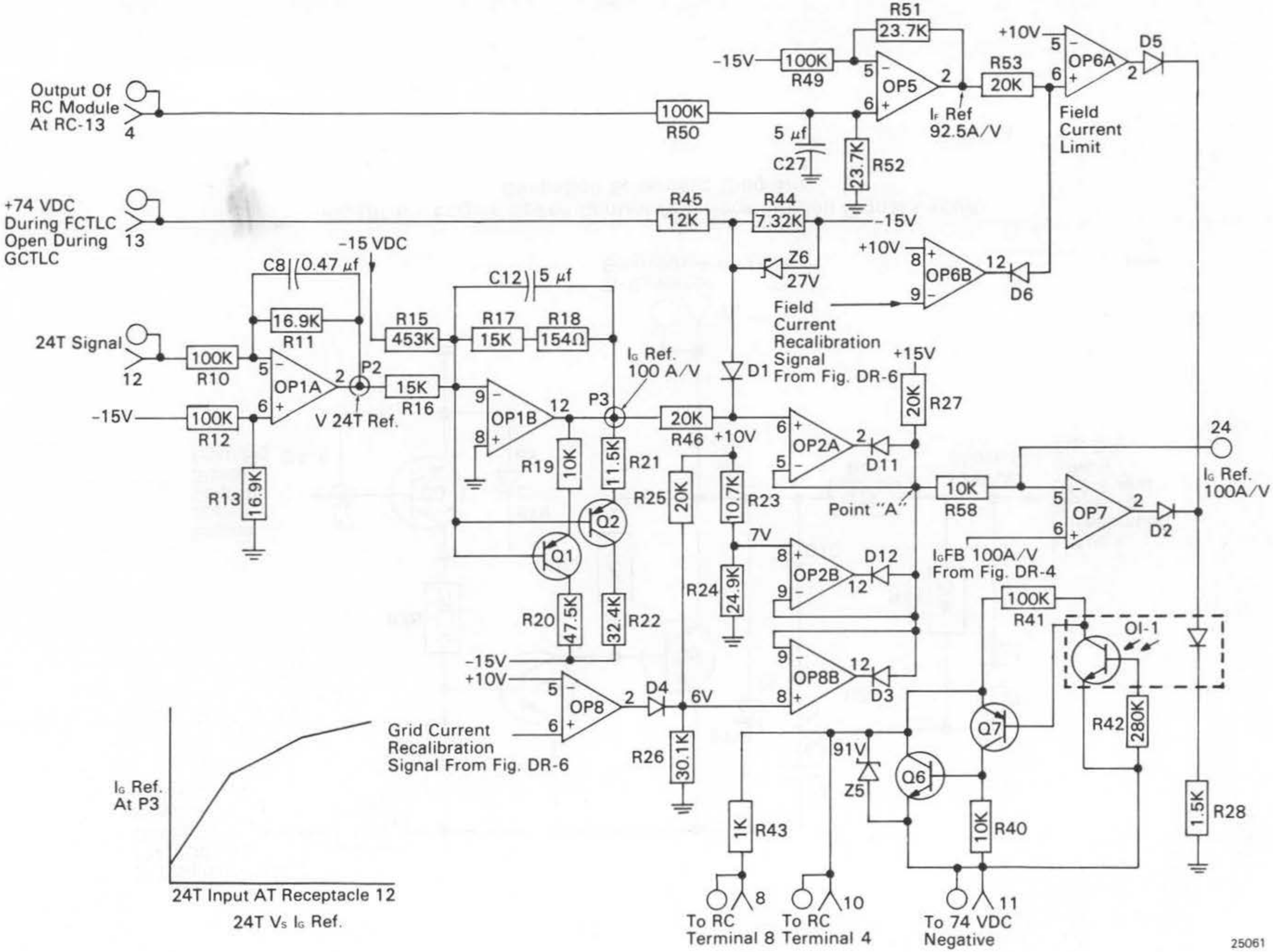


Fig.DR-7 – Grid Current And Field Current Limit Circuit, Simplified Schematic Diagram

The output signal from the least detector is applied to OP7-5 where it is compared with the grid current feedback signal I_G FB. The output of OP7-2 switches to positive saturation if I_G FB. The output of OP7-2 switches to positive saturation if I_G FB rises above I_G Ref signal at OP7-5. The positive signal at OP7-2 results in turn on of OI-1. Turn on of OI-1 provides forward bias for Q7. Turn on of Q7 provides forward bias for Q6. Turn on of Q6 discharges the rate control capacitors on the RC module. This results in a decrease of main generator excitation and a decrease in grid current. Therefore, grid current is controlled at a value proportional to I_G Ref.

The +6 VDC bias at OP8B-8 limits maximum grid current to 600 amperes when operating at idle engine speed. However, during throttle 4 engine speed, a +15 VDC grid current recalibration signal is applied to OP8-6. This results in positive saturation at OP8B-2. This allows maximum grid current to increase to 700 amperes as determined by the +7 VDC bias signal at OP2B-8. Therefore, during GCTLC operation grid current is controlled at a value proportional to the I_G Ref signal applied to OP2A-6, and is limited to 600 amperes when operating at idle speed, and limited to 700 amperes when operating at throttle 4 engine speed.

The load regulator is at maximum field position during dynamic brake operation. Therefore, the load regulator reference signal is equal to the output at receptacle 13 of the RC module. This signal is compared with the PF module feedback signal. The PF module feedback signal is proportional to traction motor field current during dynamic brake operation. Therefore, the output signal at receptacle 13 of the RC module is the field current reference signal.

The output from receptacle 13 of the RC module is applied to receptacle 4 of the DR module where it is then applied to 6 of differential amplifier OP5, Fig. DR-7. The gain of OP5 is designed to provide a field current reference signal I_F Ref output having a ratio of 82.5A/V. The I_F Ref output signal from OP5-2 is applied to OP6A-6 where it is compared with a +10 VDC bias signal at OP6A-5. The output at OP6A-2 switches to positive saturation if traction motor field current rises above 825 amperes. A positive output at OP6A-2 results in turn on of OI-1. Turn on of OI-1 results in discharge of the RC module rate control capacitors. Discharge of these capacitors results in a decrease of traction motor field current. Therefore, traction motor field current is limited to 825 amperes when operating at idle engine speed.

When operating at throttle 4 engine speed, a +15 VDC field current recalibration signal is applied to OP6B-9. This results in negative saturation at OP6B-12 which pulls OP6A-6 to negative and results in negative saturation at OP6A-2. The negative signal at OP6A-2 is blocked by D5. Therefore, the DR module does not limit traction motor field current when operating at throttle 4 engine speed. Traction motor field current is limited to about 975 amperes by the action of the PF and SB modules or the FP module when operating at throttle 4 engine speed.

During field current trainlined control FCTLC operation (+74 VDC applied to receptacle 13), a +15 VDC signal is applied to OP2A-6. This effectively nullifies the I_G Ref signal from P3. Therefore, grid current is not controlled by the I_G Ref signal during field current trainlined control operation. However, maximum grid current is still limited to 600 amperes when operating at idle engine speed and is limited to 700 amperes when operating at throttle 4 engine speed.

TWO SPEED DYNAMIC BRAKE REGULATOR MODULE DR21

INTRODUCTION

The dynamic brake regulator module DR21 is used on locomotives equipped to operate at idle engine speed when operating at lower levels of field current (below 800 amperes) and grid current (below 551 amperes). The traction motor cooling air is sufficient at these lower values of field current and grid current. Additional traction motor cooling air is required if field current rises above about 800 amperes or if grid current rises above about 551 amperes. The increased cooling is provided by automatically increasing the engine to throttle 4 speed.

A signal proportional to braking grid current is applied to receptacles 5, 6, and 7 of the DR module, Fig. DR-1. The signal from receptacles 5, 6, and 7 is applied to the grid current feedback circuit. The grid current feedback signal I_G FB output from the grid current feedback circuit has a ratio of 100 A/V. This I_G FB signal is applied to the grid current regulation and RC module discharge comparator where it is compared with the grid current reference voltage I_G Ref. If the I_G FB signal rises above the I_G Ref signal, the grid current regulation and RC discharge comparator provides forward bias for opto-isolator OI-1. Turn on of OI-1 results in discharging the RC module capacitors as necessary to limit I_G FB to I_G Ref value.

The I_G FB 100 A/V signal is also applied to a comparator where it is compared with a +5.51 VDC bias signal. If grid current rises above 551 amperes, a signal will be applied to the engine speed control amplifier and time delay drop out circuit. This circuit provides a governor control enable signal to the governor solenoid drive circuit. A +74 VDC signal 21T from receptacle 3 is applied through the governor solenoid drive circuit to receptacle 2, then to governor solenoids A and C which increases the engine to throttle 4 speed. The time delay circuit is used to keep the engine at throttle 4 speed for at least 60 seconds after grid current decreases below 551 amperes.

The dynamic brake control signal (24T signal) is applied to receptacle 12. The signal from receptacle 12 is applied to the 24T trainline voltage reference function generator to obtain a V24T Ref signal. Traction motor field current is proportional to the V24T Ref signal. The V24T Ref signal is applied to a comparator where it is compared with a +5.51 VDC bias signal. If field current rises above 800 amperes, a signal will be applied to the engine speed control amplifier and time delay drop out circuit. This circuit provides a governor control enable signal to the governor solenoid drive circuit. A +74 VDC signal 21T from receptacle 3 is applied through the governor solenoid drive circuit to receptacle 2, then to governor solenoids A and C which increases the engine to throttle 4 speed. Therefore, an increase of field current above 800 amperes or an increase of grid current above 551 amperes results in throttle 4 engine speed.

The throttle 4 engine speed signal from the governor solenoid drive circuit is applied to the grid logic circuit where it is used to increase the grid current limit from 577 amperes to 700 amperes. The throttle 4 engine speed signal is also applied to the traction motor field current limit circuit where it is used to remove the 825 ampere field current limit. Field current is then limited by action of the PF and SB modules or the FP module.

The load regulator is in maximum field position during dynamic brake operation. Therefore, the output at RC module terminal 13 is the load regulator reference signal which is compared with the main generator feedback signal. Therefore, during dynamic brake operation the traction motor field current feedback signal I_F FB is equal to the output signal at RC module terminal 13. This I_F FB signal is applied to receptacle 4. The signal from receptacle 4 is applied to the traction motor field current limit circuit. This circuit limits traction motor field current to 825 amperes when operating at idle engine speed. If field current tends to rise above 825 amperes, forward bias is applied to OI-1 which results in discharging the RC module capacitors as necessary to limit field current to 825 amperes. This 825 ampere limit is removed when operating at throttle 4 engine speed.

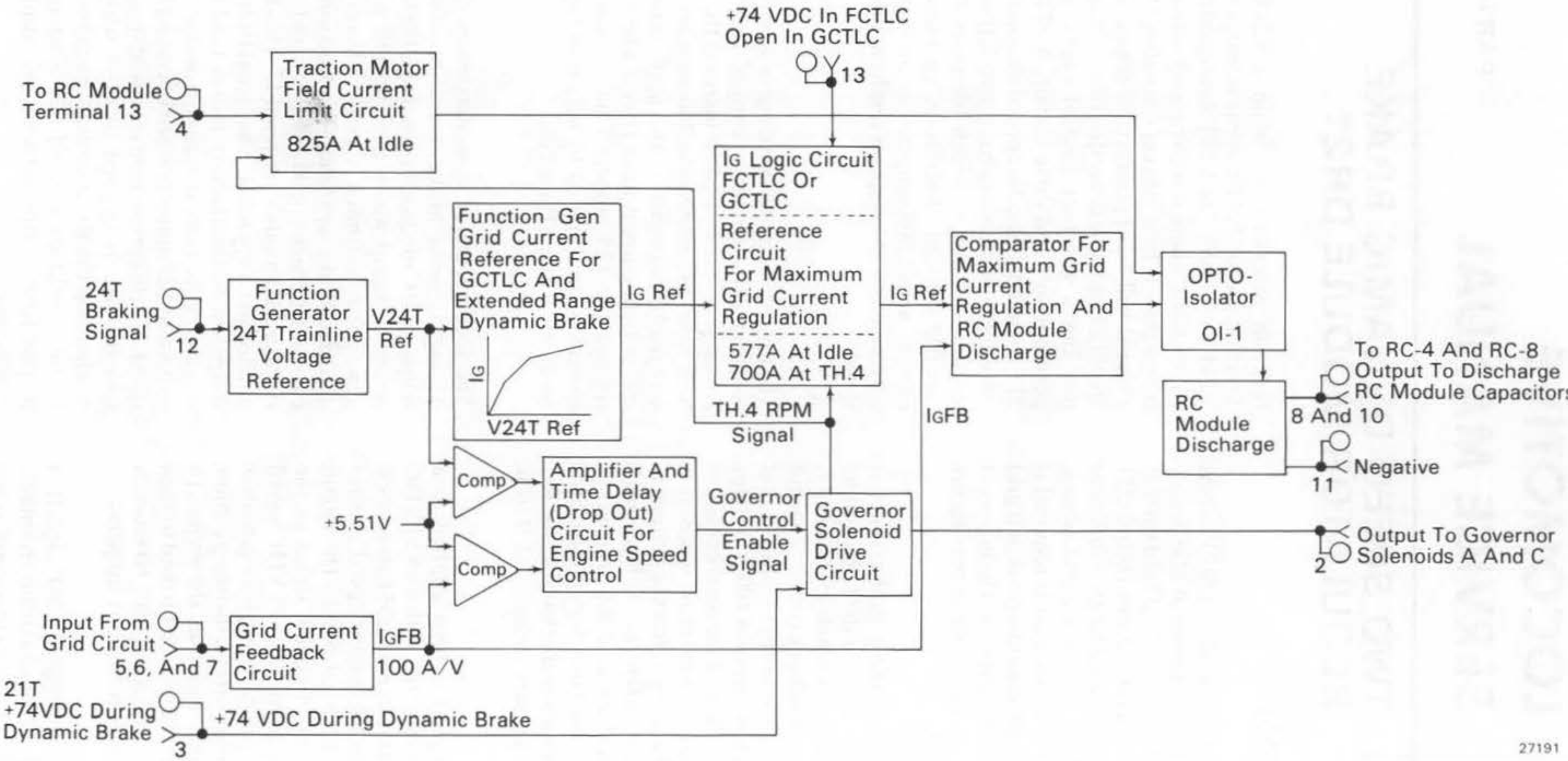


Fig.DR-1 – Dynamic Brake Regulator Module DR21, Simplified Schematic Diagram

On units equipped with grid current trainlined control (receptacle 13 left open), the V24T Ref signal is applied to a function generator to obtain a grid current reference signal I_G Ref 100 A/V. This signal is applied to the grid current logic circuit where the I_G Ref signal is compared with a bias signal of +6 VDC when operating at idle engine speed. The bias signal is recalibrated to +7 VDC when operating at throttle 4 engine speed. If I_G Ref tends to rise above the bias signal, a signal is applied to the grid current regulation and RC module discharge comparator. This results in turn on of OI-1 which discharges the rate control capacitors as necessary to limit I_G Ref to a value equal to the bias signal. Therefore, when operating with GCTLC, grid current is controlled at a value proportional to the V24T Ref signal and is limited to 577 amperes at idle engine speed or to 700 amperes at throttle 4 engine speed.

OPERATION

±15 VDC POWER SUPPLY

The solid state components of the DR module require a ±15 VDC power source. A schematic diagram of the ±15 VDC power supply is provided in Fig. DR-2.

The 74 VDC control voltage is applied between receptacles 1 positive and 14 negative. The ±74 VDC voltage from receptacle 1 is applied through R1 and C1 to negative at receptacle 14. This resistor and capacitor prevents interchange of noise or short term spikes between the control voltage and the ±15 VDC power supply.

The filtered voltage across C1 is applied through R2, Z1, and Z2 to negative so that 15 VDC is developed across Z1 and across Z2. The junction of Z1 and Z2 is the common point of the ±15 VDC and the -15 VDC. Therefore, test point 19 is +15 VDC above common and receptacle 14 is -15 VDC below common. Capacitors are used to provide filtering and to improve regulation of the ±15 VDC power supply.

REFERENCE VOLTAGE CIRCUIT

Bias voltages of +5.51 VDC and +10 VDC are used at various points on the DR module. These bias voltages are obtained by using a differential amplifier and a voltage divider, Fig. DR-3. The stabilized +68 VDC from receptacle 10 of the throttle response module is applied to receptacle 9. The +68 VDC from receptacle 9 and the -15 VDC from the ±15 VDC power supply are applied to differential amplifier OP3. The gain of OP3 is designed to provide +10 VDC at OP3-2. This +10 VDC is applied through a voltage divider consisting of R7, R8, and R9 to common. The +5.51 VDC bias voltage is obtained at the junction of R7 and R8.

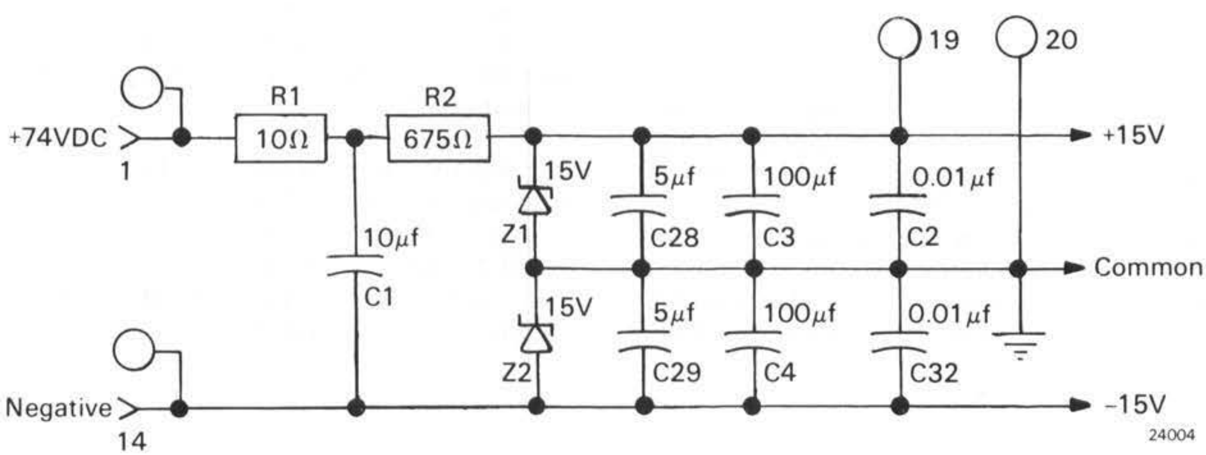


Fig.DR-2 - Power Supply, Simplified Schematic Diagram

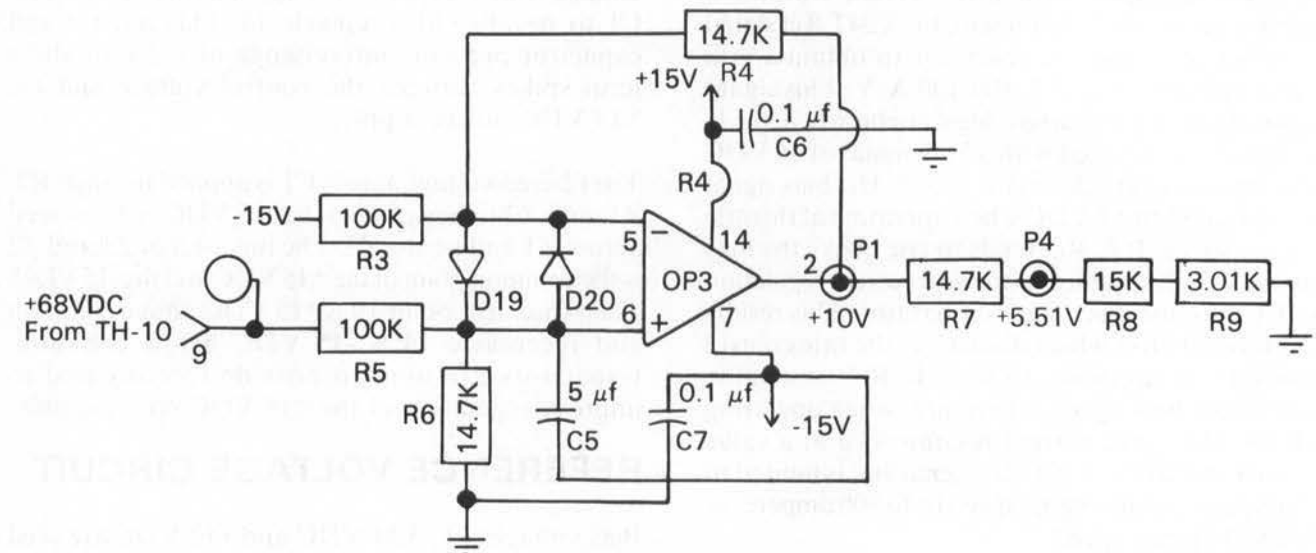


Fig.DR-3 - Reference Voltage Circuit, Simplified Schematic Diagram

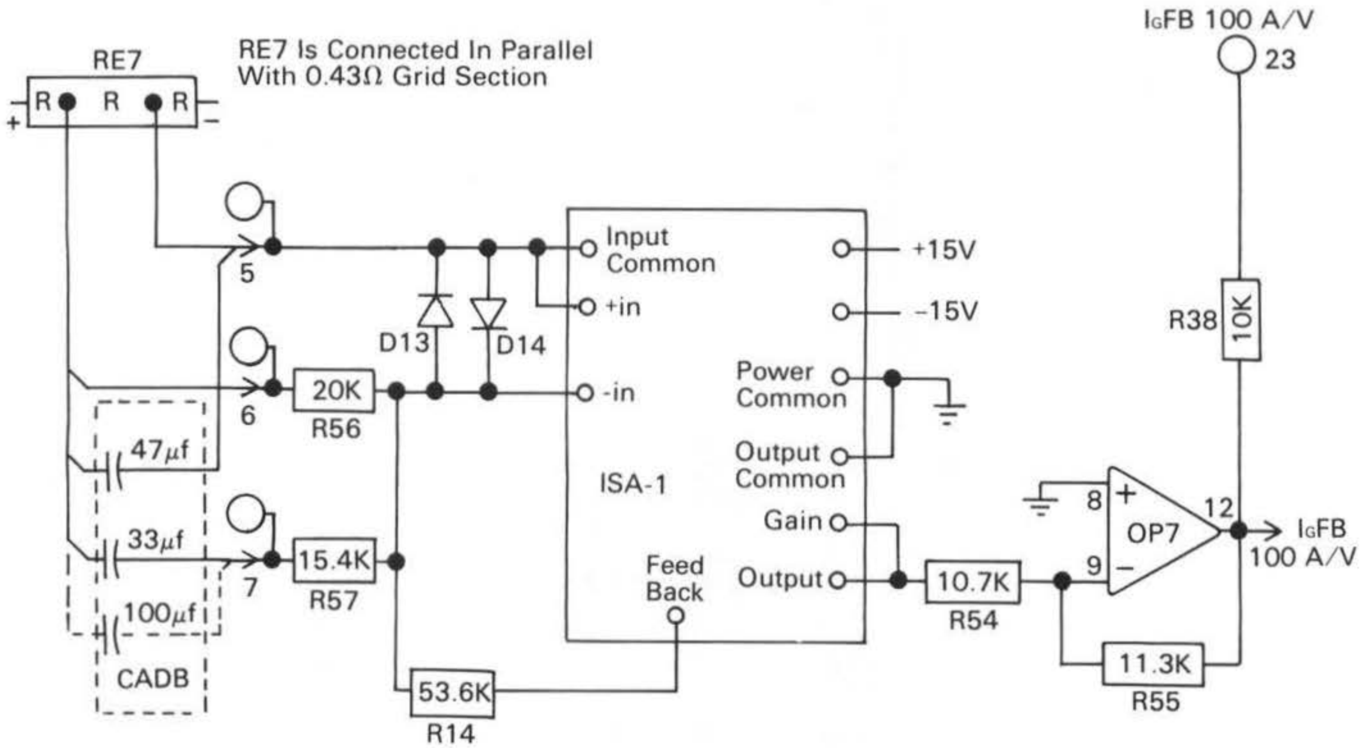
GRID CURRENT FEEDBACK CIRCUIT

A voltage divider RE7, Fig. DR-4, is connected across a section of one dynamic braking grid. A small portion of the voltage developed across the voltage divider is applied to the DR module. The voltage developed across the voltage divider is proportional to grid current. Therefore, the signal applied to the DR module is also proportional to grid current.

The signal is applied to receptacles 6 positive and 5 negative. The positive signal is also applied through a capacitor to receptacle 7. The capacitor between positive and receptacle 7 results in a time delay in buildup from minimum to maximum grid current. A 33 μF capacitor is used for 10 second anticipation or a 100 μF capacitor is used for 16 second anticipation. The 47 μF capacitor between positive and negative is used to stabilize or provide a short term average of the grid current signal.

The negative signal from receptacle 5 is applied to the non-inverting and input common terminals to isolation amplifier ISA-1. The positive signal from receptacle 6 is applied through resistor R56 to the inverting terminal of ISA-1. The positive signal is also applied through a capacitor to receptacle 7 then through R57 to the inverting terminal of ISA-1. The initial gain of ISA-1, prior to charging the capacitor in series with R57, is R14/R57 or about 3.48. This gain decreases as the capacitor charges. The stabilized gain, after the capacitor is fully charged, is R14/R56 or about 2.68.

The negative output signal from ISA-1 is applied to inverting amplifier OP7. The gain of ISA-1 and OP7 is designed to provide a grid current feedback signal I_G FB having a ratio of 100A/V when operating under stabilized conditions. Therefore, grid current is equal to the signal at test point 23 times 100A.



*33μf Capacitor Is Used For 10 Second Anticipation
100μf Capacitor Is Used For 16 Second Anticipation

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Fig.DR-4 – Grid Current Feedback Signal Circuit,
Simplified Schematic Diagram

ENGINE SPEED CONTROL CIRCUIT

Traction motor field current is proportional to the braking signal (24T signal). Therefore, the field current reference signal is obtained by applying the positive 24T signal to receptacle 12, Fig. DR-5. The positive signal from receptacle 12 is applied to differential amplifier OP1 to obtain a 24T reference signal at OP1-2. The negative signal from OP1-2 is applied to inverting amplifier OP3 to obtain the traction motor field current reference signal I_F Ref at OP3-12.

The I_F Ref signal is applied to OP4B-8 where it is compared with a +5.51 VDC bias signal at OP4B-9. The +5.51 VDC bias signal is larger than the I_F Ref signal for all values of field current less than 800 amperes. This results in negative saturation at OP4B-12. However, if field current rises above 800 amperes, the I_F Ref signal at OP4B-8 will be larger than the +5.51 VDC bias signal at OP4B-9. This results in positive saturation at OP4B-12.

The grid current feedback signal I_G FB 100A/V from Fig. DR-4 is applied to OP4A-6, Fig. DR-5, where it is compared with a +5.51 VDC bias signal at OP4A-5. The +5.51 VDC bias signal is larger than the I_G FB signal for all values of grid current less than 551 amperes. This results in negative saturation at OP4A-2. However, if grid current rises above 551 amperes, the I_G FB signal at OP4A-6 will be larger than the +5.51 VDC bias signal at OP4A-5. This results in positive saturation at OP4A-2. Therefore, a grid current more than 551 amperes or a field current more than 800 amperes results in positive saturation at P6.

The positive saturation signal at P6 is applied through R32 to C18. The charge on C18 at OP5-8 is compared with a +5.51 VDC bias signal at OP5-9. The output at OP5-12 switches to positive saturation when the charge on C18 rises above +5.51 VDC.

The positive saturation signal from OP5-12 is applied through R34, Fig. DR-5, to the base of Q3, Fig. DR-6. Turn on of Q3 results in current flow from +74 VDC at receptacle 3 through R39, R36, R35, then through Q3 to common. The voltage dropped across R36 provides forward bias for Q4. Turn on of Q4 provides forward bias for Q5. Turn on of Q5 results in a positive signal at receptacle 2. The positive signal at receptacle 2 is applied to governor solenoids A and C. Energizing governor solenoids A and C results in throttle 4 engine speed. Therefore, grid current above 551 amperes or field current above 800 amperes results in increasing engine speed from idle to throttle 4 engine speed.

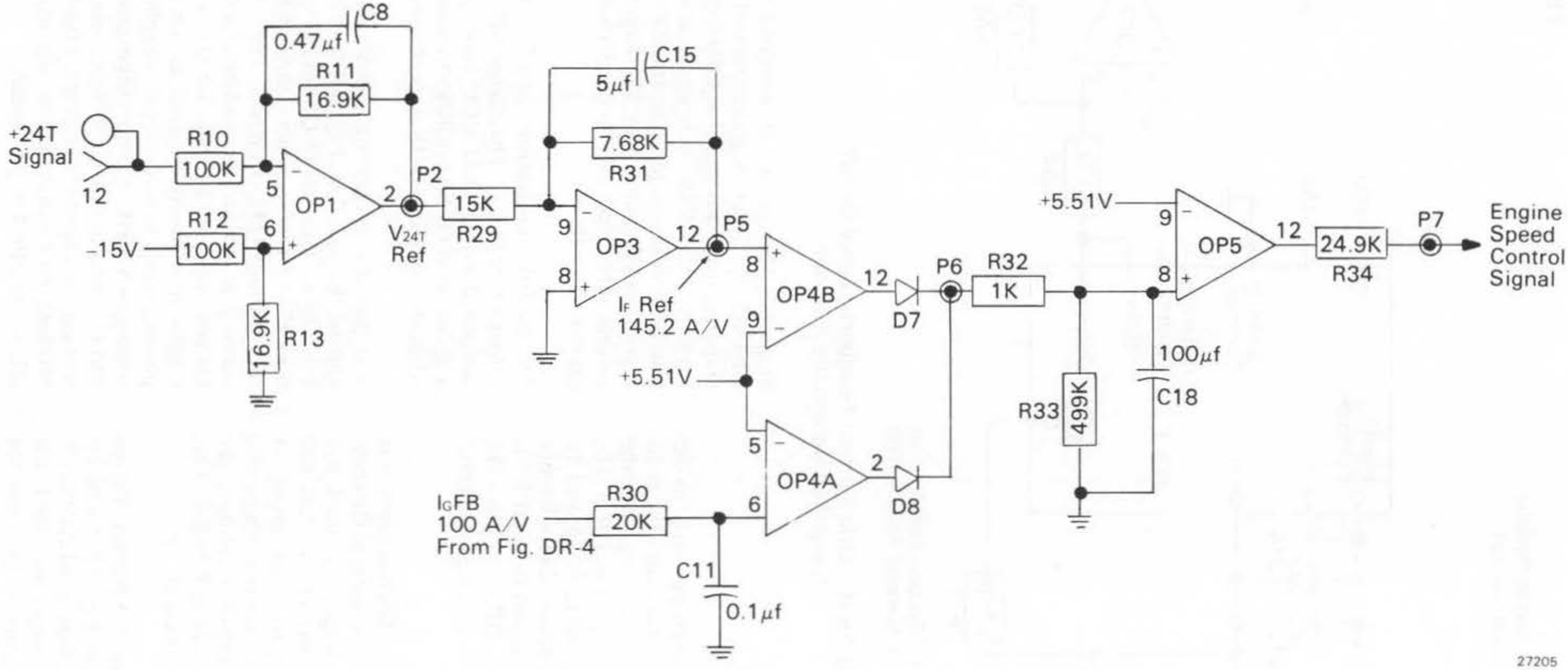


Fig.DR-5 – Engine Speed Control Signal Circuit,
Simplified Schematic Diagram

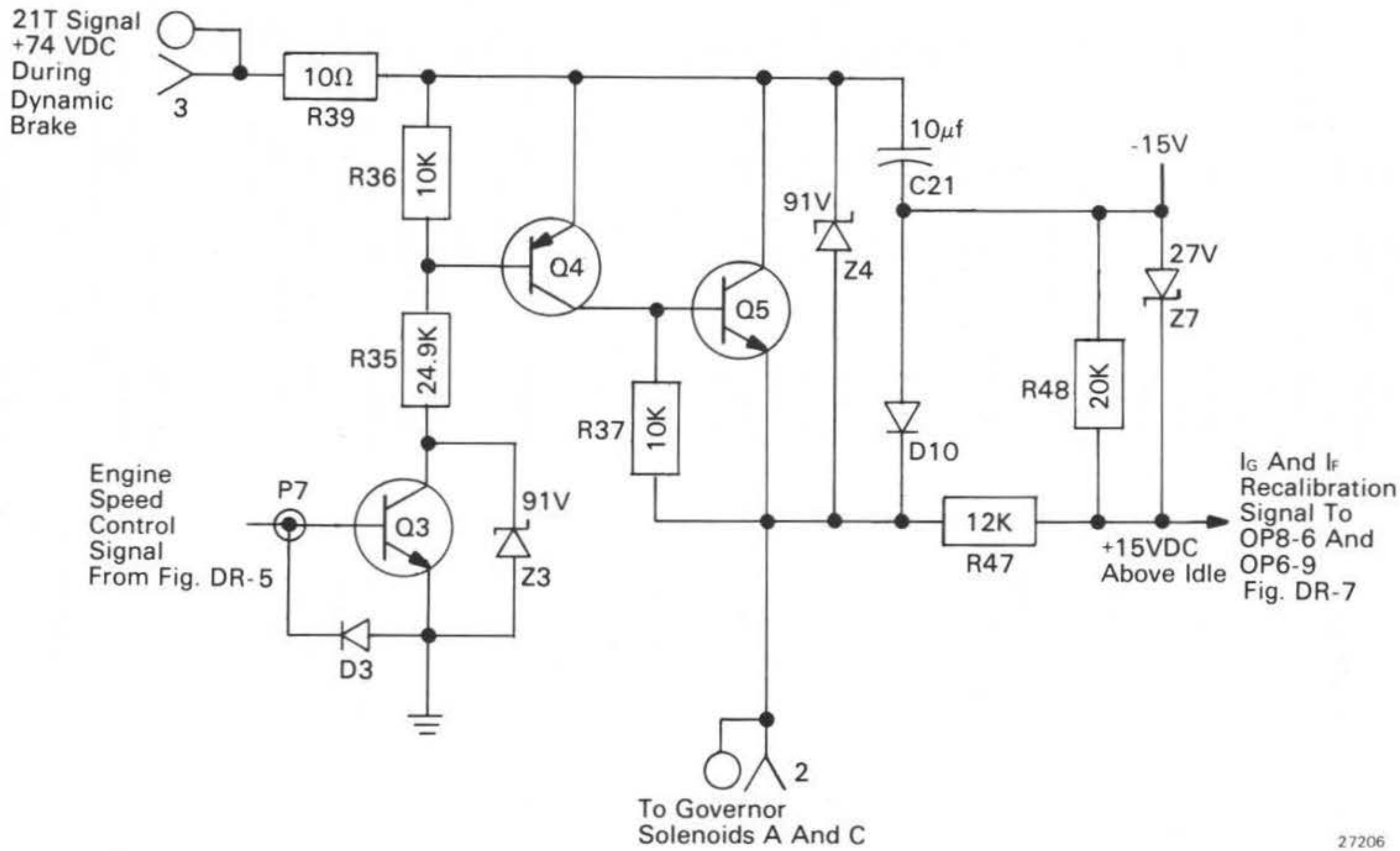


Fig.DR-6 – Engine Speed Control And Recalibration Signal Circuit, Simplified Schematic Diagram

The positive signal at the output of Q5 is also applied through R47 and Z7 to -15 VDC. A +15 VDC signal is available at the junction of R47 and Z7 whenever the positive signal is applied to governor solenoids A and C. This +15 VDC signal is applied to Fig. DR-7 and is used for recalibrating the grid current and field current limits.

GRID CURRENT AND FIELD CURRENT LIMIT

The positive dynamic braking signal (24T signal) is applied to receptacle 12, Fig. DR-7. The signal from receptacle 12 is applied to differential amplifier OP1A to provide a negative V24T Ref signal at OP1A-2. The negative V24T Ref signal from OP1A-2 is applied to a function generator consisting of OP1B, Q1, Q2, and associated resistors. The output at P3 (OP1B-12) is the grid current reference signal I_G Ref during grid current trainline control operation. The gain of OP1A and OP1B is designed to provide an I_G Ref signal ratio of 100A/V at P3.

During grid current trainline control GCTLC operation (no signal applied to receptacle 13) the I_G Ref signal from P3 is applied to OP2A-6. A +6 VDC bias is applied to OP8B-8 and a +7 VDC bias is aplied to OP2B-8. A least detector is formed by OP2A, OP2B, OP8B, D11, D12, and D3. The output of this least detector at point "A" is equal to the least signal applied to OP2A-6, OP2B-8, or OP8B-8.

The output signal from the least detector is applied to OP7-5 where it is compared with the grid current feedback signal I_G FB. The output of OP7-2 switches to positive saturation if I_G FB rises above I_G Ref signal at OP7-5. The positive signal at OP7-2 results in turn on of OI-1. Turn on of OI-1 provides forward bias for Q7. Turn on of Q7 provides forward bias for Q6. Turn on of Q6 discharges the rate control capacitors on the RC module. This results in a decrease of main generator excitation and a decrease in grid current. Therefore, grid current is controlled at a value proportional to I_G Ref.

The +5.77 VDC bias at OP8B-8 limits maximum grid current to 577 amperes when operating at idle engine speed. However, during throttle 4 engine speed, a +15 VDC grid current recalibration signal is applied to OP8-6. This results in positive saturation at OP8B-2. This allows maximum grid current to increase to 700 amperes as determined by the +7 VDC bias signal at OP2B-8. Therefore, during GCTLC operation grid current is controlled at a value proportional to the I_G Ref signal applied to OP2A-6, and is limited to 577 amperes when operating at idle speed, and limited to 700 amperes when operating at throttle 4 engine speed.

The load regulator is at maximum field position during dynamic brake operation. Therefore, the load regulator reference signal is equal to the output at receptacle 13 of the RC module. This signal is compared with the PF module feedback signal. The PF module feedback signal is proportional to traction motor field current during dynamic brake operation. Therefore, the output signal at receptacle 13 of the RC module is the field current reference signal.

The output from receptacle 13 of the RC module is applied to receptacle 4 of the DR module where it is then applied to 6 of differential amplifier OP5, Fig. DR-7. The gain of OP5 is designed to provide a field current reference signal I_F Ref output having a ratio of 82.5A/V. The I_F Ref output signal from OP5-2 is applied to OP6A-6 where it is compared with a +10 VDC bias signal at OP6A-5. The output at OP6A-2 switches to positive saturation if traction motor field current rises above 825 amperes. A positive output at OP6A-2 results in turn on of OI-1. Turn on of OI-1 results in discharge of the RC module rate control capacitors. Discharge of these capacitors results in a decrease of traction motor field current. Therefore, traction motor field current is limited to 825 amperes when operating at idle engine speed.

When operating at throttle 4 engine speed, a +15 VDC field current recalibration signal is applied to OP6B-9. This results in negative saturation at OP6B-12 which pulls OP6A-6 to negative and results in negative saturation at OP6A-2. The negative signal at OP6A-2 is blocked by D5. Therefore, the DR module does not limit traction motor field current when operating at throttle 4 engine speed. Traction motor field current is limited to about 975 amperes by the action of the PF and SB modules or the FP module when operating at throttle 4 engine speed.

During field current trainlined control FCTLC operation (+74 VDC applied to receptacle 13), a +15 VDC signal is applied to OP2A-6. This effectively nullifies the I_G Ref signal from P3. Therefore, grid current is not controlled by the I_G Ref signal during field current trainlined control operation. However, maximum grid current is still limited to 577 amperes when operating at idle engine speed and is limited to 700 amperes when operating at throttle 4 engine speed.

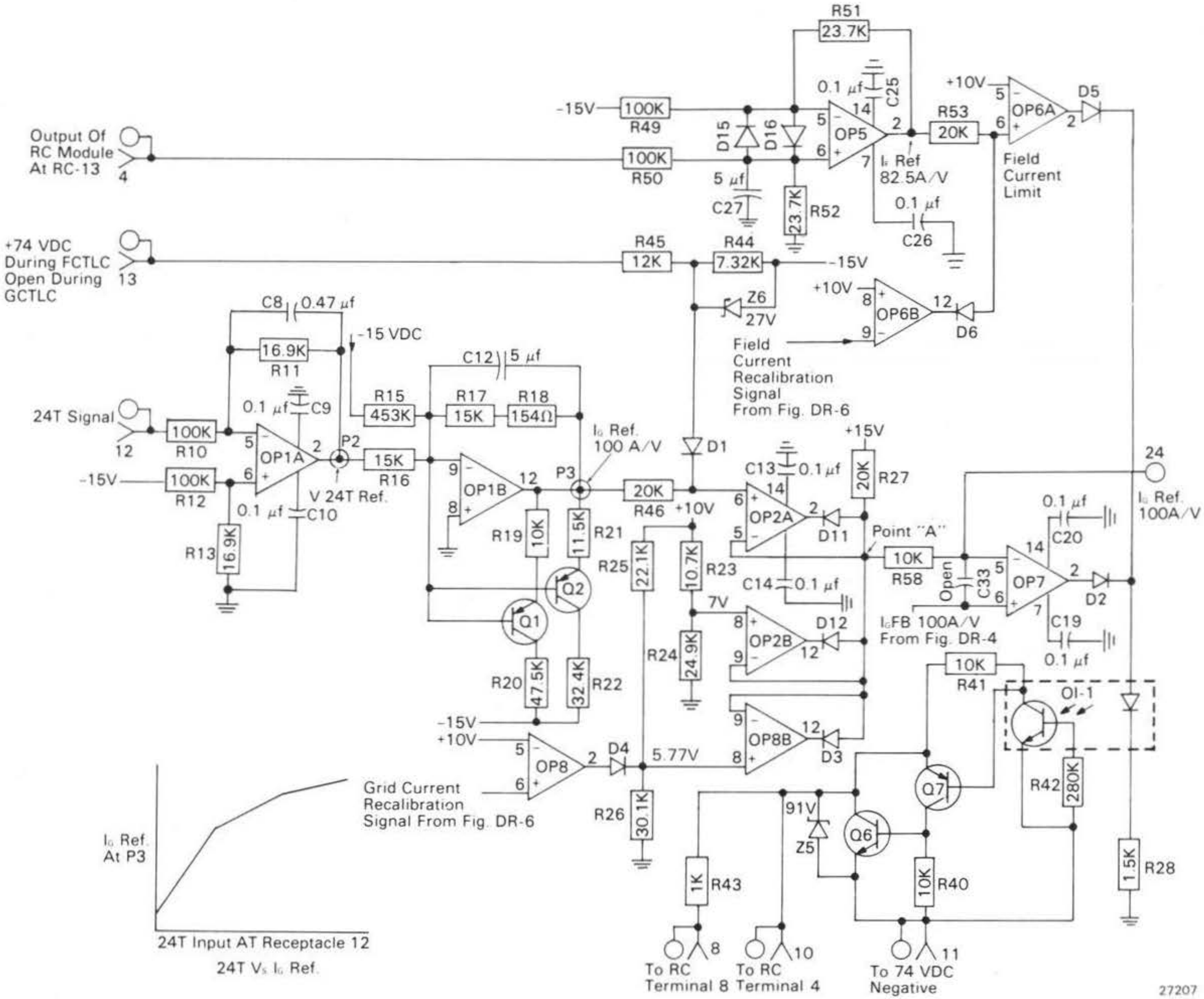


Fig.DR-7 – Grid Current And Field Current Limit Circuit, Simplified Schematic Diagram

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

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.

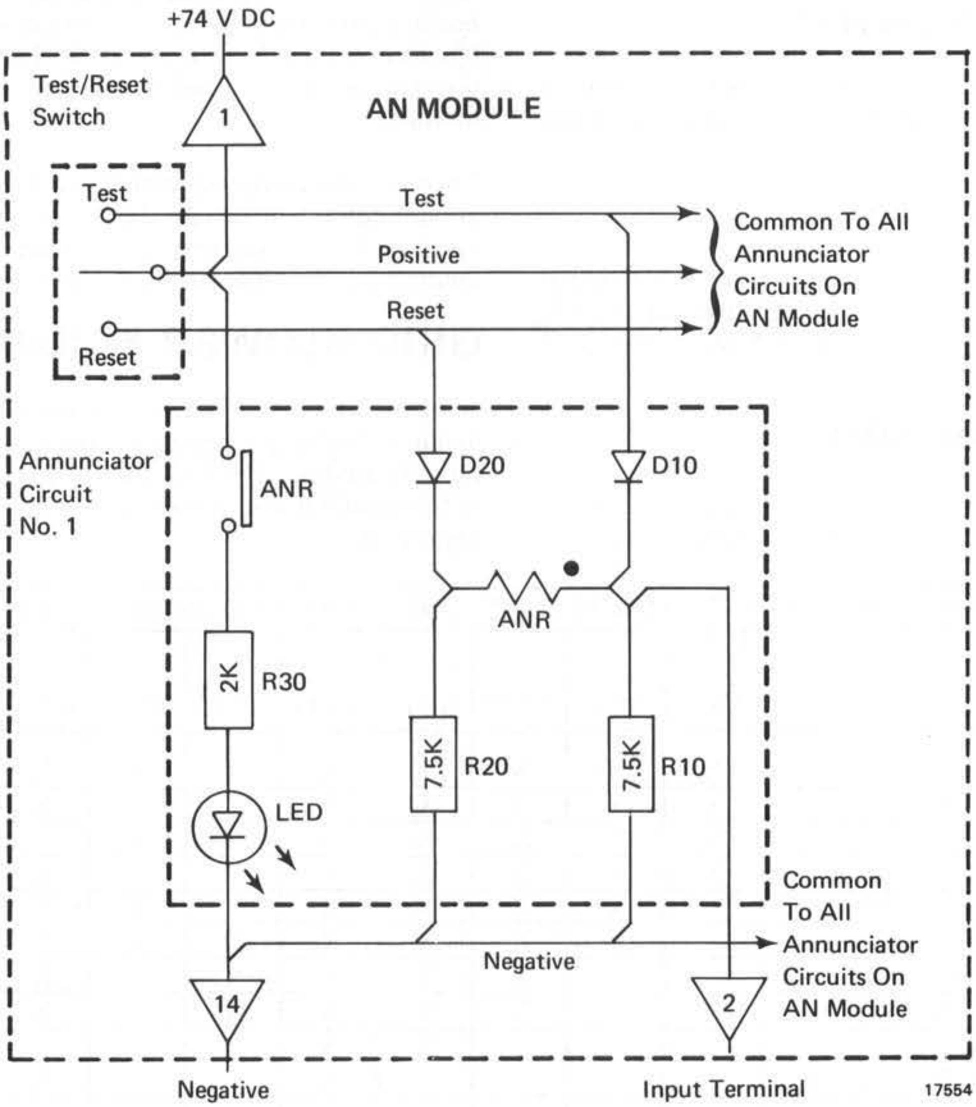


Fig.AN-1 – Annunciator Module, Simplified Schematic Diagram

The annunciator table identifies the fault signals that may be applied to AN 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.

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 restricted.

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 feed to the open circuit latching relay OCL. Pickup of OCL provides a positive feed to terminal 8 on the AN module.

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.

GRID BLOWER FAILURE

Grid blower motor current is monitored by the dynamic brake grid current transductor DGT and the DG module. The DG module provides a signal to terminal 9 if grid blower motor current becomes abnormal.

TABLE OF ANNUNCIATOR MODULE NUMBERS AND INDICATIONS

Input Term.	Fault Signal	AN10	AN11	AN12	AN13	AN14	AN15	AN16	AN17	AN18	AN19
2	Hot Engine	X	X	X	X	X	X	X	X	X	X
3	Engine Air Filter	X	X	X	X	X		X	X	X	X
4	Ground Relay	X	X	X	X	X	X	X	X	X	X
5	Excitation Limit	X	X	X	X	X	X	X	X	X	X
6	Grid Overcurrent		X	X	X	X	X	X	X	X	X
7	Motor Excitation		X	X	X	X	X	X	X	X	X
8	Grid Open Circuit		X	X	X	X	X		X		
9	Grid Blower Failure			X	X	X	X		X	X	X
10	Locked Wheel				X	X	X				
11	Dynamic Brake Ground					X			X		
12	Filter Blower									X	

DYNAMIC BRAKE GROUND

During dynamic braking, the ground relay picks up to provide a feed to input terminal 11 when a ground fault in the braking grid resistors is detected.

FILTER BLOWER

An AC relay is connected across the D14 output between the filter blower motor circuit breaker and the blower motor. A fault in the blower motor circuitry will cause the breaker to trip, opening the feed to the motor and dropping out the relay which provides a feed to input terminal 12.

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.

MISCELLANEOUS CONTROL CIRCUITS AND DEVICES

This section provides a description of miscellaneous locomotive control circuits and devices. Some of these circuits and devices are applied only upon special request of the customer. The simplified schematic diagrams used in the description are provided for convenient reference only. The applicable locomotive wiring diagrams should be used when performing troubleshooting or maintenance.

The contents of Section 7 Part F are presented in the following order:

1. Automatic ground Relay Reset Assembly 8488371 - AGR

   The automatic ground relay reset assembly resets the ground relay within 10 to 20 seconds after the first, second, and third pickup of the GR relay. The fourth pickup of GR results in lockout of the GR relay.

2. Automatic Ground Relay Reset Limiter Assembly 8408360 - AGRL

   The automatic ground relay reset limiter assembly resets the ground relay within 10 to 20 seconds after the first, second, third, and fourth pickup of the GR relay. The fourth pickup of the ground relay GR results in recalibration of the GV module for a maximum generator output voltage of 650 volts.

   The fifth pickup of GR results in lockout of the ground relay. The automatic ground relay reset limiter contains a 35 minute timer which advances the reset counter to zero in case the time between successive pickups of GR exceeds 30 to 50 minutes. Advancing the reset counter to zero returns the operating sequence to the starting point.

3. Engine Purge System - EPs

   The engine purge system is designed to provide protection for the diesel engine during cranking, in the event of a hydraulic lock.

4. Hot Engine And Engine Filter Power Reduction System - PR

   The hot engine and engine filter power reduction system is used to reduce excitation and engine RPM, when operating in some throttle positions, in case a hot engine or plugged engine filter is detected.

5. Radar Speed Module - RS

   The radar speed module provides a signal proportional to true track speed. This signal may be used to drive a speed recorder and a radar speedometer. The signal may also be used to detect an overspeed condition.

AUTOMATIC GROUND RELAY RESET ASSEMBLY 8488371 (SPECIAL ORDER), Fig. AGR-1

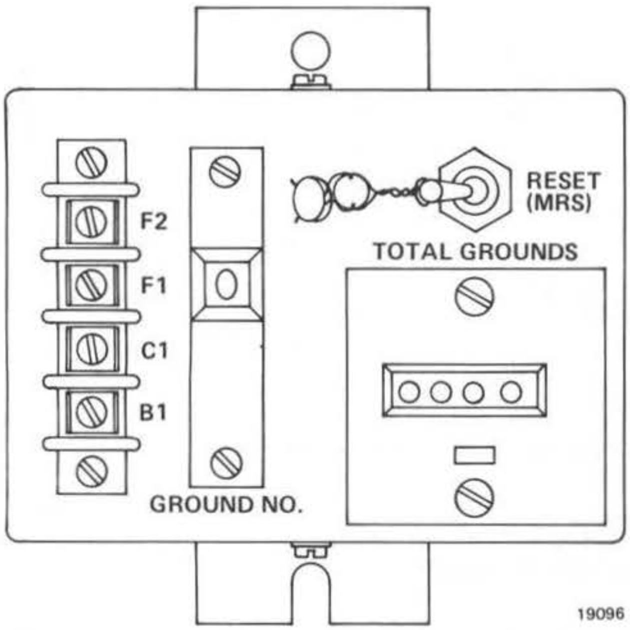


Fig.AGR-1 - Automatic Ground Relay Reset Assembly 8488371

The basic locomotive is equipped with a manual reset pushbutton for the ground relay GR. However, automatic reset circuits are available as an extra when requested by the customer. The automatic ground relay reset assembly 8488371 resets the GR relay within 10 to 20 seconds after pickup on the first, second, and third pickup of the GR relay. The fourth pickup of GR results in lockout of the GR relay. After lockout, the system can be reset only by operating the manual reset switch located on the automatic ground relay reset assembly.

A ground fault number indicator is provided to visually indicate the number of ground relay operations in a sequence. Operating the manual reset switch resets the ground fault number indicator and the reset counter to zero. A total grounds indicator provides a visual indication of the total number of ground relay operations. The total grounds indicator advances one count each time the ground relay is reset. The total grounds indicator has a count capacity of 9999. Operating the manual reset switch does not reset the total grounds indicator. A simplified schematic diagram of the automatic ground relay reset assembly is provided in Fig. AGR-2.

FIRST GROUND RELAY PICKUP

Assume that the reset counter and the ground fault indicator are reset to zero. Pickup of GR provides +74 VDC through the C-D contacts of GR, to terminal C1 of the automatic ground relay reset timer assembly. This provides a current flow through diode D1, capacitor C1 and resistor R1, diode D2, resistor R3 and reset counter relay RC. Current also flows from D1 through C2 and R2 to the totalizer counter relay TC. Pickup of RC advances the reset counter wiper arm to terminal 10 and the ground fault number indicator displays the numeral 1. Pickup of RC also closes contacts 1-18 of RC which sets up the manual reset circuit. Contacts 1-18 of RC are open only when the reset counter is set to zero. Pickup of TC does not advance the total grounds indicator. However, the total grounds indicator will advance one count when the C-D contacts of GR open to drop the feed to TC.

When the reset counter wiper arm advances to terminal 10, a feed is provided to terminal 1 of the 15 second timer. Within 10 to 20 seconds, the 15 second timer provides a feed to the GR reset relay. Pickup of GR reset relay opens the C-D contacts of GR which removes the feed from the C1 terminal and allows TC and RC relays to drop out. Dropout of TC advances the total grounds indicator one count. The reset counter wiper arm remains connected to terminal 10 until the next pickup of the GR relay or until the reset counter is reset by closing the manual reset switch MRS.

SECOND GROUND RELAY PICKUP

If a second ground relay operation occurs, the sequence of events will occur as specified for the first ground relay operation, except the counter wiper arm will advance to terminal 9 and the ground fault

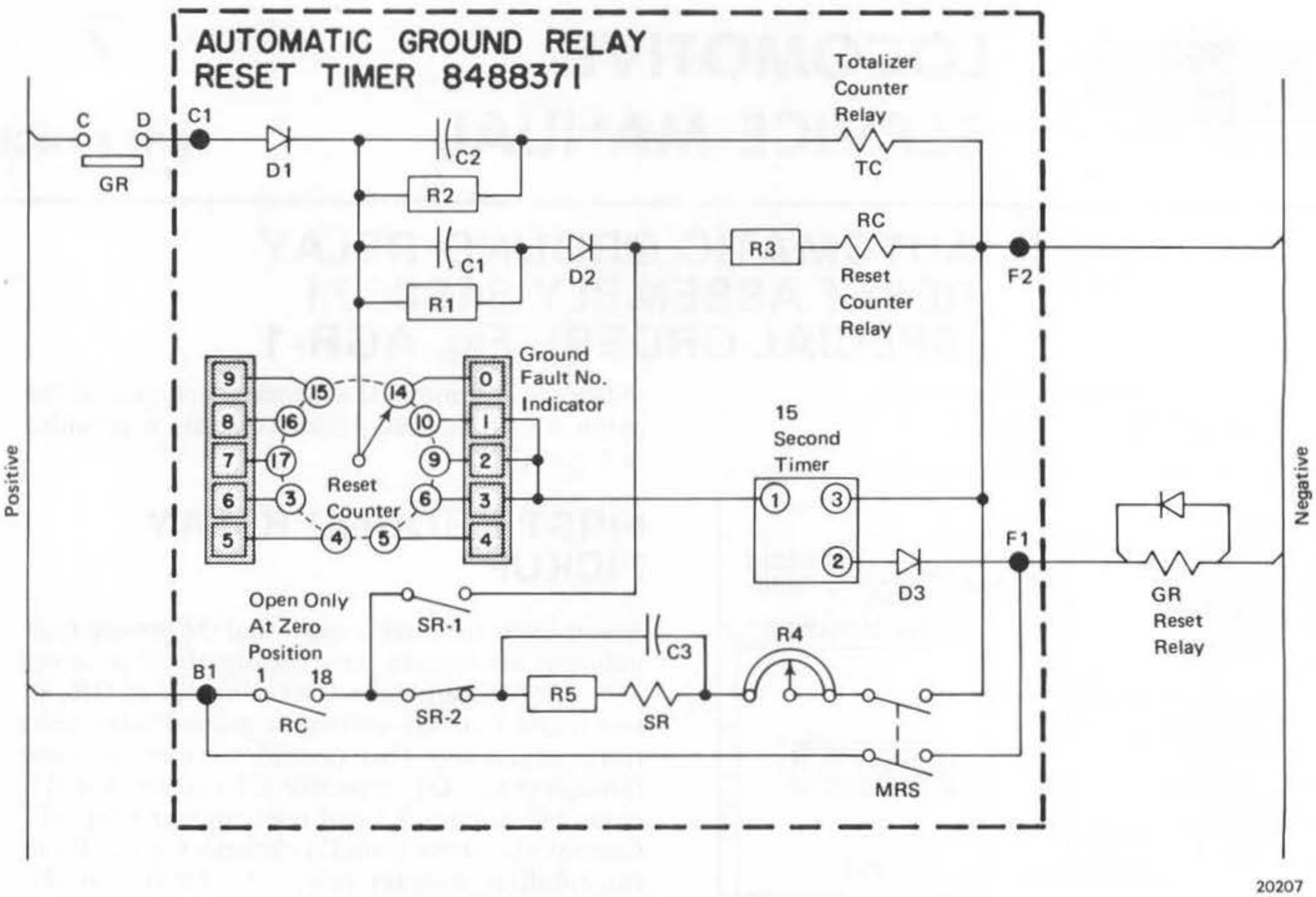


Fig.AGR-2 - Automatic Ground Relay Reset Assembly 8488371, Simplified Schematic Diagram

number indicator will display the numeral 2. This indicates the second ground relay operation in the sequence.

THIRD GROUND RELAY PICKUP

If a third ground relay operation occurs, the sequence of events will occur as specified for the first ground relay operation, except the counter wiper arm will advance to terminal 6 and the ground fault number indicator will display the numeral 3. This indicates the third ground relay operation in the sequence.

FOURTH GROUND RELAY PICKUP

If a fourth ground relay operation occurs, the wiper arm will advance to terminal 5 and the ground fault number indicator will display the numeral 4. This indicates the fourth ground relay operation in the sequence. Observe that terminal 5 is not connected to the 15 second timer and a feed cannot be provided to the GR reset relay. Therefore, the system does not reset automatically after the fourth ground relay operation in a sequence. The system can be reset manually by operating the manual reset switch MRS. However, instructions as issued by the railroad regarding manual reset must be followed. In the absence of instructions from the railroad, the cause of GR operation should be determined and necessary maintenance performed prior to making a manual reset.

OPERATION OF THE MANUAL RESET SWITCH

After the fourth ground relay operation in a sequence, the system will remain locked until the manual reset switch MRS, located on the automatic ground relay reset assembly, is operated.

Holding MRS closed provides a feed to sequence relay SR. Pickup of SR closes SR-1 contacts and opens SR-2 contacts. Closing SR-1 contacts provides a feed to the reset counter relay RC which advances the reset counter and the ground fault number indicator one count. Blocking diode D2 prevents pickup of TC. Therefore, the total grounds indicator will not advance. Opening SR-2 contacts removes the feed from the SR relay. However, C3 and R5 provide a short time delay in dropout of SR. This short time delay provides sufficient time for positive operation of RC before dropout of SR. SR dropout occurs after the short time delay provided by C3 and R5.

Droput of SR closes SR-2 contacts and opens SR-1 contacts. Closing SR-2 provides a feed to the SR relay. Pickup of SR results in a repeat of the action described in this paragraph. Each pickup of SR provides a feed to the reset counter relay RC. Each pickup of RC advances the reset counter and the ground fault number indicator one count. This pickup and dropout of SR continues until the reset counter and ground fault number indicator advance to zero. Contacts 1-18 of RC open when the reset counter has advanced to zero. This removes the feed from the SR relay which stops the sequence.

When resetting the counter, MRS should be held closed until the reset counter advances to zero. Otherwise, lockout will occur on the next GR pickup.

AUTOMATIC GROUND RELAY RESET LIMITER 8408360 (SPECIAL ORDER), Fig. AGRL-1

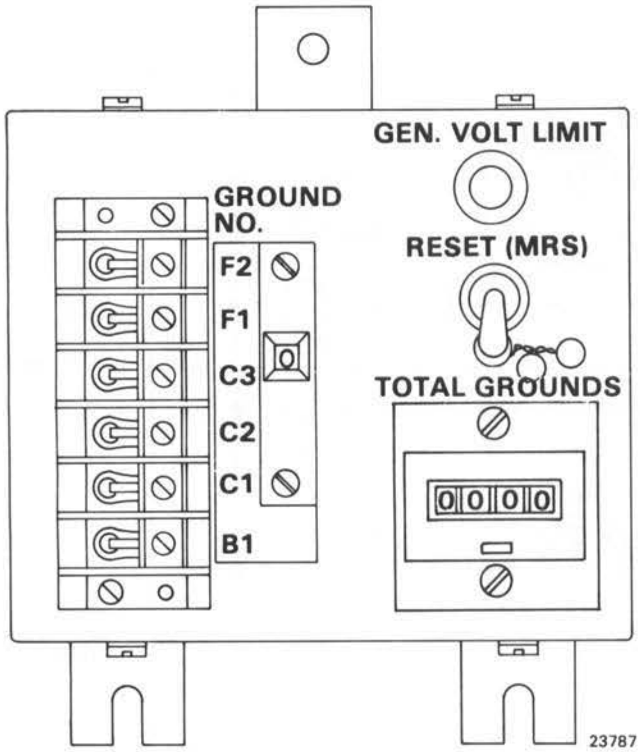


Fig.AGRL-1 – Automatic Ground Relay Reset Limiter Assembly 8408360

The basic locomotive is equipped with a manual reset pushbutton for the ground relay GR. However, automatic reset circuits are available as an extra when requested by the customer. The automatic ground relay reset limiter 8408360 resets the ground relay within 10 to 20 seconds after pickup on first, second, third, and fourth pickup of the ground relay GR. The fourth pickup of the ground relay GR also provides a feed to the generator voltage limit relay GVL and to the generator voltage limit indicator on the automatic ground relay reset limiter.

Pickup of GVL recalibrates the GV module so that generator voltage is limited to a maximum voltage of approximately 650 volts. This reduced voltage reduces the possibility of GR pickup due to insulation leakage in the presence of minor moisture grounds. This allows the locomotive to operate at reduced output until the moisture dissipates. If GR pickup occurs while operating at reduced voltage, the lockout relay LR will be energized. Pickup of LR disables the automatic reset feature and the system is locked out. After lockout, the system can be reset only by operating the manual reset switch MRS located on the ground relay reset limiter assembly.

A ground fault number indicator is provided to visually indicate the number of GR pickups in a sequence. The ground fault number indicator advances one count each time GR picks up. Operating the manual reset switch MRS resets the reset counter and the ground fault number indicator to zero. A total grounds indicator which advances one count each time the GR relay is reset, provides a visual indication of the total number of GR resets. This indicator has a count capacity of 9999. Operating the manual reset switch MRS does not reset the total ground indicator.

The automatic ground relay reset limiter assembly contains a 35 minute timer which advances the reset counter to zero in case the time between successive pickups of GR exceeds 30 to 50 minutes. Advancing the reset counter to zero returns the operating sequence to the starting point. Operation of the 35 minute timer does not advance the total grounds indicator. A simplified schematic diagram of the automatic ground relay reset limiter assembly is provided in Fig. AGRL-2.

FIRST GROUND RELAY PICKUP

Assume that the reset counter is set to zero. Pickup of GR provides +74 VDC, through E-F contacts of GR, to terminal C1 of the automatic ground relay reset limiter. This provides a current flow through diode D1, capacitor C1 and resistor R1, diode D2, resistor R3, and reset counter relay RC. Current also flows from D1 through C2 and R2 to totalizer counter relay TC. Pickup of RC advances the reset counter wiper arm to terminal 10 and the ground

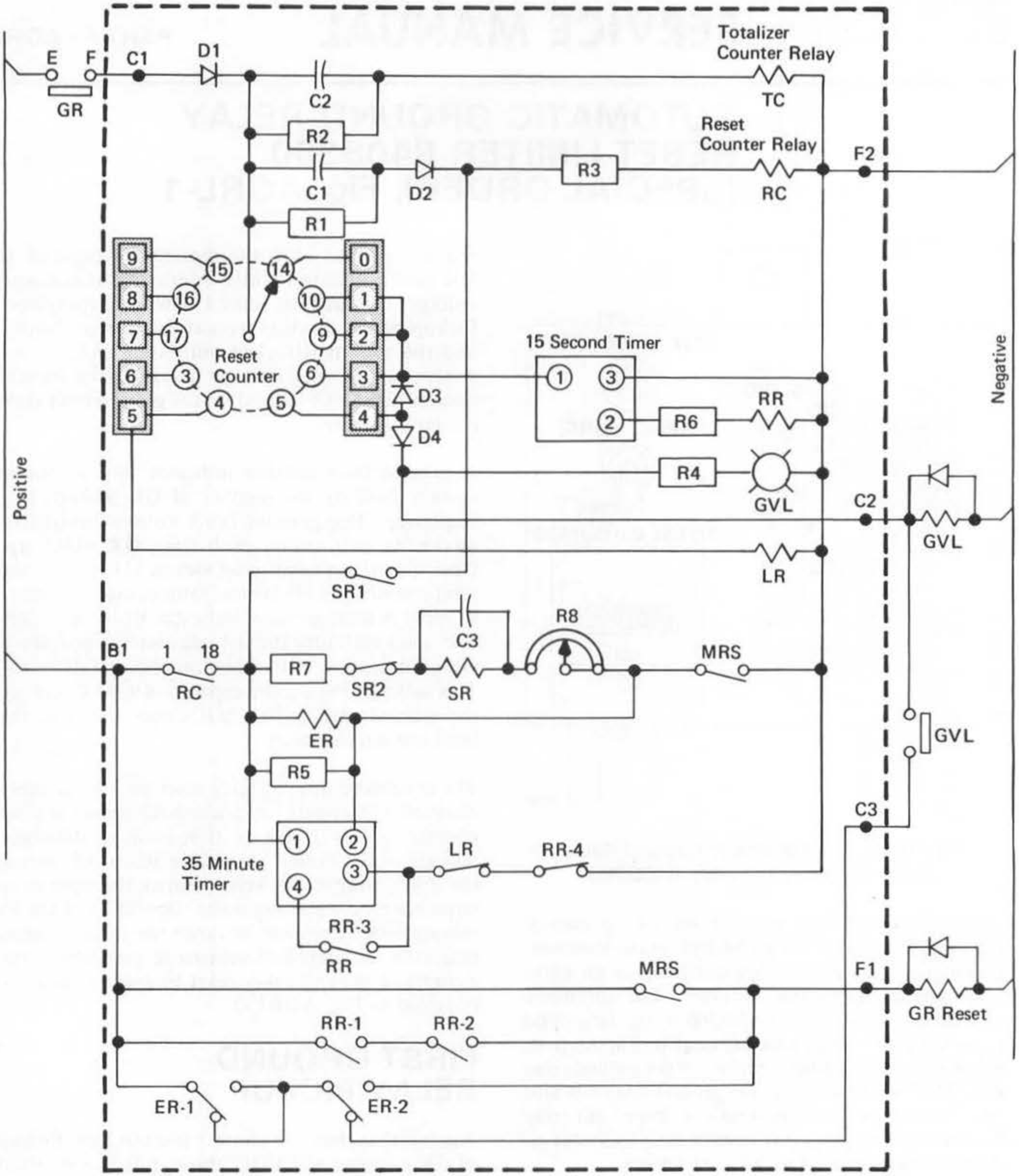


Fig.AGRL-2 – Automatic Ground Relay Limiter 8408360, Simplified Schematic Diagram fault number indicator displays the numeral 1. Pickup of RC also closes contacts 1-18 of RC which applies +74 VDC to terminal 1 of the 35 minute timer. Contacts 1-18 of RC remain closed until the reset counter advances to zero. Pickup of TC does not advance the total grounds indicator. However, the total grounds indicator will advance one count when the E-F contacts of GR open to drop the feed to TC.

When the reset counter wiper arm advances to terminal 10, a feed is provided to terminal 1 of the 15 second timer. Within 10 to 20 seconds, the 15 second timer provides a feed through R6 to reset relay RR. Pickup of RR provides a feed through RR-1 and RR-2 contacts to the GR reset relay. Pickup of RR also closes the RR-3 contacts and opens the RR-4 contacts. Closing RR-3 contacts connects terminal 3 to terminal 4 on the 35 minute timer which discharges a timing capacitor in the 35 minute timer. Opening RR-4 contacts removes the negative feed from the 35 minute timer which prevents the timer from starting the 35 minute countdown.

Pickup of the GR reset relay opens the E-F contacts of GR which removes the feed from the C1 terminal and allows the TC and RC relays to drop out. Opening the E-F contacts also removes the feed from reset relay RR. Dropout of RR opens RR-1, RR-2, and RR-3 contacts and closes RR-4 contacts. Opening RR-1 and RR-2 contacts removes the feed from the GR reset relay. Opening RR-3 contacts removes the discharge path of the timing capacitor. Closing RR-4 contacts provides a negative feed to the 35 minute timer which allows the 35 minute timer to start timing.

Dropout of TC advances the total grounds indicator one count. The reset counter wiper arm remains connected to terminal 10 until the next pickup of GR relay or until the reset counter is reset to zero.

OPERATION OF 35 MINUTE TIMER

The 35 minute timer times out if the next GR pickup does not occur within 30 to 50 minutes. Time out of the 35 minute timer provides a path from terminal 2 to terminal 3 on the 35 minute timer. This results in pickup of the excitation relay ER and the sequence relay SR. Pickup of ER provides a feed to the GR reset relay. However, GR has already been reset and ER provides no function at this time. The function of ER will be discussed in a later paragraph.

Pickup of sequence relay SR closes SR-1 contacts and opens SR-2 contacts. Closing SR-1 contacts provides a feed to the reset counter relay RC which results in advancing the reset counter and ground fault number indicator one count. Blocking diode D2 prevents pickup of TC. Therefore, the total grounds indicator will not advance. Opening SR-2 contacts removes the feed from the SR relay. However, C3 provides a short time delay in dropout of SR. This short time delay provides sufficient time for positive operation of RC before dropout of SR. SR dropout occurs after the short time delay provided by C3. Dropout of SR closes SR-2 contacts and opens SR-1 contacts. Closing SR-2 contacts provides a feed to the SR relay. Pickup of SR results in a repeat of the action described in this paragraph. Each pickup of SR provides a feed to the reset counter relay RC. Each pickup of RC advances the reset counter and ground fault number indicator one count.

This pickup and dropout of SR continues until the reset counter and ground fault indicator advances to zero. Contacts 1-18 of RC open when the reset counter has advanced to zero. This removes the feed from the SR relay which stops the sequence.

SECOND GROUND RELAY PICKUP

If a second ground relay operation follows the first ground relay operation before timeout of the 35 minute timer, the sequence of events will occur as specified for the first ground relay pickup, except the reset counter wiper arm will advance to terminal 9 and the ground fault number indicator will display the numeral 2. This indicates the second ground relay operation in the sequence. The 35 minute timer is reset to zero and will not time out until 30 to 50 minutes after the second ground relay reset.

THIRD GROUND RELAY PICKUP

If a third ground relay operation follows the second ground relay operation before time out of the 35 minute timer, the sequence of events will occur as specified for the first ground relay operation, except the reset counter wiper arm will advance to terminal 6 and the ground fault number indicator will display the numeral 3. This indicates the third ground relay operation in the sequence. The 35 minute timer is reset to zero and will not time out until 30 to 50 minutes after the third ground relay reset.

FOURTH GROUND RELAY PICKUP

If a fourth ground relay operation follows the third ground relay operation before time out of the 35 minute timer, the sequence of events will occur as specified for the first ground relay operation, except the reset counter wiper arm will advance to terminal 5 and the ground fault number indicator will display the numeral 4. This indicates the fourth ground relay operation in the sequence. The following additional events will also result from the fourth ground relay operation in a sequence.

A feed is provided through diode D4 to the generator voltage limit relay GVL and to the generator voltage limit indicator. Pickup of GVL recalibrates the GV module so that generator output voltage is limited to a maximum voltage of approximately 650 volts. Pickup of GVL also provides a holding feed for GVL from terminal B1 through ER-1 and ER-2 contacts of the excitation relay ER and the GVL contacts. Therefore, generator voltage will be limited to a maximum of 650 volts until the excitation relay picks up to drop the holding feed to GVL.

The excitation relay ER will pick up if the 35 minute timer times out before the next ground relay operation or if the manual reset switch MRS is operated. Pickup of ER drops the feed to GVL. Dropout of GVL permits generator voltage limit to return to the normal value. Time out of the 35 minute timer or closing MRS will also advance the reset counter and the ground fault number indicator to zero.

FIFTH GROUND RELAY PICKUP

If a fifth ground relay operation follows the fourth ground relay operation before time out of the 35 minute timer, the reset counter wiper arm advances to terminal 4 which provides a feed to lockout relay LR and the ground fault number indicator displays the numeral 5, which indicates the fifth ground relay operation in the sequence. No positive feed is provided to the 15 second timer. Therefore, the automatic reset feature is disabled. Pickup of LR removes the negative feed from terminal 3 of the 35 minute timer. This prevents time out of the timer so that ER and SR do not pick up and the reset counter does not advance to zero. Therefore, the E-F contacts of GR remain closed and the system is locked out.

The generator voltage limit relay GVL picked up and locked in during the fourth ground relay operation. During the fifth ground relay operation, excitation to the main generator is removed and GVL remains locked in. After the fifth ground relay operation, the system will remain locked out and GVL will remain locked in until the manual reset switch MRS is operated.

MANUAL RESET SWITCH OPERATION

After the fifth ground relay operation, the system will remain locked out until the manual reset switch MRS, located on the automatic ground reset limiter assembly, is operated.

Holding MRS closed provides a negative feed to ER and SR and provides a positive feed to the GR reset coil. Pickup of the GR reset coil opens the E-F contacts of GR. This results in advancing the total grounds indicator one count. Pickup of ER removes the holding feed from GVL which removes the recalibration circuit from the GV module. Pickup of SR results in advancing the reset counter and the ground fault number indicator to zero. The lockout relay LR drops out and provides a negative feed to terminal 3 of the 35 minute timer. Contacts 1-18 of the reset counter open when the reset counter advances to zero. This removes the positive feed from the 35 minute timer.

When resetting the counter, MRS should be held closed until the reset counter advances to zero. Otherwise, lockout will occur on the next GR pickup.

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

ENGINE PURGE SYSTEM (SPECIAL ORDER)

INTRODUCTION

An accumulation of water or fuel oil in one or more cylinders of a diesel engine may result in damage to the engine from a hydraulic lock during cranking. It has been determined that a diesel engine will not be damaged by a hydraulic lock during cranking, if cranking speed is less than 30 revolutions per minute.

The engine purge system is designed to provide protection for the diesel engine during cranking, in the event of a hydraulic lock. This protection is provided by regulating cranking speed to 25 to 30 revolutions per minute for at least one complete revolution.

GENERAL DESCRIPTION

The engine purge system, Fig. EP-1, limits engine starting speed by inserting a resistance RE EPC in series with the starting motors. This resistance limits starting motor cranking speed by decreasing both current and voltage available to the starting motors.

Resistor RE EPC is inserted into and taken out of the starting motor circuit by pickup and dropout of relay EPC. Starting motor rotational speed and likewise engine cranking speed are directly proportional to the ratio of starting motor voltage to starting motor current (Esm/Ism). A magsense amplifier senses this ratio and operates when this ratio exceeds a value representing an engine speed greater than 30 RPM.

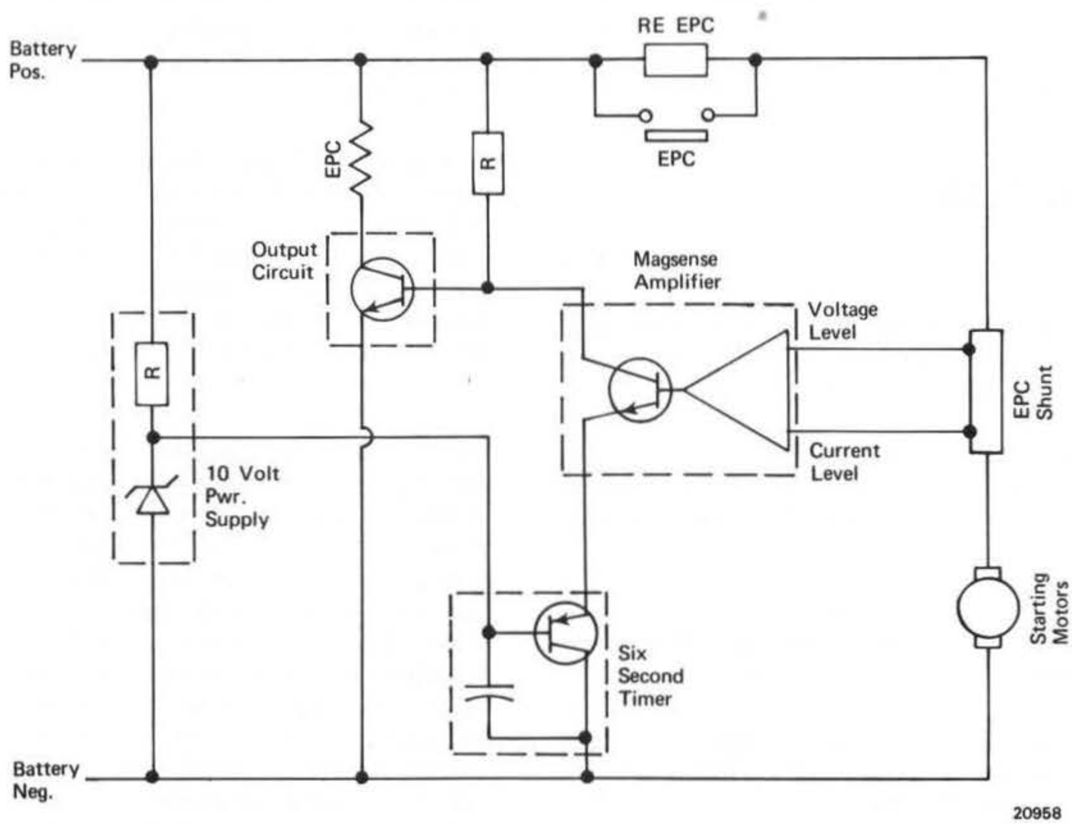


Fig.EP-1 - Engine Purge System Block Diagram

At the instant the starting circuit is energized, the Esm/Ism ratio is at a low level and the magsense amplifier is turned off. This results in forward bias to the output circuit and EPC picks up to short out RE EPC. As the starting motors rotate and increase speed, the Esm/Ism ratio increases. When the Esm/Ism ratio reaches the level proportional to an engine speed of 30 RPM, the magsense amplifier operates to complete a path to the six second timer. This results in reverse bias to the output circuit which drops out EPC and inserts RE EPC in series with the starting motors.

The starting motor speed decreases and the Esm/Ism ratio decreases sufficiently to turn off the magsense amplifier. When the magsense amplifier is turned off, the output circuit is forward biased and EPC again picks up.

This cycling action continues for six seconds, during which time engine speed is limited to 30 RPM. After six seconds, the six second timer operates to open the circuit from the magsense amplifier to negative. This prevents the output circuit from turning off and EPC remains picked up to allow normal engine cranking speed during the remainder of the starting period.

CAUTION

When starting the engine, the injector control lever should not be advanced until timeout of the six second timer. This ensures against engine start until the engine has made at least one complete revolution.

OPERATION

A simplified schematic diagram of the engine purge module EP11 is provided in Fig. EP-2 for reference only. The applicable locomotive wiring diagram should be used when performing troubleshooting or maintenance of the engine purge system.

The engine purge module EP11 contains an output circuit, a six second timer, a magsense amplifier MS1, and a regulated 10 volt DC power supply.

Holding the fuel prime/engine start switch FP/ES to engine start position provides 74 volts DC to receptacles 1 and 8 of the EP module and to the EPC coil. The voltage applied to receptacle 1 is used to provide a regulated 10 volt DC power supply. Output of the 10 volt DC power supply provides operating voltage for the output circuit, the six second timer, and the magsense amplifier MS1.

The 10 volt DC power supply provides forward bias for transistors Q1 and Q2 of the output circuit and to transistors Q3 and Q4 of the six second timer. Turnon of Q3 and Q4 connects terminal 14 of the magsense amplifier MS1 to negative. Turnon of Q1 and Q2 results in pickup of EPC.

Pickup of EPC provides 74 volts DC to receptacle 2 of the EP module. This results in charging capacitor CA4 to approximately 74 volts in about 30 milliseconds and provides a feed to the light emitting diode LED located on the EP module faceplate. The LED provides a visual indication of EPC pickup. Pickup of EPC opens the circuit between receptacles 2 and 10 and also connects receptacle 12 to receptacle 4 of the EP module. The voltage at receptacle 4 is applied to terminal 10 of MS1. This results in turnon of MS1 (connects terminal 4 to 14 of MS1). Turnon of MS1 removes forward bias from Q1 and Q2. Turnoff of Q1 and Q2 drops out EPC.

Dropout of EPC removes the 74 volts DC from receptacle 2 of the EP module, disconnects receptacle 12 from receptacle 4, and connects receptacle 2 to 10. Capacitor CA4 discharges through R16, from receptacle 2 to 10, then through the RCX coil to negative. This results in pickup of RCX.

Disconnecting receptacle 12 from 4 removes the feed from terminal 10 of MS1 which results in turnoff of MS1. Turnoff of MS1 reapplies forward bias to Q1 and Q2. Turnon of Q1 and Q2 results in pickup of EPC.

Pickup of RCX provides a holding feed for RCX from receptacle 8 to 10, connects receptacle 5 to 6, and opens the circuit between receptacles 8 and 12. Connecting receptacle 5 to 6 provides a feed to the starting auxiliary contactor coil STA. Pickup of STA results in pickup of STX and pickup of STX provides a feed to the starting contactor coil ST.

Pickup of ST provides full battery voltage to the starting motors through the closed contacts of EPC connected across RE EPC. At ST pickup, the cranking motors are at rest and are not producing a counter-electromotive-force. This results in a large current flow through the starting motors and the EP shunt. A signal proportional to the current through EP shunt is applied beween terminals 8 and 10 of MS1. This large current flow through the internal resistance of the battery results in a lower than normal battery terminal voltage: A signal proportional to cranking motor voltage is applied to terminal 10 of MS1. Therefore, at ST pickup the cranking motor voltage-to-current ratio (Esm/Ism) is very low.

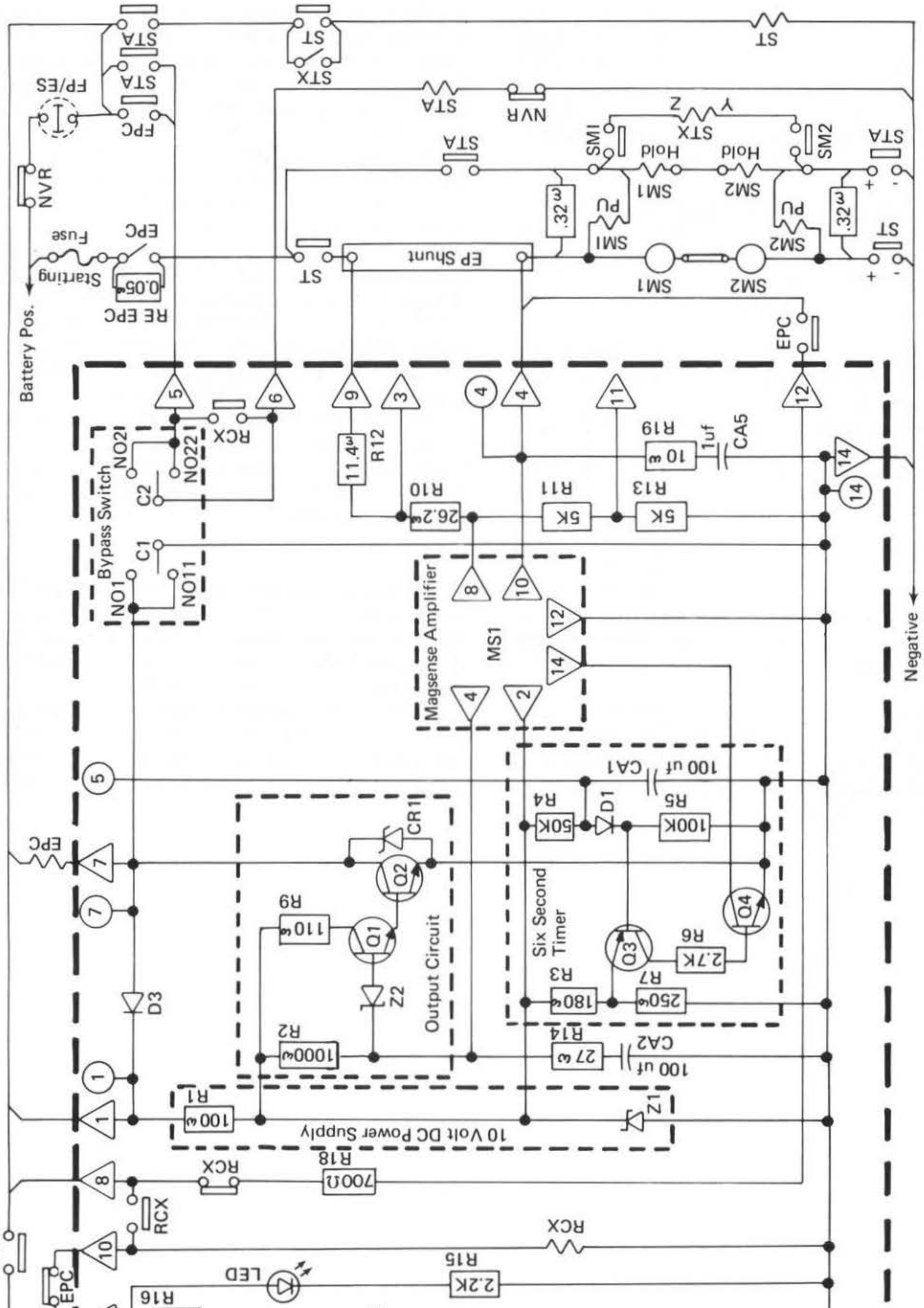


Fig.EP-2 - Typical Engine Purge System Simplified Schematic Diagram

When the cranking motors start to rotate a counter-electromotive-force is produced by the cranking motors. This results in a decrease of current to the cranking motors and an increase in applied voltage to the cranking motors. Therefore, an increase in cranking motor speed results in an increase in cranking motor voltage-to-current ratio.

The cranking motor current signal applied to MS1 tends to hold the circuit open between MS1 terminal 4 and terminal 14. The cranking motor voltage signal tends to close the circuit between MS1 terminal 4 and terminal 14.

The current signal is larger than the voltage signal when the diesel engine is being cranked at a rate below approximately 25 revolutions per minute. Therefore, the circuit between MS1 terminals 4 and 14 is open when the diesel engine is being cranked at a rate below approximately 25 revolutions per minute.

The voltage signal is larger than the current signal when the diesel engine is being cranked at a rate above approximately 30 revolutions per minute. Therefore, the circuit between MS1 terminals 4 and 14 is closed when the diesel engine is being cranked at a rate above 30 revolutions per minute.

Closing the circuit between MS1 terminals 4 and 14 provides reverse bias for Q1 and Q2 which results in dropout of EPC. Dropout of EPC decreases cranking voltage by inserting RE EPC in series with the starting motors.

The decrease in cranking voltage results in a slower cranking rate and a lower cranking voltage-to-current ratio. When the cranking rate decreases to about 25 revolutions per minute, the current signal opens the circuit between MS1 terminals 4 and 14. This applies forward bias to Q1 and Q2 which results in pickup of EPC. Pickup of EPC shorts out RE EPC so that full battery voltage is again applied to starting motors SM1 and SM2 causing an increase in cranking rate. When the cranking rate increases to about 30 revolutions per minute, MS1 and the six second timer places reverse bias on Q1 and Q2 which results in dropout of EPC. Dropout of EPC again inserts RE EPC in series with starting motors SM1 and SM2 to decrease the cranking rate. The action of MS1 and the six second timer results in pickup and dropout of EPC as necessary to limit the cranking rate to about 25 to 30 revolutions per minute until timeout of the six second timer. After timeout of the six second timer, EPC remains picked up and cranking speed increases as required to start the engine.

If the engine fails to crank over when the fuel prime/engine start FP/ES switch is held to engine start position, bar the engine over to ensure that there is no hydraulic lock, then hold the BYPASS switch on the EP module to the closed position and hold FP/ES to engine start position. If the engine cranks over, the EP module should be replaced. If the engine does not crank over, check starting fuse, EPC, and other components in the starting circuit.

HOT ENGINE AND ENGINE FILTER POWER REDUCTION

An engine temperature switch ETS is installed in the water manifold on the equipment rack. Excessive water temperature causes the ETS contacts to close. Closing these contacts provides a feed to the HOT ENGINE light and to the throttle limit relay THL. Pickup of THL provides a feed to the alarm bell and to the annunciator module. Pickup of THL also provides a feed to the DV input on the TH module and to the governor DV solenoid when operating in throttle positions 7 and 8.

The engine filter switch EFS located in the electrical cabinet monitors the pressure drop across the inertial plus the engine air filters. A pressure differential of 24 inches of water causes the EFS contacts to close. Closure of the EFS contacts provides a feed to the engine filter latching relay EFL. Pickup of EFL provides a feed to the GOVERNOR SHUTDOWN/6TH THROT. light. Pickup of EFL also provides a feed to the DV input on the TH module and to the governor DV solenoid when operating in throttle positions 7 and 8.

The feed to the DV inputs on the TH module causes a reduction of approximately 17 volts in TH module output voltage to the RC module when operating throttle positions 7 and 8. This reduction in output voltage results in reduced excitation. Pickup of the governor DV solenoid results in decreasing engine speed by approximately 175 RPM when operating in throttle positions 7 and 8. Refer to Fig. PR-1 for typical values.

Throttle Position	Governor Solenoid Energized		Engine Speed RPM		TH14 Module Output Volts	
	Normal	Engine Filter or Hot Engine	Normal	Engine Filter or Hot Engine	Normal	Engine Filter Or Hot Engine
5	BV-CV-DV	BV-CV-DV	655	655	43.3	43.3
6	AV-BV-CV-DV	AV-BV-CV-DV	730	730	51.2	51.2
7	BV-CV	BV-CV-DV	829	655	61.4	43.3
8	AV-BV-CV	AV-BV-CV-DV	904	730	68.0	51.2

Fig.PR-1 - Throttle Position, Normal Engine Speed, And Reduced Power Speed

RADAR SPEED MODULE RS15

INTRODUCTION

The RS15 module consists of a ±7.5 VDC power supply, a speed recorder drive isolation stage, a frequency-to-voltage converter, a radar speedometer drive buffer stage, an overspeed selection and detection circuit, an overspeed relay drive circuit, and test circuits. A block diagram of the RS15 module is provided in Fig. RS-1.

Most of the solid state circuits on the RS module use ±7.5 VDC for operation. This is obtained from a power supply on the RS module. A potential of 74 VDC is applied between receptacles 1 and 14. This 74 VDC is applied to a power supply preregulator which provides an output voltage of 24 VDC. This 24 VDC is applied to a 24 VDC to 15 VDC converter which provides an output of 15 VDC which is isolated from the input power source. The 15 VDC is applied to a ground reference circuit. The ground reference circuit provides a dual output voltage of +7.5 VDC and -7.5 VDC when referenced to common.

An eight volt peak-to-peak digital square wave pulse train from the radar transceiver is applied as an input to the RS module. The frequency of this signal is 19 Hz/MPH or the frequency is equal to track speed in miles per hour times 19 Hz. The signal is applied to an isolation stage and to a frequency-to-voltage converter stage.

The square wave signal from the speed recorder drive isolation stage is provided as an output from the RS module to the speed recorder on units so equipped. The frequency-to-voltage converter stage converts the digital square wave signal to an analog signal that is proportional to the frequency of the square wave input from the transceiver. Output of the frequency-to-voltage converter is 22.5 MPH/V. This analog signal is applied to a buffer stage and an overspeed selection and detection stage. The output from the buffer stage is applied to the radar speedometer if the locomotive is so equipped.

The overspeed selection and detection stage is programmed to provide an overspeed signal to the overspeed relay OSR, on units so equipped, at any speed between 30 miles per hour and 120 miles per hour in steps of two miles per hour. The speed at which the overspeed signal is provided is determined by jumpers installed in the electrical cabinet.

If track speed rises above the overspeed trip setting, the overspeed indicator located on the RS module faceplate will go on and power will be removed from the ORS relay. Drop out of ORS removes the feed from the magnet valve overspeed solenoid MV-OS (not shown.) Removing the feed from MV-OS results in an overspeed alarm. Excitation to the main generator will be removed and a penalty application of the air brakes will occur if track speed is not reduced below the overspeed trip point within a timed period of about 4 to 6 seconds. The locomotive may be designed so that the penalty brake application will not occur if a service application has been made.

OPERATION

OUTPUT SIGNAL TO SPEED RECORDER

The eight volt peak-to-peak digital square wave input signal from the radar transceiver is applied to receptacle 28, Fig. RS-2. This eight volt square wave signal is referenced to -7.5 VDC so that its range is from -7.5 VDC to +0.5 VDC. The signal from receptacle 28 is applied to 6 of OP4 where it is compared with a -3.77 VDC bias signal at 5 of OP4. The output at 2 of OP4 is at positive saturation (about +7.5 VDC) when the input signal at 6 of OP4 is between -3.77 VDC and +0.5 VDC. The output at 2 of OP4 is at negative saturation (about -7.5 VDC) when the input signal at 6 of OP4 is between -3.77 VDC and -7.5 VDC.

A positive output at 2 of OP4 provides reverse bias for opto-isolator OI-2. A negative output at 2 of OP4 provides forward bias for OI-2. Therefore, OI-2 switches on and off at a rate determined by the frequency of the input signal at receptacle 28. The isolated pulses from OI-2 are provided to the speed recorder on units so equipped.

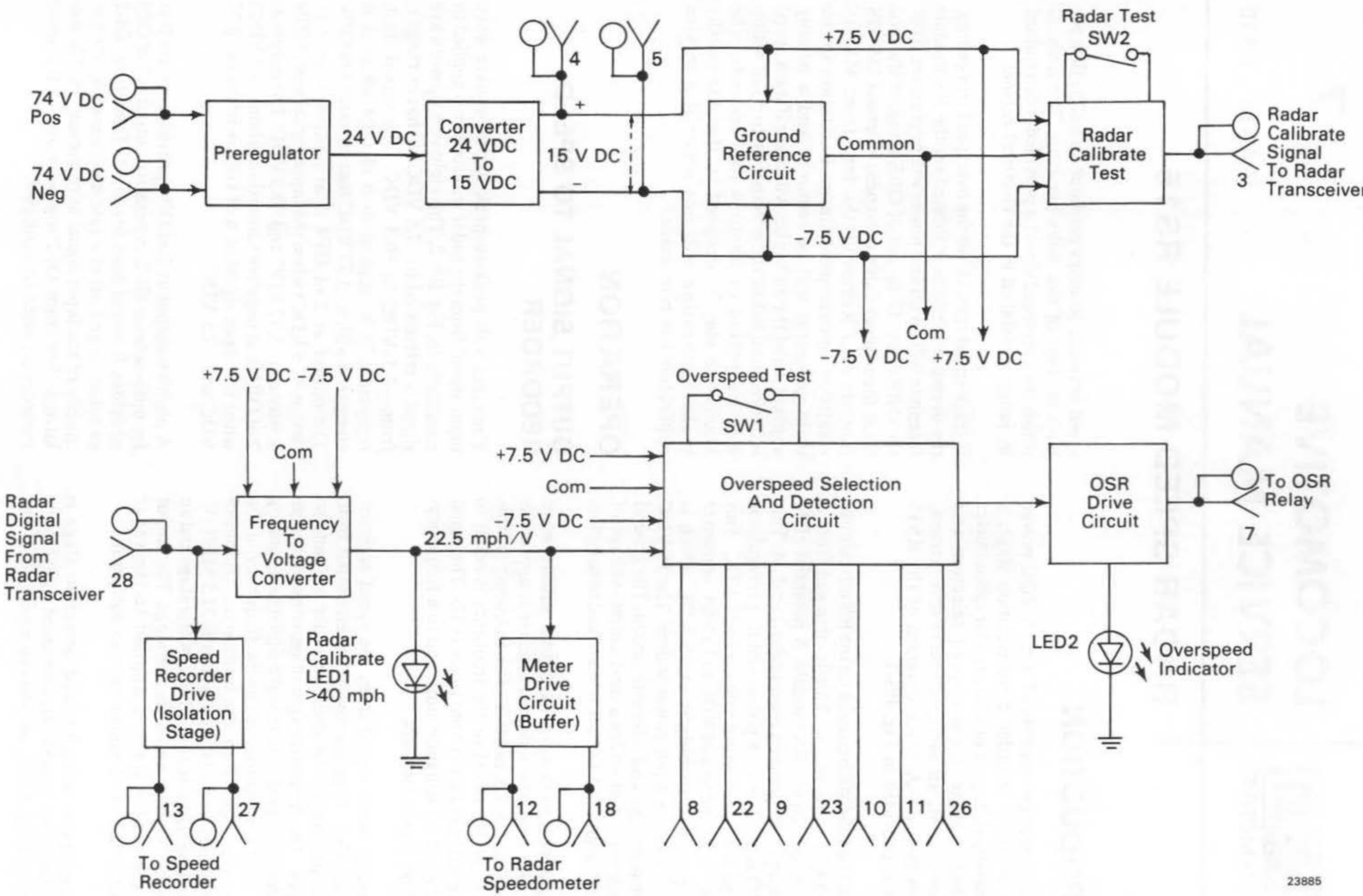


Fig.RS-1 – Radar Supply Module RS15, Simplified Block Diagram

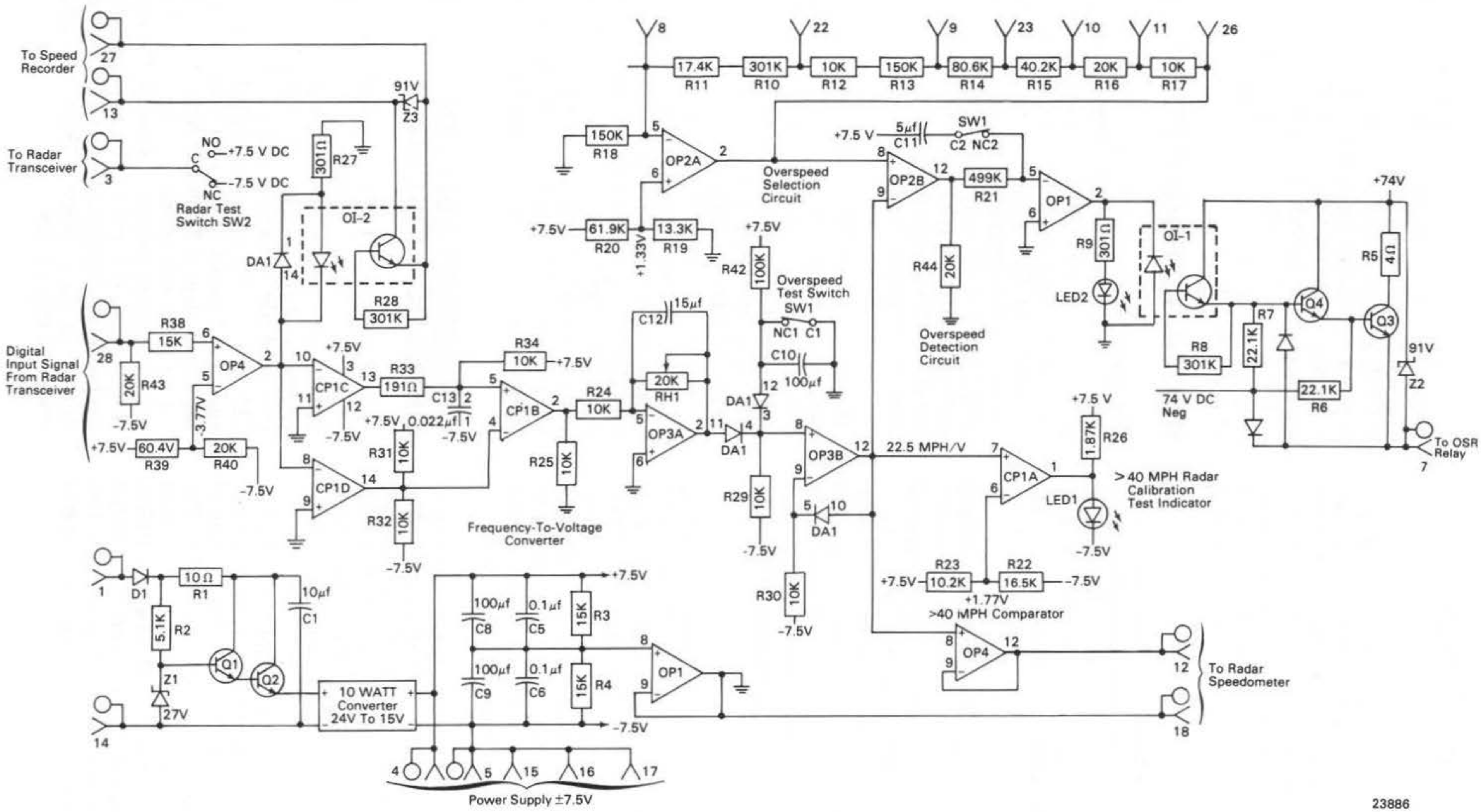


Fig.RS-2 – Radar Supply Module RS15, Simplified Schematic Diagram

FREQUENCY-TO-VOLTAGE CONVERTER

The output pulses from OP4-2 are applied to a frequency-to-voltage converter which provides an analog output signal which is proportional to the frequency of the pulses at OP4-2. The frequency-to-voltage converter consists of three voltage comparators CP1B, CP1C, and CP1D, and an integrating circuit consisting of OP3A, C12, and associated circuitry.

The output at 2 of OP4 goes to negative saturation (about -7.5 VDC) when the input at receptacle 28 is between -3.77 VDC and -7.5 VDC. This negative signal is applied to CP1C-10 and CP1D-8. This results in turn off of CP1C and CP1D which results in about +7.5 VDC at CP1C-13 and CP1D-14.

The +7.5 VDC at CP1D-14 is applied to CP1B-4 causing CP1B to turn on and results in about -7.5 VDC at 2 of CP1B. This negative signal is applied through R24 to OP3A-5 causing OP3A-2 to go to positive. This positive signal results in feedback through RH1 and C12 to OP3A-5 then through R24 to -7.5 VDC at CP1B-2. This feedback is limited to a value sufficient to drive OP3A-5 to common potential. This causes the potential at OP3A-2 to rise as C12 charges.

The +7.5 VDC at CP1C-13 provides a charging current through R33 to C13. The charge on C13 rises rapidly due to the low values of R33 and C13. When the charge on C13 rises to about +7.5 VDC, CP1B turns off and CP1B-2 goes to common. Therefore, the feedback from OP3A-2 to CP1B-2 is limited to the time required for C13 to charge to about +7.5 VDC. Capacitor C12 charges a small amount during the negative pulse at CP1B-2.

The output at 2 of OP4 goes to positive saturation (about +7.5 VDC) when the input at receptacle 28 is between -3.77 VDC and +0.5 VDC. This positive signal is applied to CP1C-10 and CP1D-8. This results in turn on of CP1C and CP1D which results in about -7.5 VDC at CP1C-13 and CP1D-14.

The -7.5 VDC at CP1D-14 is applied to CP1B-4. Resistors R33 and R34 form a voltage divider between +7.5 VDC and CP1C-13. The junction of this voltage divider is applied to CP1B-5. The potential at this junction is about -7.22 VDC. With -7.5 VDC at CP1B-4 and -7.22 VDC at CP1B-5, comparator CP1B will be turned off and CP1B-2 will be referenced to common through R25. This results in a common reference through R25 and R24 to OP3A-5.

The sequence repeats at intervals determined by the frequency of the square wave input at receptacle 28. This results in a sequence of narrow negative pulses at CP1B-2. These pulese are integrated and inverted to provide a positive analog signal at OP3A-2 which is proportional to the frequency of the square wave input signal at receptacle 28. Therefore, the output at OP3A-2 is a positive analog signal which is proportional to track speed. This signal has a ratio of 22.5 MPH/V.

RADAR SPEEDOMETER SIGNAL

The analog output signal from OP3A-2 is applied from 11 to 4 of DA1 to 8 of OP3B. This results in a positive output at OP3B-12. The feedback from 10 to 5 of DA1 compensates for the voltage drop from 11 to 4 of DA1. Therefore, the output at OP3B-12 is the same as the output at OP3A-2 which has a ratio of 22.5 MPH/V. The output at OP3B-12 is applied to 8 of buffer amplifier OP4. The 22.5 MPH/V signal from OP4-12 is applied through receptacles 12 and 18 to the radar speedometer on units so equipped.

The output from OP3B-12 is also applied to CP1A-7 where it is compared with a +1.77 VDC bias signal. Comparator CP1A will be turned off when the radar analog signal is less than +1.77 VDC (track speed less than about 40 MPH). Turn on of CP1A results in about -7.5 VDC at CP1A-1. A negative at CP1A-1 prevents current flow through LED1. Therefore, LED1 will not turn on when the radar analog speed signal is below +1.77 VDC (below 40 MPH). When the radar analog speed signal rises above +1.77 VDC (above 40 MPH) CP1A turns off. Turn off of CP1A results in about +7.5 VDC at CP1A-1 and LED1 goes on. Therefore, LED1 will be on when the radar speed signal is above +1.77 VDC (track speed above 40 MPH).

OVERSPEED SELECTION AND DETECTION CIRCUIT

A fixed bias of +1.33 VDC is applied to 6 of OP2A. The gain of OP2A is equal to 1 + (Rx divided by 150,000) where Rx is the active resistance between receptacles 8 and 26. The output at OP2A-2 is the overspeed trip reference signal and has a ratio of 22.5 MPH/V. The overspeed trip point may be set at any speed between 30 miles per hour and 120 miles per hour in steps of 2 miles per hour. The overspeed trip set point is determined by shorting out various resistors between receptacles 8 and 26. The applicable resistors are shorted out by applying external jumpers in the control cabinet at the factory prior to delivery of the locomotive. Refer to Table 1 for overspeed trip settings.

TABLE NO. 1
EXTERNAL JUMPER WIRE LOCATION FOR SELECTION OF THE DESIRED OVERSPEED TRIP SETTING

Desired Speed MPH	Jumper Wire					
	From	To	From	To	From	To
30	8	26				
32	8	11				
34	11	26	8	10		
36	8	10				
38	10	26	8	23		
40	10	11	8	23		
42	11	26	8	23		
44	8	23				
46	23	26	8	9		
48	23	11	8	9		
50	11	26	23	10	8	9
52	23	10	8	9		
54	10	26	8	9		
56	10	11	8	9		
58	11	26	8	9		
60	8	9				
62	9	26	8	22		
64	9	11	8	22		
66	11	26	9	10	8	22
68	9	10	8	22		
70	10	26	9	23	8	22
72	10	11	9	23	8	22
74	11	26	9	23	8	22
76	9	23	8	22		
78	23	26	8	22		
80	23	11	8	22		
82	23	10	11	26	8	22
84	23	10	8	22		
86	10	26	8	22		
88	10	11	8	22		
90	11	26	8	22		
92	8	22				
94	22	26				
96	22	11				
98	22	10	11	26		
100	22	10				
102	22	23	10	26		
104	10	11	22	23		
106	22	23	11	26		
108	22	23				
110	23	26	22	9		
112	22	9	23	11		
114	22	9	23	10	11	26
116	22	9	23	10		
118	22	9	10	26		
120	22	9	10	11		

The overspeed trip reference signal is applied to OP2B-8 where it is compared with the radar analog speed signal applied to OP2B-9. The output at OP2B-12 is positive when the reference signal is larger than the analog speed signal. This positive signal at OP2B-12 is applied to OP1-5 and results in negative saturation at OP1-2. This negative at OP1-2 provides forward bias for opto-isolator OI-1. Turn on of OI-1 provides forward bias for Q4 and Q3. Turn on of Q3 provides approximately +74 VDC to the overspeed relay OSR for normal operation.

The output at OP2B-12 switches to negative saturation (about -7.5 VDC) if the analog speed signal applied to OP2B-9 rises above the overspeed reference signal applied to OP2B-8. Capacitor C11 provides a short delay in coupling the negative signal from OP2B-12 to OP1-5. This delay prevents false operation due to spikes and noise signals, but permits operation due to a true overspeed.

A negative signal applied to OP1-5 results in positive saturation at OP1-2. This results in turn on of overspeed indicator LED2 on the module faceplate and removes forward bias from OI-1. Turn off of OI-1 removes forward bias from Q4 and Q3. Turn off of Q3 removes power from overspeed relay OSR.

Drop out of OSR results in an overspeed alarm. Excitation to the main generator will be removed and a penalty brake application will occur if track speed is not reduced below the overspeed trip point within a timed period of about 4 to 6 seconds. The locomotive may be designed so that the penalty brake application will not occur if a service application has been applied before the time out period.

OVERSPEED TRIP TEST CIRCUIT, TEST SWITCH SW1

A check of the overspeed trip circuit may be performed at standstill or during normal power operation.

The double pole, double throw, overspeed test switch SW1 is normally closed. Opening SW1 disconnects C11 from OP1-5 which removes the delay in transferring the output signal from OP2B-12 to OP1-5. Opening SW1 also allows C10 to assume a charge. When performing the test at standstill, the charge on C10 is applied from 12 to 3 of DA1 to OP3B-8. The output signal at OP3B-12 and the signal to the radar speedometer should follow the charge on C10.

When performing the test during normal power operation, the radar speedometer should indicate true track speed until the charge on C10 rises above the radar analog speed signal. The radar speedometer should then indicate an increasing speed as the charge on C10 increases.

The output at OP3B-12 is also applied to OP2B-9 where it is compared with the overspeed reference signal at OP2B-8. The overspeed indicating light LED2 will come on when the signal at OP2B-9 rises above the overspeed reference signal at OP2B-8. The overspeed trip point can be accurately determined by observing the radar speedometer indication when LED2 comes on. If the unit is not equipped with a radar speedometer, the voltage between receptacles 12 positive and 18 negative may be measured with a digital voltmeter. The voltmeter indication in volts, at the time LED2 comes on, multiplied by 22.5 is the overspeed trip point in miles per hour. The output signal at OP3B-12 returns to zero immediately when SW1 is returned to normal during a standstill test. The output signal at OP3B-12 returns to the radar analog speed signal value immediately when SW1 is returned to normal during normal power operation.

RADAR TEST CIRCUIT, TEST SWITCH SW2

Closing radar test switch SW2 applies +7.5 VDC through receptacle 3 to the radar transceiver. This results in a calibrated square wave output signal of about 950 to 1050 Hz from the radar transceiver to receptacle 28 of the RS module.

This square wave signal is processed by the frequency-to-voltage converter, Fig. RS-2 to provide an analog speed signal of about +2.35 VDC at OP3B-12. This represents a track speed of about 50 to 55 miles per hour. This analog signal is applied through buffer amplifier OP4 to the radar speedometer. Therefore the radar speedometer indication should rise to about 50 to 55 miles per hour. If the unit is not equipped with a radar speedometer, a digital voltmeter may be used to measure about +2.35 VDC between faceplate test points 12 positive and 18 negative. This provides a functional check of the radar transceiver, the frequency-to-voltage converter, and the radar speedometer.

The analog output signal from OP3B-12 is also applied to 7 of the > 40 MPH comparator CP1A. The > 40 MPH indicator LED1 on the module faceplate should come on when the output signal from OP3B-12 rises above +1.77 VDC (indication of radar speedometer rises above 40 miles per hour).

ELECTRO-MOTIVE

LOCOMOTIVE SERVICE MANUAL

INSPECTION AND REPLACEMENT OF CONTACT TIPS FOR CONTACTORS AND MOTOR OPERATED TRANSFER SWITCH

For information on maintenance of contactors and transfer switches see the following.

REFERENCES

Power Contactor – 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
 –Switch Module 8453175 . . . . M.I. 5421-1
 –Motor Module 8453176 . . . . M.I. 5421-2
Load Test Transfer Contactors . . . . M.I. 5408

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 lugs, 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 low left front of the electrical cabinet.

2. Using 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 775/24 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 ternimal.

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

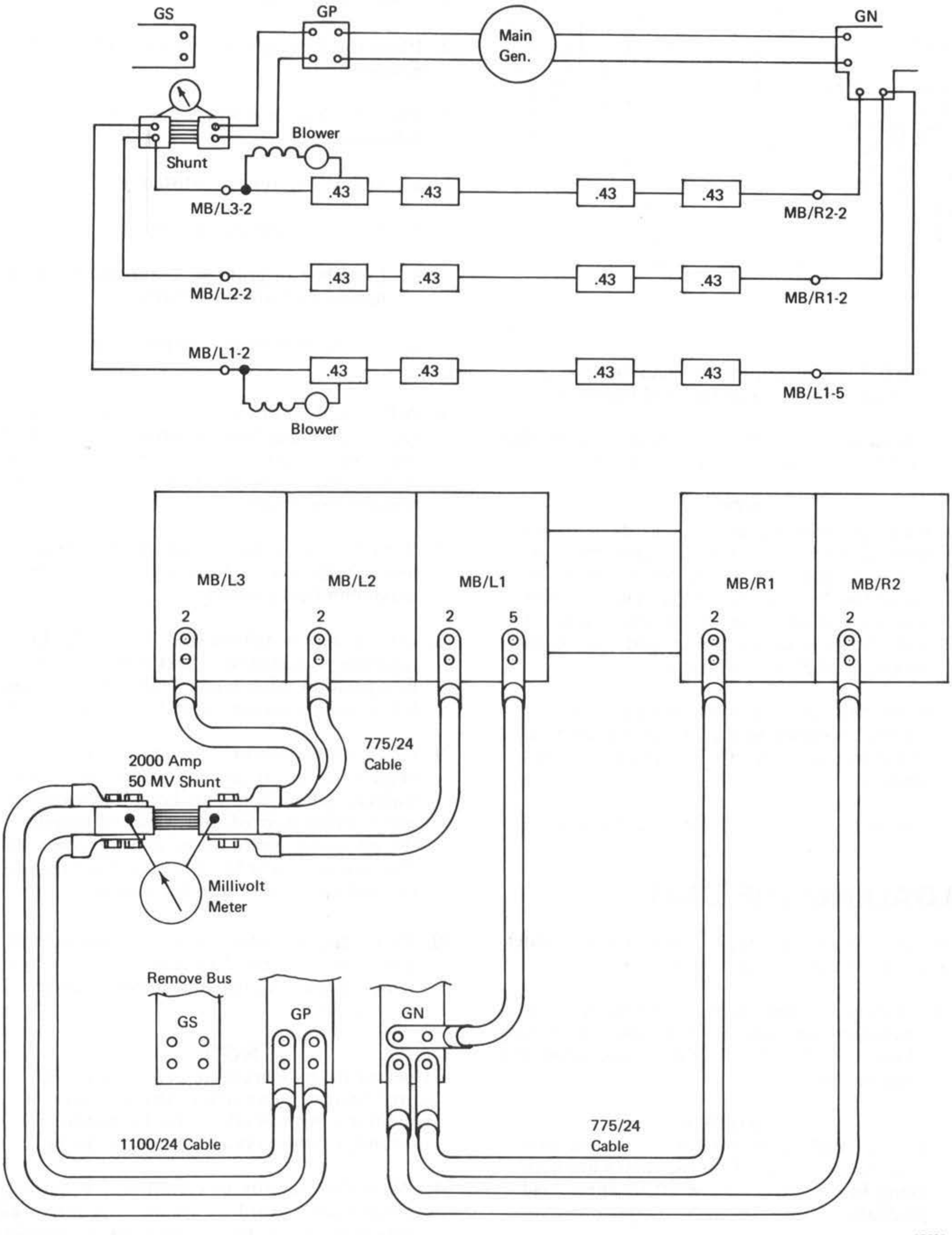


Fig.9-1 – Test Setup For loading On Dynamic Braking Grids

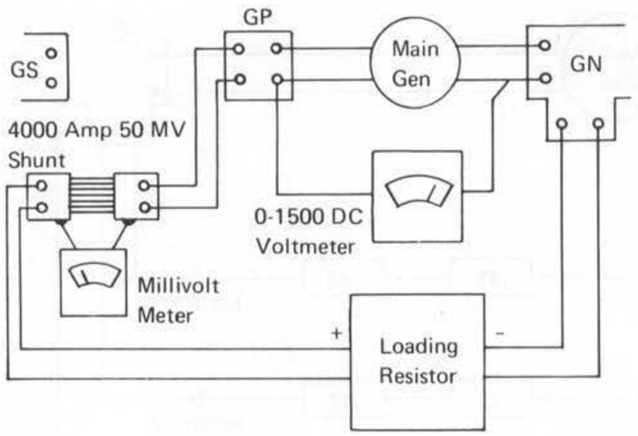


Fig.9-2 – Test Setup For Load Testing On Load Box or External Grid Hatches

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 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. Make certain that the generator and AC control circuit breakers are closed. 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, apply 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. 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 a 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 engineroom 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 engineroom 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 HORSE-POWER 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 Maintenance Instruction M.I. 928, 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.

When loading a unit on its own dynamic braking resistor grids, verify whether or not the unit is equipped to isolate the DR module during such loading (i.e., MR L1-L2 interlocks and RE45 located between braking resistors and the DR module input). If the unit is not so equipped, pull out the DR module during loading.

SERVICE DATA
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.

645E3B Engine Maintenance Manual

Lube Oil Coolers	M.I. 927
Lubricating Oil Cooler Service Limits	M.I. 928

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 13 mm (1/2″) spacing in open air to keep temperature within 120° C rise.

THERMOMETERS REQUIRED

Dial Indicating Thermometer 0° - 70° C (0° - 150° F) Equipped With 1/4″ N.P.T. Threaded Stud.

Glass Thermometer 0° - 70° C (0° - 150° F).

Glass Thermometer 30° - 120° C (100° - 250° F) Bulb 6 mm (1/4″) Maximum Diameter.

Caged Glass Thermometer 30° - 120° C (100° - 250° F).

SERVICE DATA (CONT'D)

SPECIFICATIONS

Governor Rack	Engine RPM	Total Horsepower Adjusted To Standard Conditions
*0.84	900-908	2383-2529 kW (3195-3390 HP)

*Rack setting for 0.845 specific gravity fuel.

When locomotive is adjusted for other than the basic rack setting, consult EMD representative for expected total horsepower and correction factors.

Formulas: Input To Generator= Generator Horsepower= $\frac{\text{Main Gen. Volts x Main Gen. Amps.}}{\text{Generator Efficiency Factor††}}$

††A factor of 700 is recommended

Total Horsepower Adjusted To Standard Conditions= $\frac{\text{Gen. HP + Auxiliary HP}}{\text{A x B x C x D}}$

Where in the formula –

A - Is the correction factor for air temperature.
(Standard is 15.5 degrees C [60 degrees F]).

NOTE

See correction factors chart for difference between blower inlet temperature and ambient.

B - Is the correction factor for altitude.
(AAR Standard is 28.86 inches Hg, which approximates 1000 feet altitude.)

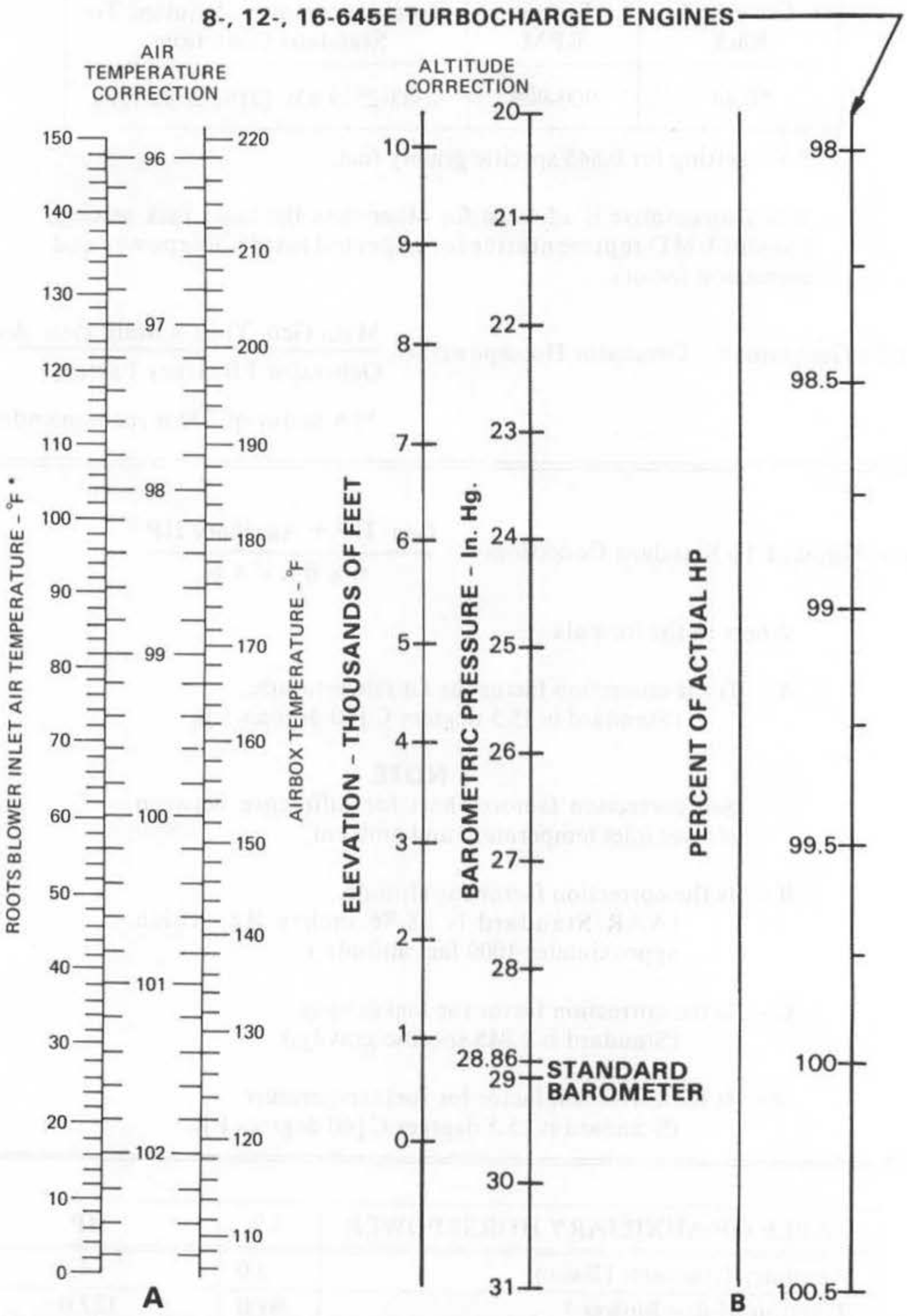
C - Is the correction factor for fuel density.
(Standard is 0.845 specific gravity.)

D - Is the correction factor for fuel temperature.
(Standard is 15.5 degrees C [60 degrees F]).

TABLE OF AUXILIARY HORSEPOWER	kW	HP
Auxiliary Generator (Basic)	3.0	4.0
Traction Motor Blower †	91.0	122.0
3 Cooling Fans*† (48" 6 Blade)	68.6	92.0 (30.7 HP ea.)
Inertial Filter Blower	9.0	12.0
WLN Compressor - Unloaded	11.2	15.0
Total Auxiliary Power	197.2	264.0

*Deduct applicable HP valve for each fan not running.
†@ 0.070 Lb/Ft³ Ambient Air Density.

HORSEPOWER CORRECTION FACTORS



BAROMETRIC CORRECTION FACTOR NOMOGRAPHS FOR SPECIFIC ENGINE MODELS

These nomographs should be utilized per instructions given in the Locomotive Service Manual to correct HP to a barometric pressure of 28.86 in. Hg. The standard barometer under the AAR engine rating conditions is 28.86 in. Hg.

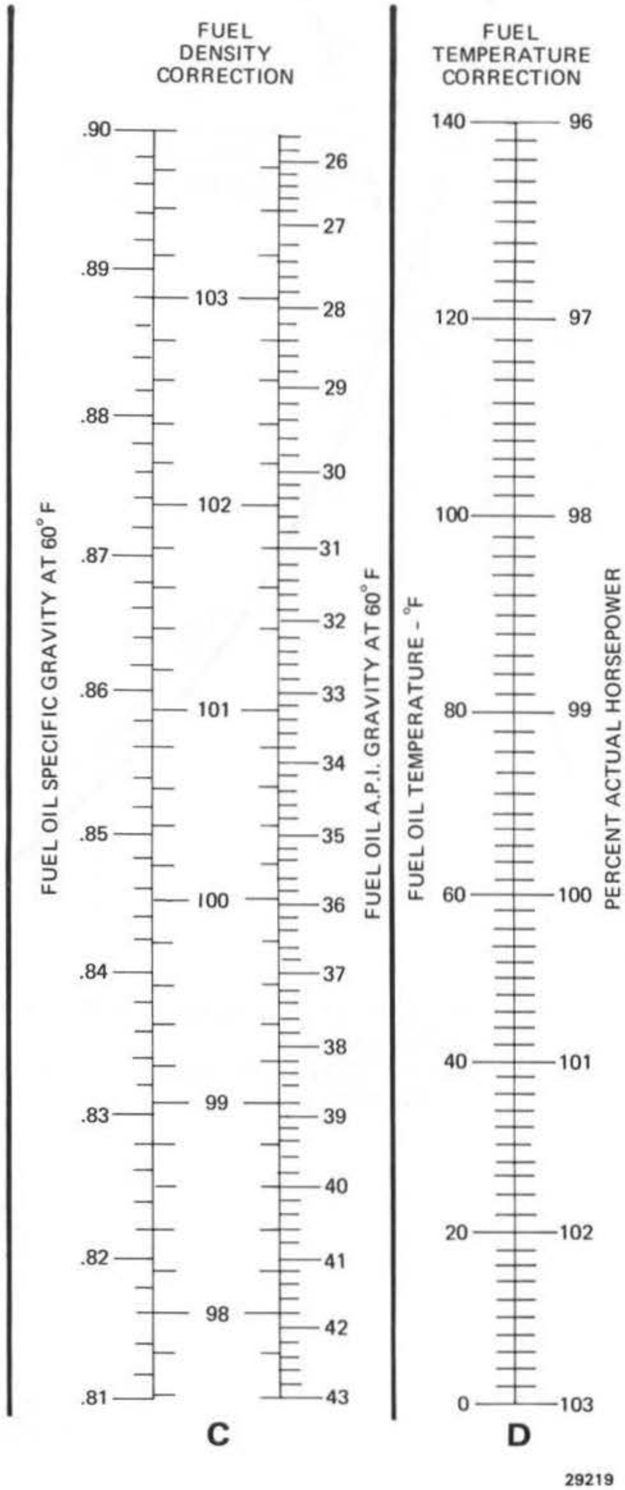
***Add 5° to Ambient to Obtain Inlet Temperature**

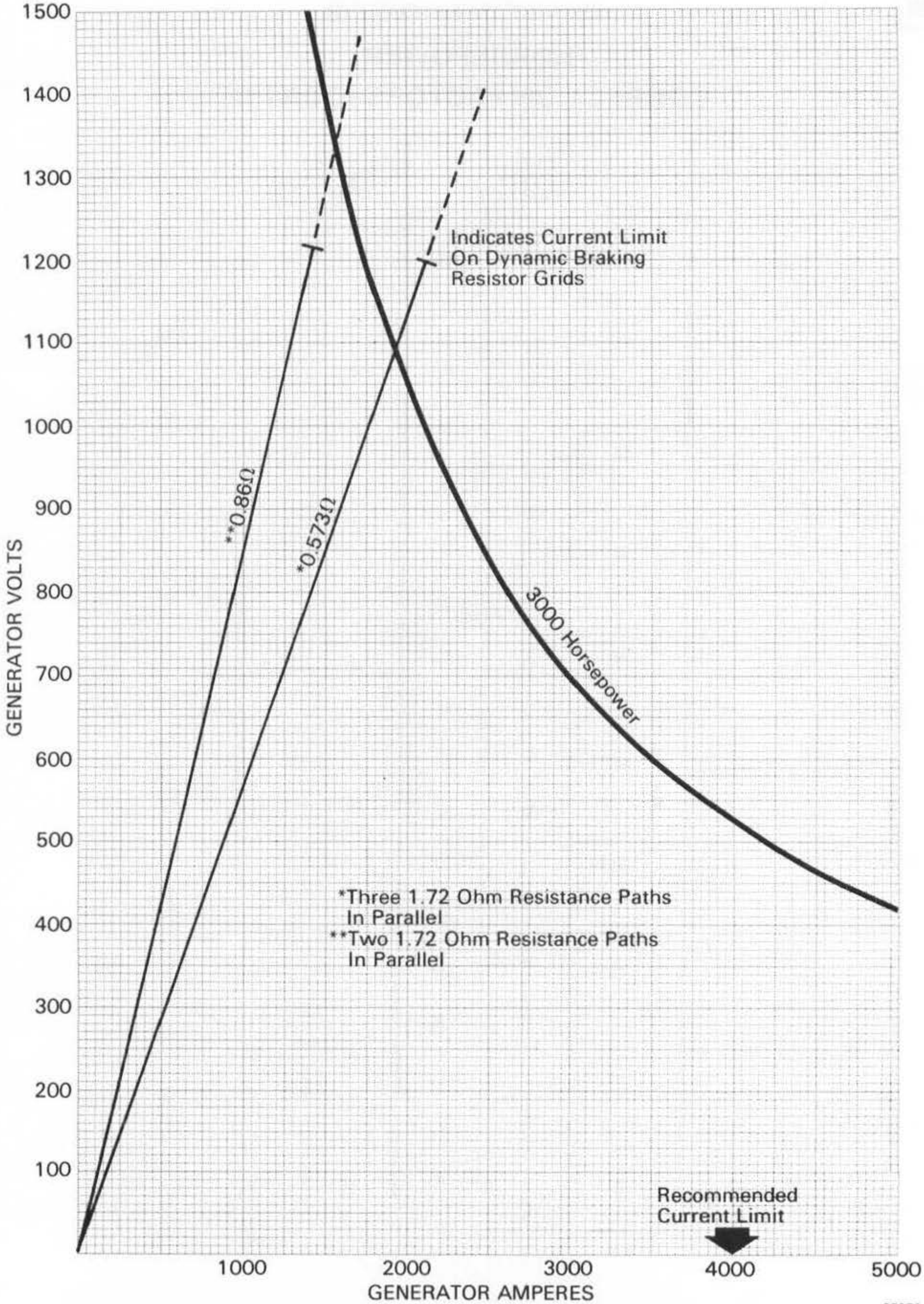
29225

Horsepower Correction Factors

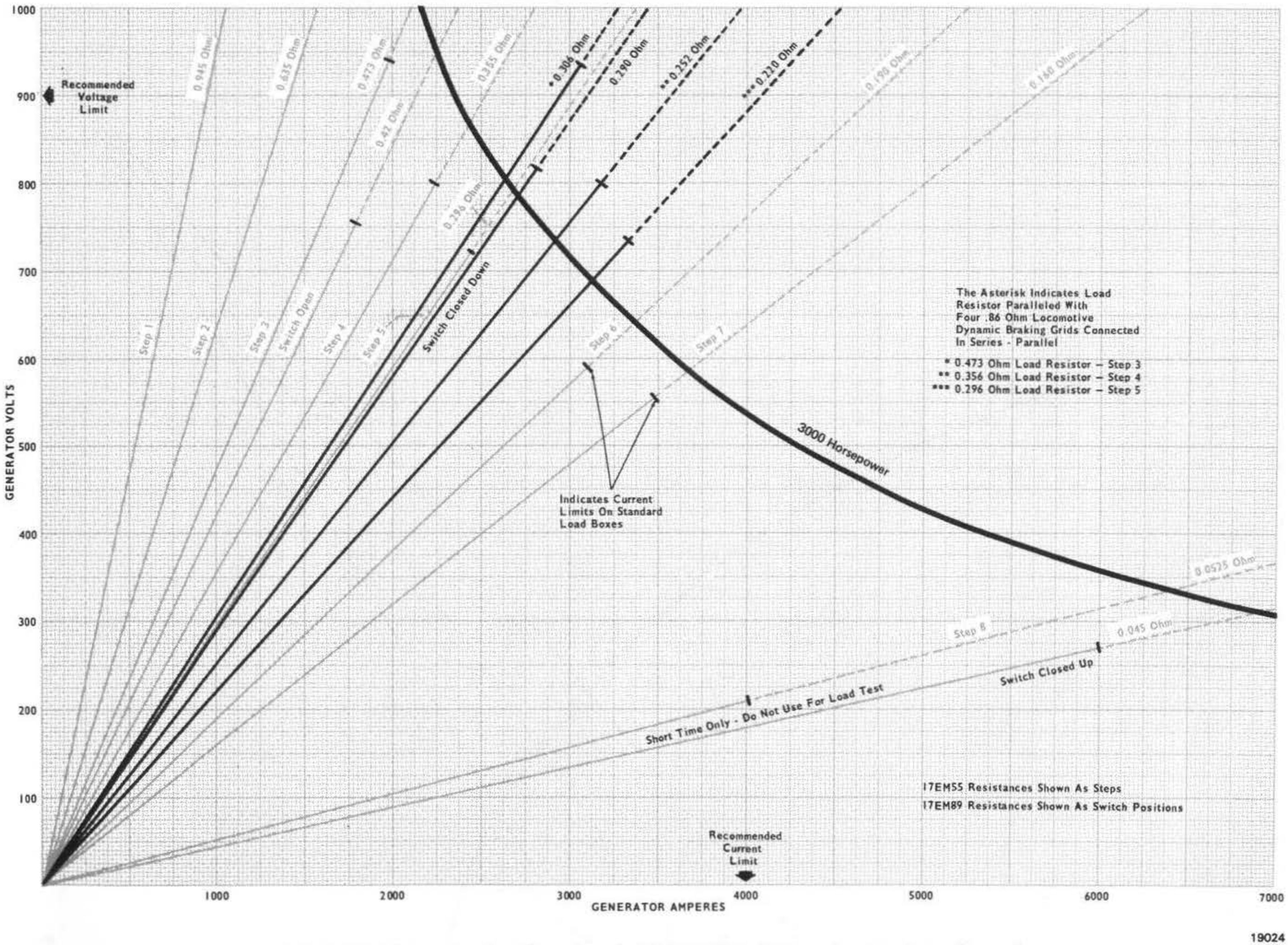
SERVICE DATA (CONT'D)

HORSEPOWER CORRECTION FACTORS (CONT'D)

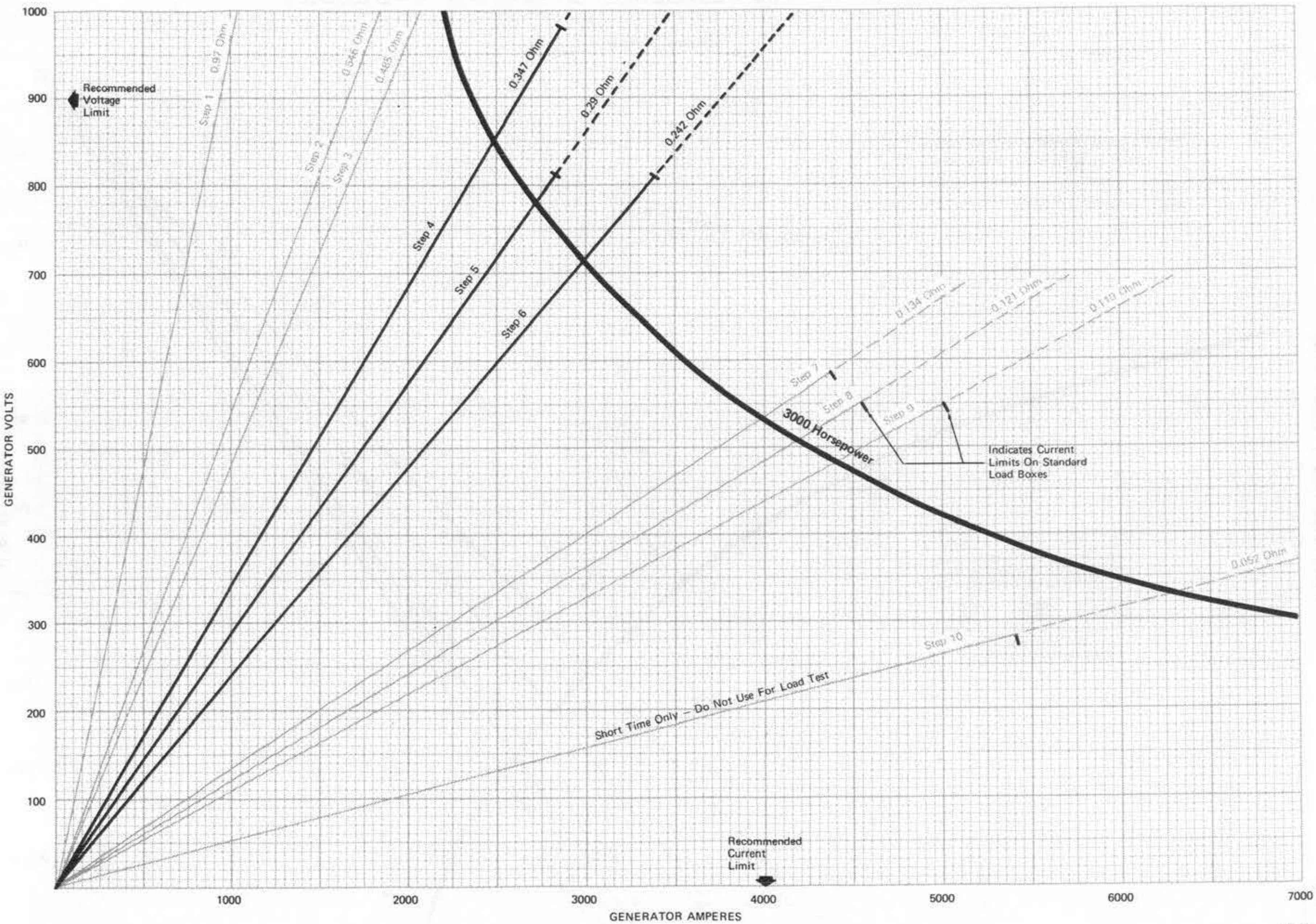




3000 HP Generator Loading Graph (Dynamic Brake Grid Load)



3000 HP Generator Loading Graph (17EM55 & 89 Loading Resistor Boxes)



3000 HP Generator Loading Graph (17EM99 Loading Resistor 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 section provides a guide for high potential testing of locomotive wiring and equipment. Service Data 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. Verify the good condition of the machine 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 test 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-volt 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 in Service Data 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 megohmmeter (500 VDC 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 in Service Data 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 megohmmeter 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 Service Data 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 on zero (0), and the control switch is off.
2. Connect one electrode firmly in contact with the insulated conductor of the circuit being tested. Refer to wiring diagram for suitable points of connection.
3. Connect 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.

SERVICE DATA

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.

2. Open ground relay cutout switch.

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 terminal strip vacated by the module, jumper pins 15 and 16 to pin 17.

7. Jumper positive to negative at the battery charging rectifier CRBC.

8. Jumper from left-yellow to right-yellow on ground relay CRGR.

9. 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+.

10. At main generator output, jumper all positive and negative buses together.

11. Disconnect or jumper out any electronic equipment such as radio, train control, speed indicator, automatic reset devices, and fault counters.

12. High Voltage DC Circuits

    Ground the low voltage DC circuits, 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.

13. 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.

14. Low Voltage DC Control Circuits

    Remove the ground from the low voltage DC circuits, and connect the ground to the D14 alternator. Perform megohmmeter check on low voltage DC circuits and equipment, including the engine cranking motors.

15. When the tests are completed, be certain to remove all shorting and grounding jumpers.

16. 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 a 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 follows:

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 in 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 VDC 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 VDC 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 preforming 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 VDC.

MANOMETER

A simple water manometer will be required to measure air pressure drops across various devices.

CAUTION

Never use a test lamp, bell ringer, or megohmmeter for troubleshooting modular or solid state control circuits. A lamp may overload the circuits, and a bell ringer or megohmmeter may produce destructive voltages.

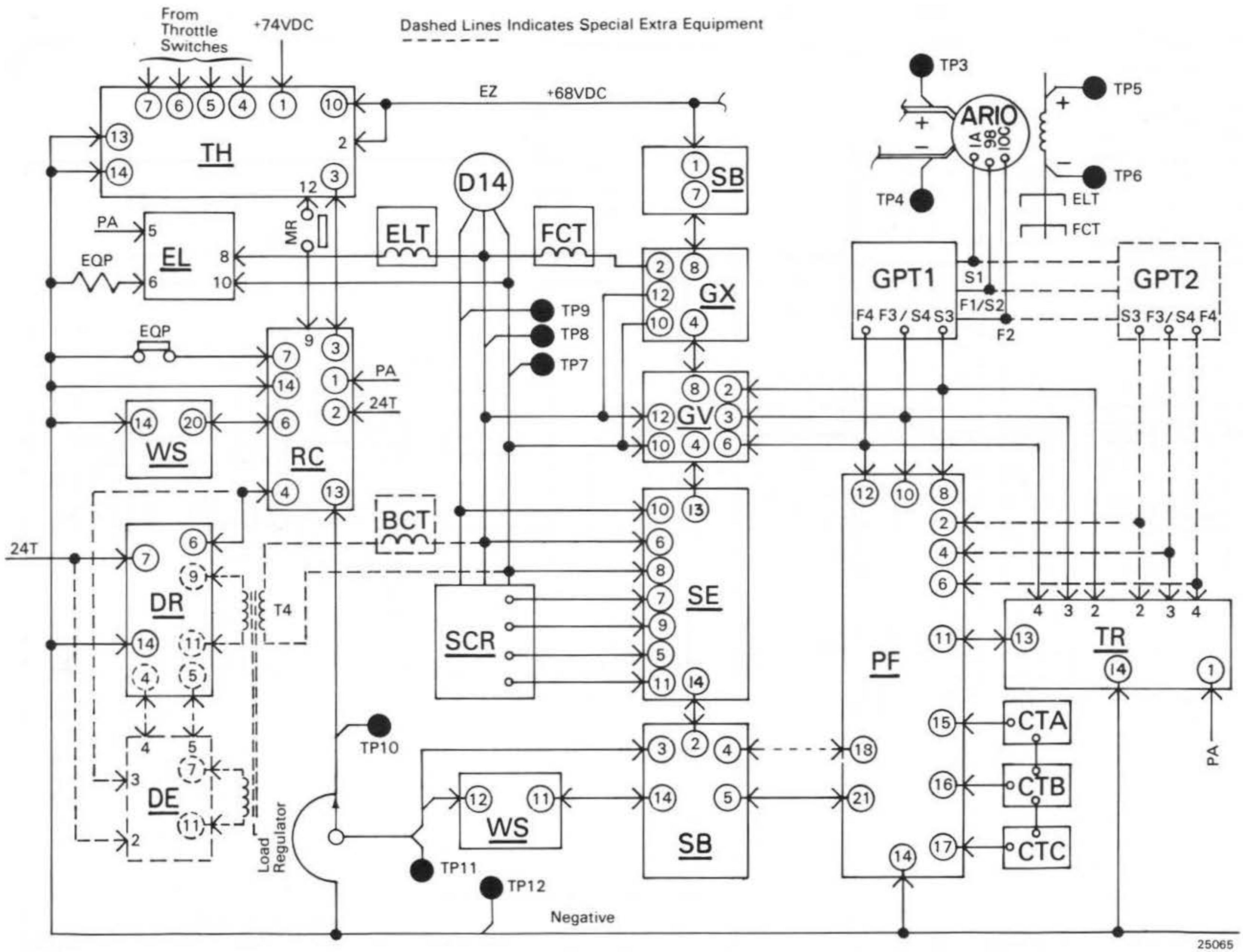
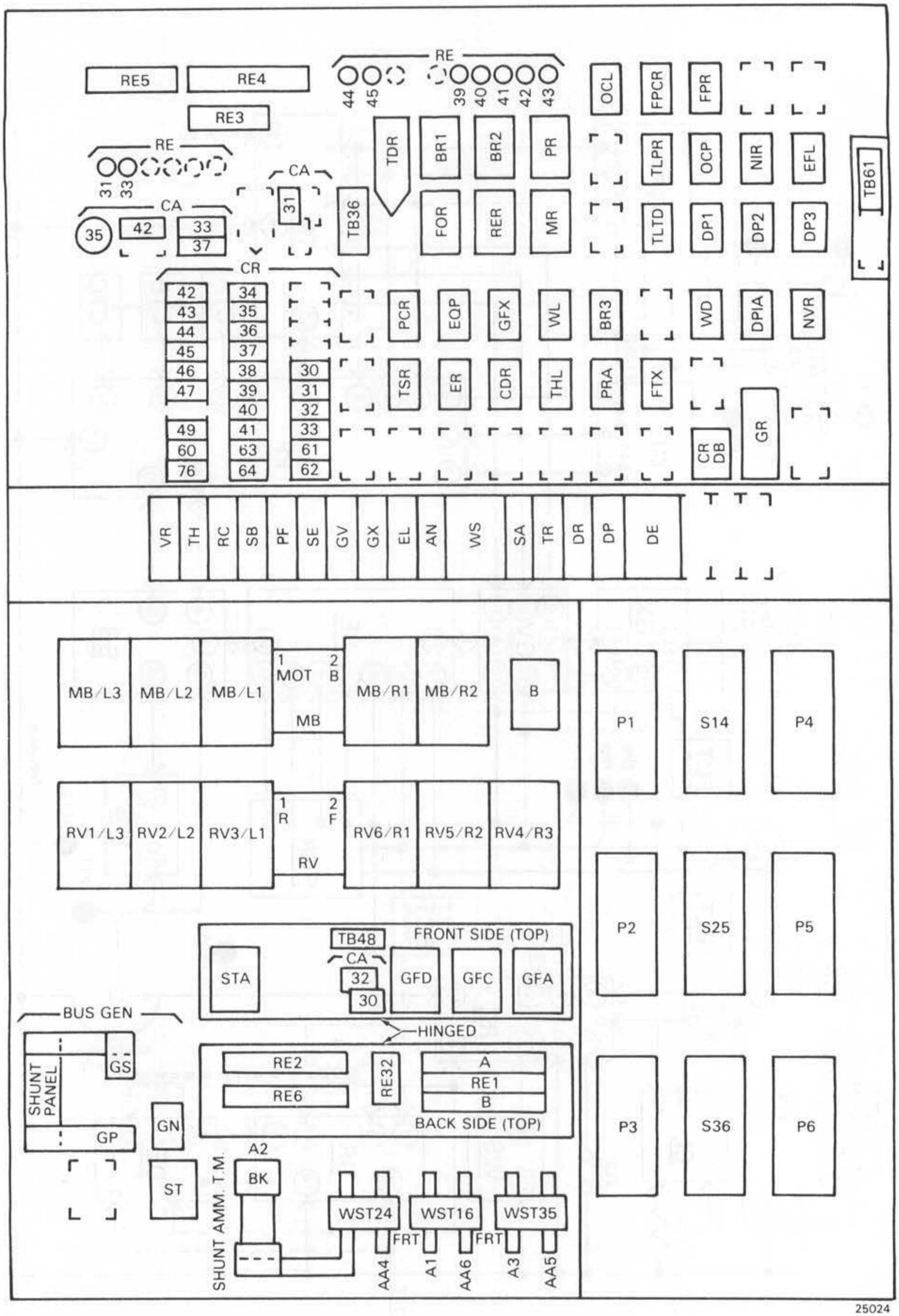
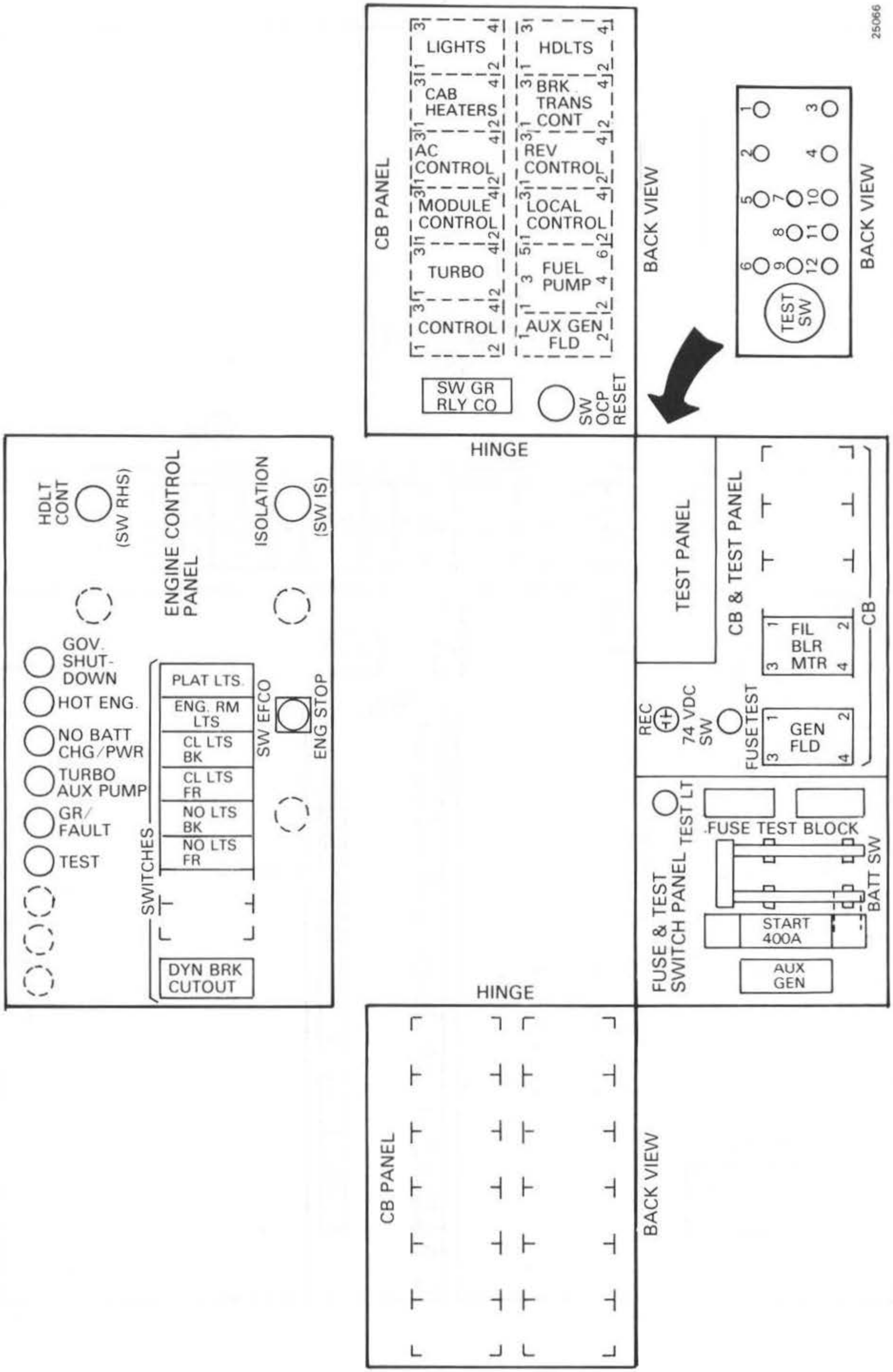


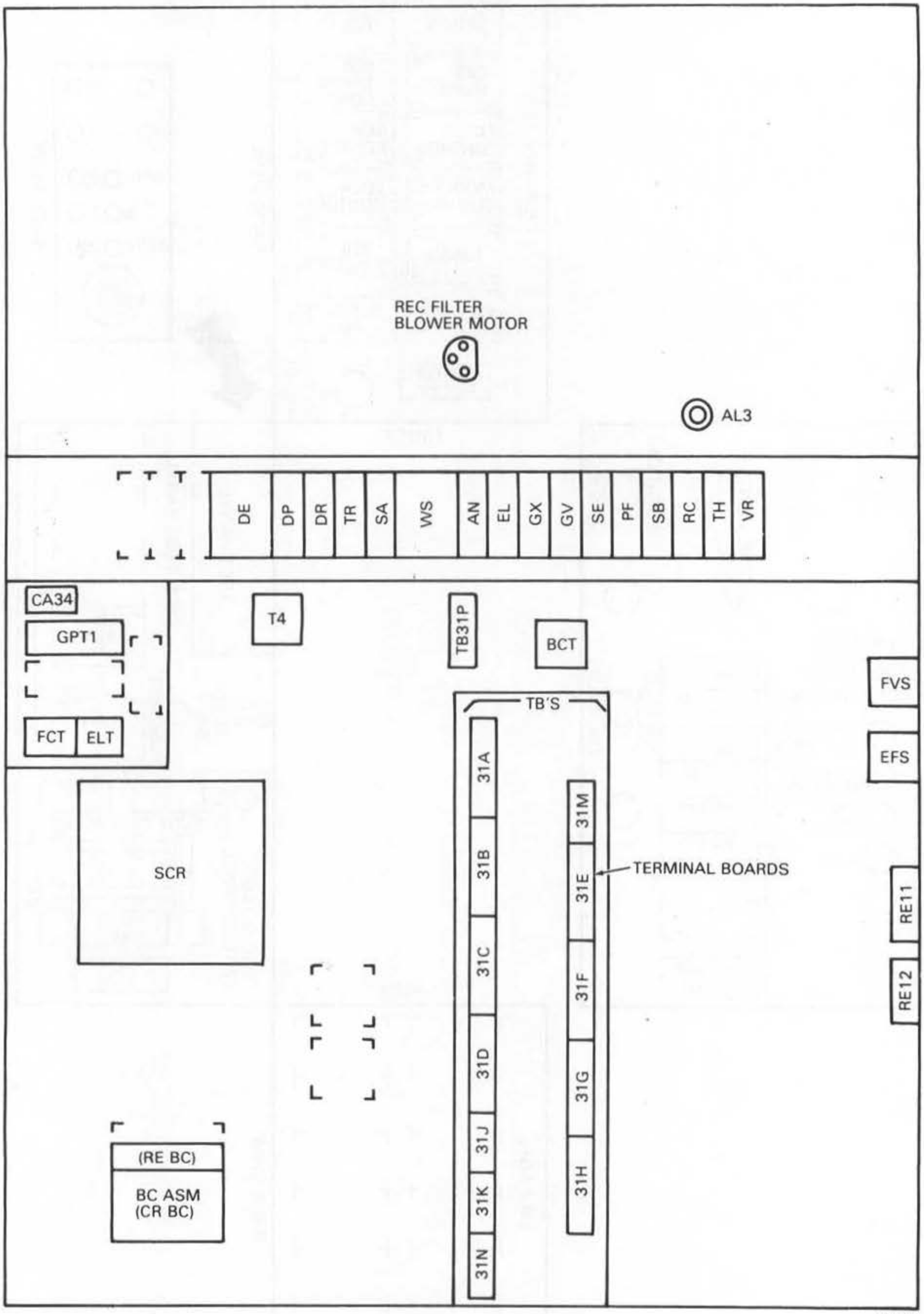
Fig.11-1 – Excitation System Simplified Block Diagram



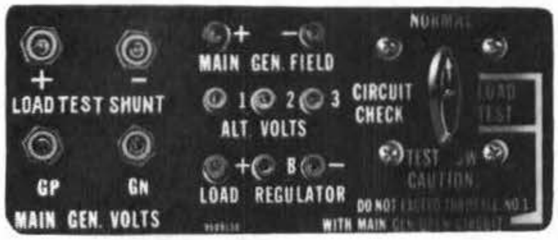
Typical Component Location Block Diagram



25066
CB PANEL
LIGHTS
HDLTS
CAB HEATERS
BRK TRANS CONT
AC CONTROL
REV CONTROL
MODULE CONTROL
LOCAL CONTROL
TURBO
FUEL PUMP
CONTROL
AUX GEN FLD
SW GR RLY CO
SW OCP RESET
BACK VIEW
TEST SW
BACK VIEW
HINGE
HDLT CONT
(SW RHS)
ENGINE CONTROL PANEL
ISOLATION
(SW IS)
GOV. SHUT-DOWN
HOT ENG.
NO BATT CHG/PWR
TURBO AUX PUMP
GR/ FAULT
TEST
SWITCHES
PLAT LTS.
ENG. RM LTS
CL LTS BK
CL LTS FR
NO LTS BK
NO LTS FR
DYN BRK CUTOUT
SW EFCO
ENG STOP
TEST PANEL
CB & TEST PANEL
FIL BLR MTR
CB
REC
74 VDC SW
FUSE TEST
GEN FLD
TEST LT
FUSE TEST BLOCK
BATT SW
START 400A
AUX GEN
FUSE & TEST SWITCH PANEL
HINGE
CB PANEL
BACK VIEW



Typical Component Location Block Diagram



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NOTE
Load Regulator Positive 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

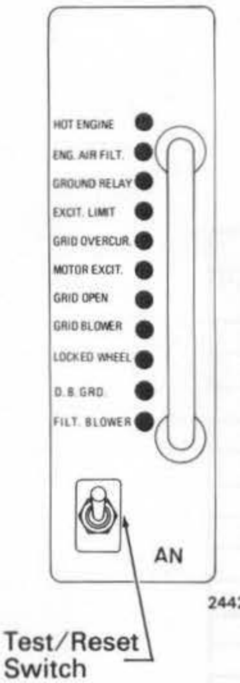
Circuit check position does not prevent excitation of the main generator. On units NOT equipped for automatic self loading, load test position will open circuit the main generator. Do not exceed throttle No. 1 with AR10 open circuit.

Do not return test switch to normal position while unit is under Load.

25287

Test Panel

OPERATING FUNCTIONS AT TEST POINTS



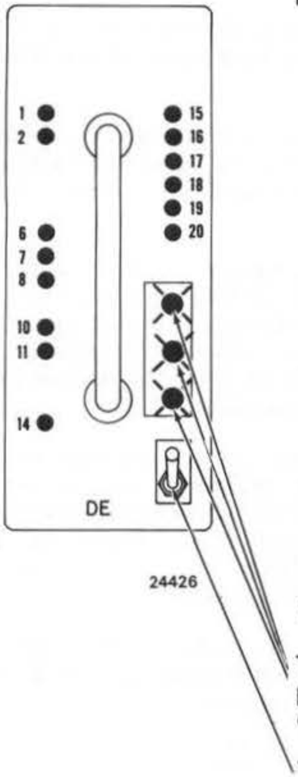
AN The annunciator module receives signals from various fault detecting devices. When a fault signal has been received, the applicable fault light remains on until the reset switch is operated after the fault signal has ceased.

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 special extras, the eighth light is provided on units equipped with dynamic brakes, a ninth light is provided on units equipped for locked wheel detection, a tenth also available on units with dynamic brakes, and an eleventh available to indicate filter blower fault.

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.	Restricted 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 field 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.
LOCKED WHEEL	One or more motor armatures fail to turn, either under power or isolated.
D.B. GRD.	Current path to locomotive ground in the dynamic brake grid resistor circuitry.
FILT. BLOWER	Tripped filter blower motor circuit breaker.

OPERATING FUNCTIONS AT TEST POINTS



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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 and dropout of grid shorting contactors.

Test Switch-Operate to sequence 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.

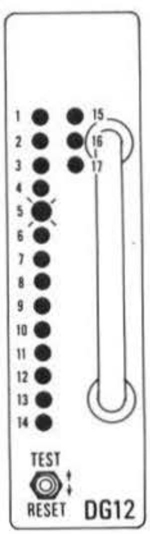
17 Output to pick up pilot relay DP2 and grid shorting contactor DC2, and dropout grid shorting contactor DC1.

18 Output to hold DP2 picked up.

19 Output to pick up the pilot relay DP3 and grid shorting contactor DC1.

20 Output to hold DP3 picked up.

DG Provides protection for the dynamic brake grids should a fault occur in either grid blower motor circuits. DG operates to dropout the "B" contactor should a fault occur.



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1 Control circuit DC positive input; reduced to plus and minus 15 VDC by zener diodes.

2 Zener diode output; +15 VDC when referenced to terminal 13 which is common.

3 +74 VDC output to AN module when DGR is picked up.

4 +74 VDC output to DGX relay when DGR is dropped out.

5 Red LED; indicates DG has detected a fault in the grid blower circuit, or the switch has been activated.

6 When referenced to common, indicates voltage applied to 6 and 8 of OP2 which is compared with the +4.3 VDC bias applied to 5 and 9 of OP2.

7, 8, 9, 10, 11, 12 Inputs from grid blower motor circuit.

13 Common

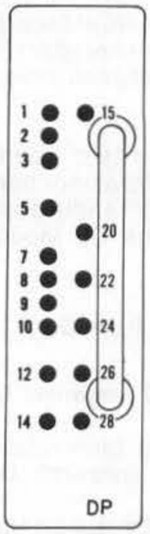
14 Locomotive negative

15 When referenced to common, indicates +4.3 VDC bias applied to 5 and 9 of OP2.

16 When referenced to common, voltage at this terminal is bias voltage applied to Q2 of the output stage.

17 When referenced to common, voltage at this terminal will indicate positive or negative saturation at 12 of OP1.

OPERATING FUNCTIONS AT TEST POINTS



24427

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 VDC 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.

20 On units with extended range dynamic brakes, negative input from dynamic brake grids provided only during pickup of grid shorting contactors to disable grid protection circuitry.

22 Pos input from traction motor armature and brake grids to brake warning circuit.

24 Same as TP22.

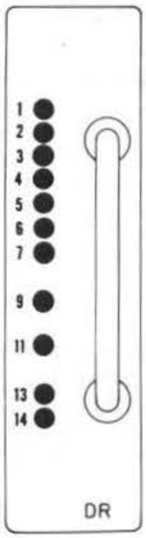
26 Same as TP22.

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.



24428

1 Positive high voltage input from dynamic braking grids.

2 Provision only.

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 trainlined control, but not equipped for extended range dynamic braking.

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.

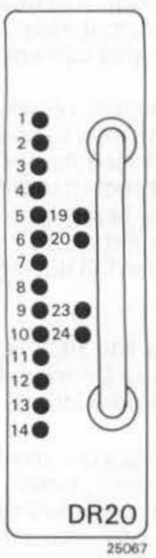
7 Functional on units equipped for grid current trainlined control and not equipped with extended range dynamic brakes. 24T input from brake rheostat. Signal is at a value related to braking handle position. It is matched with BCT signal (TP9-11 below).

9, 11 Not used on units equipped for extended range dynamic brakes. On units equipped for grid current trainlined 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



DR20 The DR20 module is used on units which operate at idle engine speed with field current levels below 800 amperes and grid current levels below 575 amperes. If field current or grid current levels rise above these values during dynamic braking, this module applies a signal to the engine speed control circuitry which automatically increases engine to throttle 4 speed. The throttle 4 speed signal is applied to the grid logic and field current limiting circuits increasing the grid current limit and removing the field current limit. Field current limiting is then controlled by the PF and SB modules or the FP module.

The proportional braking grid signal received by this module is applied to the grid current feedback circuit. Signal output from this circuit is applied to the grid current regulation and RC module discharge comparator where it is compared with the grid current reference signal. If the feedback signal rises above the reference signal, the RC module capacitors discharge as necessary to limit the feedback signal to the reference value.

1 Positive 74 VDC control voltage input to module power supply.

2 Output from governor solenoid drive circuit to governor solenoids A and C to increase engine to throttle 4 speed.

3 +74 VDC signal (21T) input to governor solenoid drive circuit during dynamic braking.

4 Field current feedback signal from RC module to traction motor field current limit circuit.

5 Proportional grid current feedback negative input.

6 Positive grid current feedback input.

7 Positive grid current anticipation input to stabilize regulation.

8 Discharge path from RC module capacitors, RC terminal 8.

9 Stabilize +68 VDC from TH module to differential amplifier OP3 of reference voltage circuit.

10 Discharge path from RC module capacitors, RC terminal 4.

11 Negative 74VDC (NM).

12 24T braking signal voltage reference.

13 +74 VDC input to grid current reference circuit during field current trainlined control operation to nullify the reference signal, left open on units equipped with grid current trainlined control.

14 Negative control voltage input to module power supply.

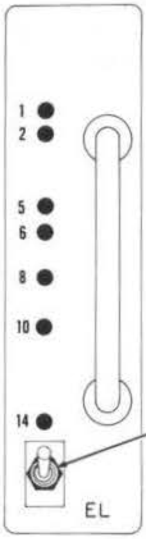
19 +15 VDC above common from module power supply.

20 Common

23 100 A/V grid current feedback signal.

24 100 A/V grid current reference signal.

OPERATING FUNCTIONS AT TEST POINTS



23845

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.

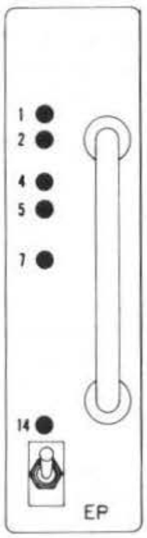
Simulates excessive generator excitation.

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.



21622

EP Regulates engine cranking speed between 25 and 30 RPM for six seconds. This protects the engine in case of a hydraulic lock.

1 +74 VDC input to EP module.

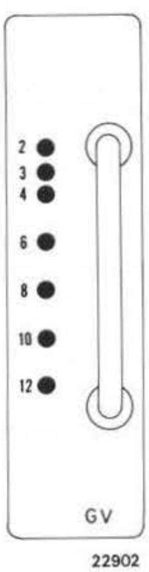
2 Light emitting diode indicates pickup of EPC.

4 Voltage input signal from EP shunt.

5 Voltage signal on timing capacitor of six seconds timer.

7 Q2 collector voltage.

14 Negative.



22902

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.

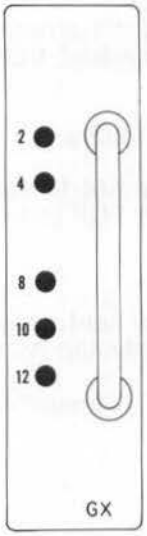
2, 3, 6 } Input, generator voltage signal from generator potential transformer GPT.

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.

OPERATING FUNCTIONS AT TEST POINTS



23847

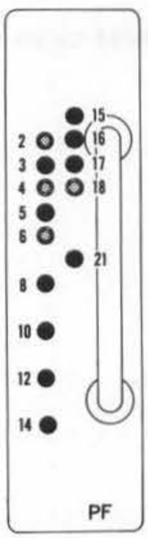
GX Provides a limit to the generator field current by interrupting the current to the SE control winding. Receives a signal proportional to field current from the FCT (field current transductor).

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.



23848

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.

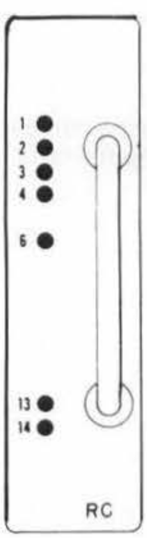
8, 10, 12 } AC feedback signal from generator potential transformer GPT1.

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.)



24096

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 VDC.

2 Input, 24T variable DC from brake rheostat.

3 Input, variable DC from TH module.

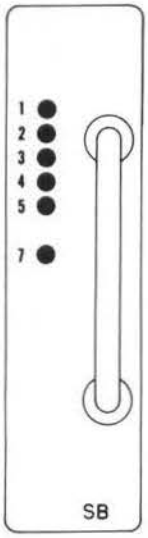
4 Input, brake regulation by DR module.

6 Output, discharge of rate capacitor at wheel slip and when DC contactors operate.

13 Output, reference voltage to load reg.

14 Control circuit DC negative; NA.

OPERATING FUNCTIONS AT TEST POINTS



23011

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 VDC.

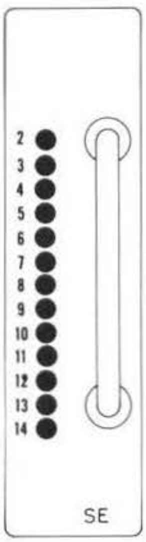
2 Input signal from Sensor.

3 Reference voltage input signal from load regulator.

4 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. This signal is utilized below minimum continuous speed.

7 Output to Sensor control windings thru GX and GV modules.



21552

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.

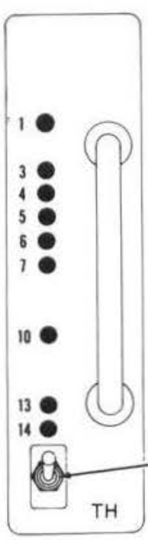
6, 8, 10 } AC power supply from D14.

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.



21553

TH Provides a closely regulated voltage (68 VDC) at terminal 10 for use as a reference.

TH throttle response circuit modifies the output voltage so that output voltage increases to 68 VDC in Run 8.

1 Input, 74 VDC to VRR.

3 Output, variable DC from throttle response relays.

4 Input to TH from THS 2, 4, 6, 8.

5 Input to TH from THS 5 thru 8.

Operate to drive load regulator toward minimum field position.

6 Input to TH from THS 3 thru 8.

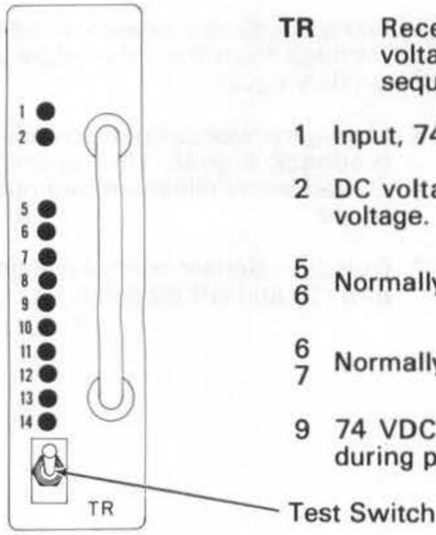
7 Input to TH from THS Stop, 5, 6.

10 68 VDC output from VRR.

13 Negative - throttle response circuit.

14 Negative - VRR circuit.

OPERATING FUNCTIONS AT TEST POINTS



23012

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 VDC; supply voltage.

2 DC voltage proportional to AR10 voltage.

5
6 Normally open BTR interlock.

6
7 Normally open FTR interlock.

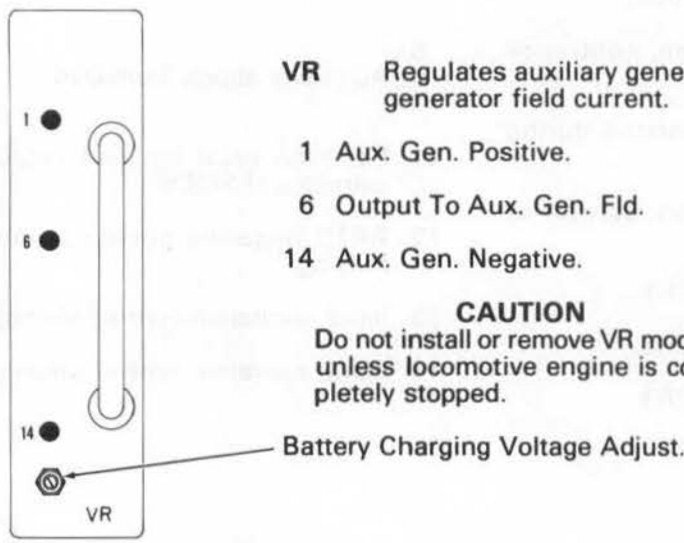
9 74 VDC input to recalibrate FTR during parallel motor connection.

11 Timed 74 VDC input to recalibrate FTR and BTR for a delayed period to prevent cycling.

12 Momentary 74 VDC signal holds FTR dropped out and BTR picked up.

13 Current feedback signal from PF module.

14 NA negative.



21554

VR Regulates auxiliary generator voltage to 74 VDC by controlling the auxiliary generator field current.

1 Aux. Gen. Positive.

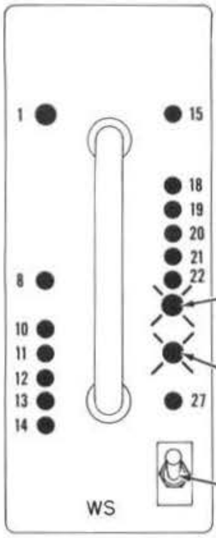
6 Output To Aux. Gen. Fld.

14 Aux. Gen. Negative.

CAUTION
Do not install or remove VR module unless locomotive engine is completely stopped.

OPERATING FUNCTIONS AT TEST POINTS

WS Receives signals from WST and, on units equipped with dynamic brakes, from motor voltage bridge circuit. Provides various corrections to reference voltage; actuates sanding, wheel slip light, and ORS under some conditions.



22901

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.

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 Ouptut to base of SB transistor.

13 Control circuit DC negative; N.

14 Control circuit DC negative; NM.

15 Input upon pickup of WO RB relay 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 VDC input to test switch.

27 Test point for zener breakdown voltage of 16 VDC.

SD40-2 ELECTRICAL QUALIFICATION AND TROUBLESHOOTING GUIDE

NOTE

Refer to the following information when operating test switches on the DG, EL, and WS modules.

The test circuits used in the DG, EL, and WS modules rely on adequate D14/D18 and 74 V control voltage for proper response. When low idle was applied to locomotives, problems were encountered with the test procedures due to the lower D14/D18 voltages in low idle mode and EMD recommended all tests be performed with the engine at normal idle speed.

Locomotives are now being equipped with AC auxiliary generators and because of inherent characteristics of this machine, both D14/D18 74 V control voltages are lower than normal with the engine at normal idle. The low voltages are now causing problems with the DG, EL and WS test procedures. Extensive modifications in the control circuitry would be required to permit proper functional tests in normal idle. This type of modification would be impractical; therefore, EMD recommends the throttle be advanced if the test procedure fails in normal idle.

If the DG, EL or WS module test procedure fails in normal idle, advance the throttle with reverser centered until normal control voltage is obtained and the module re-tested. In most cases throttle 3 position will be adequate to perform a satisfactory test.

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 Switch	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	27 to 60 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	None	10.9V	Open Gen. Field Circuit Breaker & Remove SB Module During Test. Test Panel TEST SWITCH In CIRCUIT CHECK Position. All Voltages ± 1V Except As Noted. Measure Voltage From TH14 Test Point 3 To RC12 Test Point 14
				Throttle Two	None	21.6V	
				Throttle Three	None	28.6V	
				Throttle Four	None	35.7V	
				Throttle Five	None	43.3V	
				Throttle Six	None	51.2V	
				Throttle Seven	None	61.4V	
				Throttle Eight	None	68.0 ± 0.3V	
	3.	RC12	Rate Control	8th Throttle Power	None	50 ± .5V	At RC-TP13
	4.			8th Throttle Brake		49.6 ± 1.5V	
	5.	GV12	Voltage Limit Regulator	0.8 to 0.9 Ohm Grid Load	None	1250 ± 25V	Run 8, 5 to 9 Jumpered
	6.	GX2	Excitation Limit Regulator	AR10 Short Circuit Measure Gen. Field Current	None	108 ± 2A	5 to 6 Jumpered
	7.	EL11	Excitation Limit Protection	AR10 Short Circuit Measure Gen. Field Current	None	114 ± 3A	Pick-Up
III DYNAMIC BRAKE	1.	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	Pick-Up
						628 ± 26A	Drop-Out
	3.	DP12	Mtr. Field Current Protection	AR10 Open Circuit In Dynamic Brake	None	75 ± 4V	Pick-Up
						30 ± 5V	Drop-Out
	4.	OCP	Open Circuit Protection		None	550 ± 50V	Pick Up. Reset At OCP Reset Button
	5.	IPS	Flat Wheel Protection		Device	See Air Piping Sch.	Drops Out DC Contactors

24097

ELECTRICAL QUALIFICATION
AT STANDSTILL

PURPOSE OF CHECK	GENERAL QUALIFICATION TEST SETUP	ACTION	RESPONSE
Checking excitation system response to throttle.	Power setup; Engine running; Reverser Fwd; Air Brake set.	Place throttle in No. 1.	Load current indicating meter rises slowly to between 200 and 350 and stops.
		Momentarily place throttle in No. 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 in 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 when WS test switch is released.
		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 VDC. 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 VDC. (74 VDC 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 with SB module pulled.)
		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 VDC in Run 8. (About 18 to 36 seconds build up time.)
		Return throttle to idle.	**NOTE** If SB module has been pulled, 50 VDC will be present in throttle No. 8.

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 No. 8.	Voltmeter indicates between 40 and 50 VDC.
		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.	Ohmmeter should show low resistance.
		Ohmmeter on low resistance (R x 100) scale. Lead of positive polarity at GV-TP8; lead of negative polarity at GV-TP4.	
		Pull out to disconnect GV module.	Ohmmeter indicates high resistance.
		Disconnect ohmmeter. Reinstall GV and SB modules.	

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.) Braking handle in SET UP position. ER switch off.	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 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 VDC. 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 braking handle to OFF and reset AN module. Operate reverser handle to Bkwd. and Fwd.	
Checking for grid over-current protection.	Engine running; controls set up for dynamic braking; Braking handle in SET UP 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 VDC 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 Trouble-shooting 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 braking handle in position 3.	Engine speed increases to Run 5 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 indications.
		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 braking handle to SET UP position.	Engine goes to idle speed; lamps remain on.
		Return braking handle to OFF position.	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. *Units with automatic self loading:* 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. *Units without automatic self loading:* 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.	OCP should pick up and the GRID OPEN light on the AN module should come on at approximately 550 volts.

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.

		Throttle IDLE. Reverser forward. Disconnect jumpers and meter. Move braking handle to SET UP position.	The "B" contactor will *not* pick up.

CAUTION

Do not allow main generator voltage to exceed 800.

		Return test switch to NORMAL position. Reverser Fwrd. 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 braking handle 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 braking handle to SET UP. Operate DG module reset switch. *Reset annunciator.*	DG test lamp goes out. GRID BLOWER light goes out.
Checking LW module response.	Power setup; Engine running; Throttle idle; Locomotive at standstill.		**NOTE** Proper LW test response can be obtained on a dead unit if the 13T, control, and local control circuits are energized.
			LW module LT-A light on.
		Turn LW test switch to TEST 1 position.	LT-A light off; LT-B light on.
		Turn LW test switch to TEST 2 position.	LT-A and LT-B light off. LOCKOUT light on. WHEEL SLIP light on steady; Alarm bell (and buzzer) sounds.
		Turn LW test switch to RESET position, then to NORMAL.	LT-A on; LT-B and LOCKOUT lights off. WHEEL SLIP light off; bell (and buzzer) off.
		Reset AN module.	LOCKED WHEEL light off.
Checking input to LW module.	Power setup; Unit moving under its own power or being pulled at speed above 1 MPH.	Connect 0-50 DC voltmeter negative lead at LW test point 13. Connect positive meter lead at test points TM-1 thru TM-6.	Voltage nominally equal at all test points at a given speed. Lack of voltage may indicate faulty cable or connection at traction motor pickup.
		Locomotive at standstill; open all TM toggle switches and hold test switch in TEST 1 position.	Voltage nominally equal at all test points. Low voltage at any test point indicates a faulty LW module.

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. 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 VAC, 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 2 to 5 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 CORRECTION 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 VDC; 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 VDC; 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 VDC. If less than 65 VDC; Failed TH module. b. SB-TP1 to SB-TP7 - If more than 35 VDC; Failed SB. c. GX-TP8 to GX-TP4 GV-TP8 to GV-TP4 - If more than 5 VDC; Failed GX or GV. d. SE-TP13 to SE-TP14 - If more than 5 VDC; Failed SE. e. SB-TP2 to SB-TP4 - If more than 35 VDC; Failed SB. f. SB-TP2 to SB-TP5 - If more than 35 VDC; Failed SB.

g. PF-TP21 to PF-TP14 –
PF-TP18 to PF-TP14 –
Voltages less than 10 VDC. If voltage is 50 VDC; Failed PF. If voltage is more than 50 VDC; Failed SB. If there is no voltage; Failed WS or SB.

h. Check for equal voltages (approximately 75 VAC 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 VDC; 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 VDC, check wiring to TH-TP1.

b. TH-TP10 to TH-TP14 – If less than 65 VDC, failed TH.

c. TH-TP3 to TH-TP14 – If less than 65 VDC, failed TH, or wiring error from TH-TP10 to TH-TP2.

d. RC-TP3 to TH-TP14 – If less than 65 VDC, check wiring between TH and RC.

e. RC-TP13 to RC-TP14 – If less than 40 VDC, remove WS. If voltage increases to more than 65 VDC, 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 VDC, 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 VDC, failed WS.

h. Non-dynamic unit – WS-TP12 to WS-TP11 } -If more than 15 volts,
Dynamic Unit – SB-TP3 to WS-TP11 } 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 VDC. 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 jumepr is applied, replace DP module with a qualified DP and repeat test.
LOSS OF POWER REPORTED UNDER SEVERE TRACK AND GRADE CONDI-TIONS	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 RE-PORTED	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-TP8 to DR-TP10 should be 135 to 165 VAC. 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 trainlined 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.

GENERAL TROUBLE GUIDE

OPERATING OR TEST CONDITION	ENGINE SPEED	HP V x A / 700	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

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.

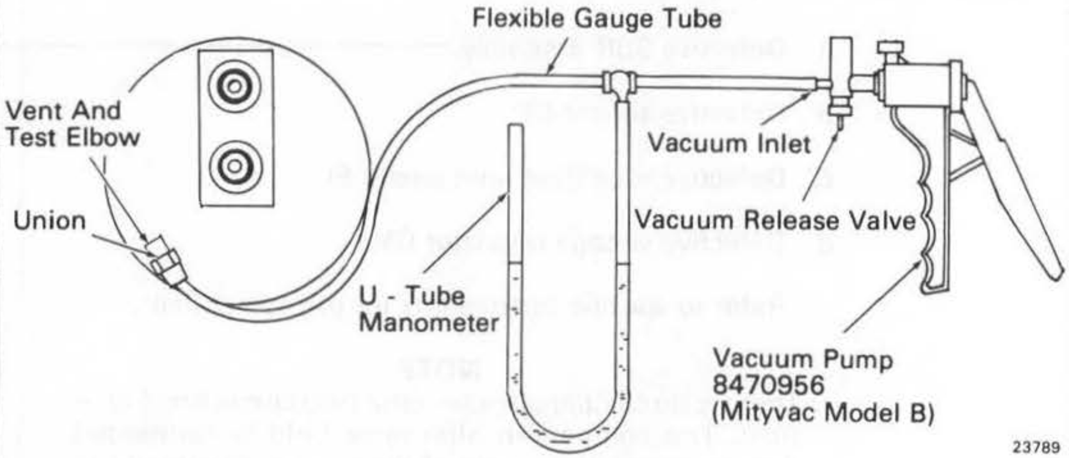
BATT	Battery
CB	Circuit Breaker
CP	Crankcase (Oilpan) Pressure
CT	Current Transformer
EL	Main Generator Field Excitation Limit Module
EMM	Engine Maintenance Manual
FP	Feedback Performance Module
FZ	Fuse
GCT	Grid Current Transductor
GOV	Governor
GPT	Generator Potential Transformer
GR	Ground Relay
GV	Generator Voltage Module
GX	Generator Excitation Module
HDL	Headlights
HOT	Hot Engine
LO	Low Oil Pressure
LR	Load Regulator
MFCT	Motor Field Current Transductor
NVR	No Voltage Relay (Aux. Gen; Comp. Alt.)
RC	Rate Control Module
SA	Sanding Module
SCR	Main Gen. Excitation Controlled Rectifier
SE	Sensor Module
TEM	Temperature Switches
TH	Throttle Response (And Reference Voltage Regulator) Module
UL	Underloading-Unloading
UL-D	Unloading - Dynamic Brakes
VR	Voltage Regulator Module
WO	Wheel Overspeed Module
WS	Wheel Slip Module
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 VDC.	
	→ *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 companion 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 manufacturer's manual.) Check voltage at auxiliary generator fuse clip and right side of main battery switch.	
	→ Between 71 and 78 VDC.	
	→ *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
CB	AUX. GEN. FIELD BREAKER TRIPPED	
	→ Engine shut down and isolated. Pull out the VR module and open the auxiliary generator circuit breaker. 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. circuit breaker.	
	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.	
	NOTE There is no companion alternator field circuit breaker or fuse. The companion alternator field is connected directly across the output of the auxiliary generator in order to minimize any voltage drop in the cabling and thus maintain full companion alternator excitation and ensure rapid fan motor starting. If a short circuit appears across the output of the auxiliary generator, the machine being self excited will not support the short. Voltage will come down and the machine will not be harmed. A "no power" alarm will be given, and engine speed and power will be reduced to idle condition.	

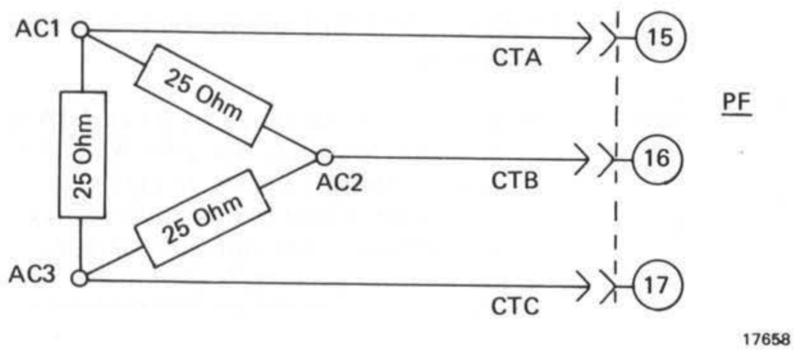
GENERAL TROUBLESHOOTING OUTLINE

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
CP	CRANKCASE PRESSURE DETECTOR SUSPECTED DEFECTIVE — Any time a true crankcase pressure trip has occurred, or is suspected to have occurred.	
	→ Check crankcase (oil pan) pressure detector trip value, using 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 3.0" 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. 260*



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 —**	
CT	CTA, CTB, CTC, CURRENT TRANSFORMERS SUSPECTED DEFECTIVE — Underloading	UL

AR10 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 31M 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*

CAUTION

Do not excite the main generator with wires CTA, CTB, and CTC disconnected. Extremely high and damaging voltage will result.

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 23.6 ± 2.36 ohms. Greater variation indicates shorted turns or open windings.)

If current transformers are not defective, verify that there is no fault in generator wiring.

GENERAL TROUBLESHOOTING OUTLINE

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 —**	
EL	EL MODULE SUSPECTED FAULTY	
	→ With isolation switch in RUN, generator field switch OFF, reverser handle in NEUTRAL, and throttle at IDLE, operate the EL test switch.	
	- - → EXCIT. LIMIT light on AN module comes on. The EQP relay drops out.	
	→ *If EQP relay fails to drop out and AN light fails to come on, advance throttle to No. 2 (or No. 3 if necessary) and again operate the test switch. If EQP relay fails to drop out and annunciator light fails to come on, replace EL module with a qualified module and retest. If replacement module fails to respond to test switch, qualify excitation limit transductor ELT.* → (go to 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 setting charts 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 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	Instruction Reference
	—— Test Procedure – – – Normal Indication For Test Setup Or Operating Condition *—— Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
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 No. 1 on basic units, and to No. 3 or 4 on units equipped for automatic self loading.	
	CAUTION Do not exceed No. 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.	
	→ Also read from PF-TP2 to TP4; TP2 to TP6; TP4 to TP6.	
	– – → The three readings should balance within 10% of each other.	
	→ *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	
	CHECKING FOR FAULT IN GV	
	→ Pull out the GV module; Connect a jumper from 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.* →	*GPT-2*
	(Continued)	

GENERAL TROUBLESHOOTING OUTLINE

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference

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 —**

(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 15K resistor in series with a 5K potentiometer. Connect the remaining potentiometer lead to TR-TP14. Connect the remaining resistor lead to TR-TP2. Position the brush arm at the terminal connected to the resistor lead. Connect the brush arm terminal to SB-TP5.

→ Connect an AC voltmeter at PF receptacle pins 8 and 10, then advance throttle as required and position the potentiometer to obtain an AC voltage reading.

→ 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.*

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
GR	GROUND RELAY 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*

GENERAL TROUBLESHOOTING OUTLINE

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

GROUND RELAY 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 collector 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.

GENERAL TROUBLESHOOTING OUTLINE

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

GROUND RELAY LIGHT FAILS TO COME ON
GROUND RELAY LIGHT COMES ON UNNECESSARILY

Locomotive controls set up for power operation; Air brakes set; Engine running; Reverser 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 VDC 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 VDC 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 at 150 VDC or less generator output.

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 31J 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 31J at the back of the electrical cabinet. Insulate or fold back the wire ends, and open the ground relay cutout switch. Apply 74 VDC across TB31J-L2 and TB31J-L3. If the relay fails to pick up, some ground relay circuit component is faulty.

GENERAL TROUBLESHOOTING OUTLINE

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 —**	
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 VDC) 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 VDC appears between GV-TP8 and TP4. No load current.	
	→ *Low voltage (less than 10 VDC) 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
GX	GX MODULE SUSPECTED FAULTY Unit not loading. Excitation limit annunciator light reported →	EL
	→ Connect jumper from C1 to C2 of GFX and from EL-TP5 to EL-TP6. Connect a 0-74 DC voltmeter from GX-TP4 to PF-TP14.	
	→ Controls set up for power operation; Throttle No. 1; Motors stalled.	
	→ Operate EL test switch.	
	- - → Voltmeter reading should drop to zero or near zero, and load meter at control stand should drop to zero or near zero.	
	→ *If readings are incorrect:* *a. Check AC input at GX-TP10 to TP12.* *b. Check AC input at GX-TP2 to TP12, and again press the EL test switch. AC voltage reading should increase. If it does not, perform FCT checks.* →	*GX-2*
	c. If AC inputs are correct, replace GX with a qualified GX and retest.	

GENERAL TROUBLESHOOTING OUTLINE

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 —**	
GX	GX MODULE OR FCT TRANSDUCTOR SUSPECTED FAULTY → Remove the generator bus at the base of the electrical cabinet, and short circuit the main generator. Disconnect the wires from the front negative terminal of GFD contactor and bolt one side of a 300 ampere 75 millivolt shunt to the terminal. Bolt the wires to the other side of the shunt. Connect a 0-75 millivolt meter to the shunt. → Connect a jumper from EL-TP5 to EL-TP6. → With the engine running and controls set up for power operation, advance throttle as required. – – → Generator field current should regulate at nominally 108 amperes. ▬→ *If regulation is not correct, check AC input at GX-TP2 to TP12 and at GX-TP10 to TP12. If AC input appears correct, replace GX with a qualified GX and retest.* ▬→ *If retest fails, replace FCT transductor with a qualified transductor and retest.* **CAUTION** Hold high field current levels for as short a time as practicable. → Return throttle to idle.	

GENERAL TROUBLESHOOTING OUTLINE

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; companion alternator output is satisfactory.	
	→ *Check for shorted SCR.*	*SCR**
	→ Check for tripped AC Control CB.	
	→ *AC Control Breaker tripped. Pull out circuit modules SE, WO, GV, EL, 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, 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 companion alternator voltage.	
	→ *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 tripped Aux. Gen. CB. If breaker is open, 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.* **CAUTION** *Make certain that the engine is completely stopped before removing or inserting a VR module.*	*VR*

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
	(Grid load checks continued from preceding page.)	
PF	PF MODULE OPERATING CHARACTERISTICS CHECK **NOTE** Use of the applicable Operating Characteristics graph is required during this check. The operating characteristics graph number is referenced on the PF module drawing. → Connect a load box in parallel with the dynamic braking grids or disconnect the grids and connect the load box independently. → Select steps of external loading resistance to obtain values of total loading resistance approximating the following. 1. 0.016 Ohm 3. 0.296 Ohm 2. 0.022 Ohm 4. 0.42 Ohm → Connect meters to read the following: 1. Main generator voltage = V_G 2. Main generator current = I_G 3. Load regulator voltage (+ to –) = V_{LR} 4. Load regulator arm voltage (arm to –) = V_{ARM} To determine generator voltage and current points within the power control (feedback) lines on the characteristics graph (grid load), apply the following formulas. $V_{GFB}=V_G\left(\frac{V_{LR}}{V_{ARM}}\right)$ $I_{GFB}=I_G\left(\frac{V_{LR}}{V_{ARM}}\right)$ V_{GFB} is the generator voltage that would result if horsepower were not controlled by load regulator action. I_{GFB} is the generator current that would result if horsepower were not controlled by load regulator action. - - → Each V_{GFB} - I_{GFB} point should fall within the power control (feedback) lines on the characteristics graph (grid load portion). → *If incorrect indications are obtained, check the various inputs to the PF module* → *If inputs are satisfactory, replace the PF module with a qualified PF, and retest.*	*GPT* *CT's*

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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
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 VDC in from 18 to 36 seconds time. → Jumper from RC-TP6 to RC-TP14. → Voltage should drop to less than 10 volts in 2 to 5 seconds. → *If incorrect indications are obtained, replace RC module with a qualified RC and retest.*	

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
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 VDC should appear across SB-TP2 to TP4. If it does not, replace SB with a qualified module and retest.*	

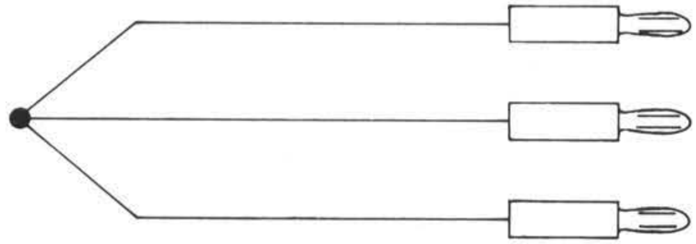
Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM Test Procedure Normal Indication For Test Setup Or Operating Condition *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault* —*	Instruction Reference
SCR	MAIN GENERATOR EXCITATION RECTIFIER SCR SUSPECTED FAULTY **NOTE** Most 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

GENERAL TROUBLESHOOTING OUTLINE

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 —**	
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 VAC. *Voltage incorrect or out of balance.* *a. AC control or Gen Field CB open.* *b. Open wiring or defective connection.*	

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
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 No. 1; Record current; Return throttle to IDLE and remove jumpers. → b. Jumper TP9 to TP5 to TP11 to check output to SCR G2. Place throttle in No. 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 No. 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.*	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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
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.) Special Switch Settings TA — FC1 — 155° F. TB — FC2 — 163° F. TC — FC3 — 171° F. (Verify temp indicated on switch nameplate.)	
	- - → Fans come 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 auxiliary gen. fuse to BN is minimum 72 VDC.*	

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
TH	TH MODULE THROTTLE RESPONSE OR REFERENCE VOLTAGE REGULATION SUSPECTED FAULTY	
	→ Engine running and warm; Open the Generator Field circuit breaker; Place test panel test switch in CIRCUIT CHECK position; Pull out SB module; Set up controls for power operation; Throttle Run 1.	
	- - → Voltage TH-TP10 to TP14; 67.7 to 68.3 VDC. Voltage TH-TP3 to TP14; 9.9 to 11.9 VDC. Advance throttle to Run 8. Voltage TH-TP3 to TP14 increases in steps to 67.7 to 68.3 VDC.	
	→ *Voltage out of tolerance; Qualify VR module.* →	*VR*
	If voltage TH-TP1 to TP14 is satisfactory (71 to 77 VDC) 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*

GENERAL TROUBLESHOOTING OUTLINE

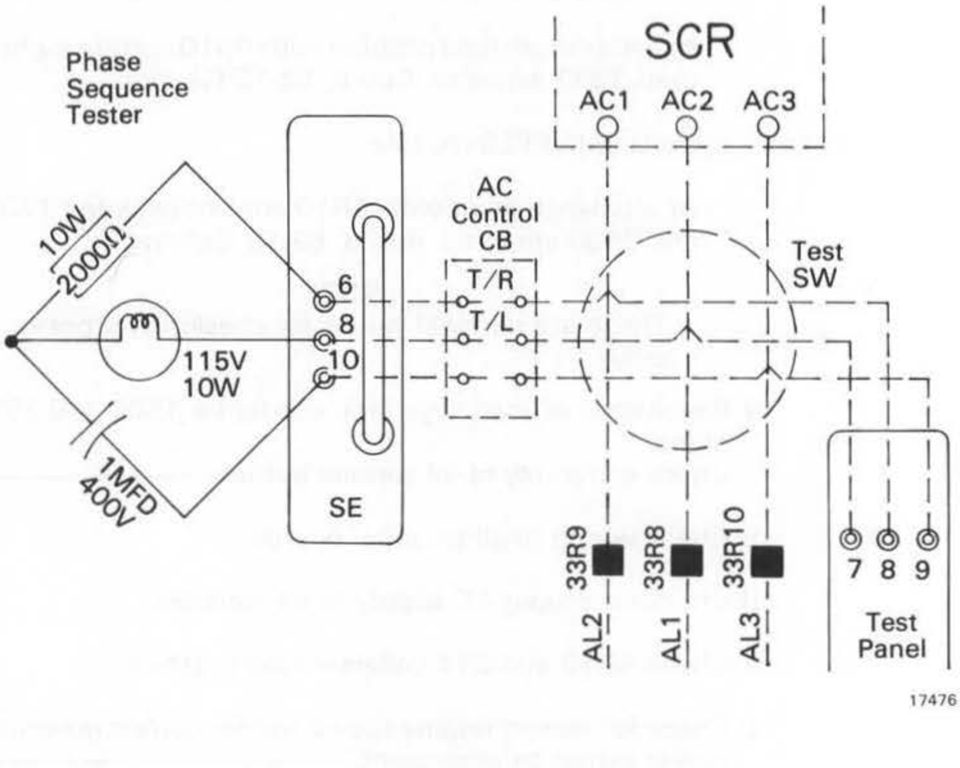
Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference
	—— Test Procedure – – – Normal Indication For Test Setup Or Operating Condition —— *Fault Indication And Corrective Step* *Asterisk Indicates Most Probable Fault —**	
TR	TR MODULE SUSPECTED FAULTY	
	→ Engine running; Generator 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.*	
	NOTE A locked wheel indication may occur when the "P" contactors drop out. Reset the LW module and the AN module if a locked wheel indication does occur.	

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
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.	
	c. Units with PF29 module. At a balance point with AR10 current between 1700 and 3600 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 collector 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.	

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
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 terminal boards.	
	4. Check SCR assembly.	SCR



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 —**	
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 VDC. If this voltage is correct, the DR module is satisfactory. The excitation system should be checked.	
	Voltage RC-TP13 to TP14 lower than 42 VDC 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.	

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
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 VDC 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 VDC.	
	→ *Replace VR with qualified module if any of the following conditions are observed.* *Voltage fluctuates between 20 and 40 VDC.* *No regulation. Auxiliary generator fuse blows.* *No voltage.* *Voltage oscillates between 80 and 85 volts.* *Low voltage cannot be brought up by adjusting screw.*	

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
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.*	

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
WST	WHEEL SLIP TRANSDUCTOR SUSPECTED FAULTY	

CAUTION

Use the following recommended method for obtaining differential current at the transductors.

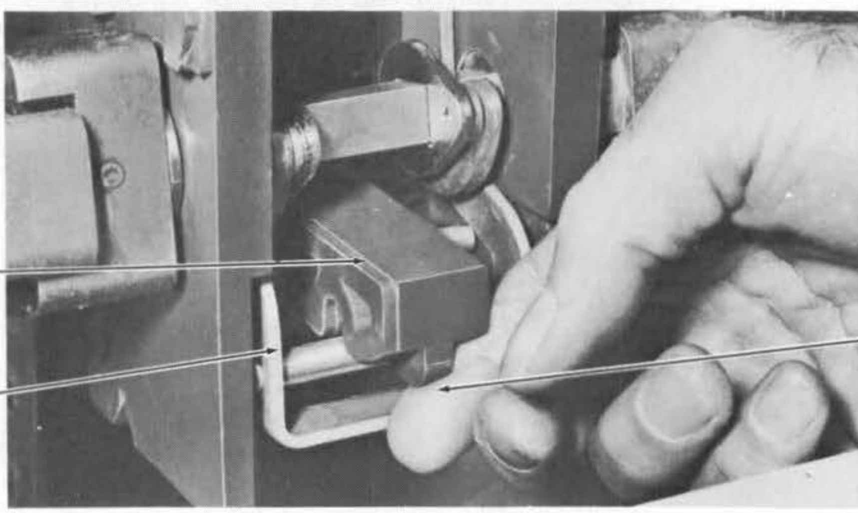
Do not place insulating material between power contactor or transfer switch main contact tips. The presence of foreign material at contact tips will lead to failure of the device.

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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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
	(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.	
	— Load 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*

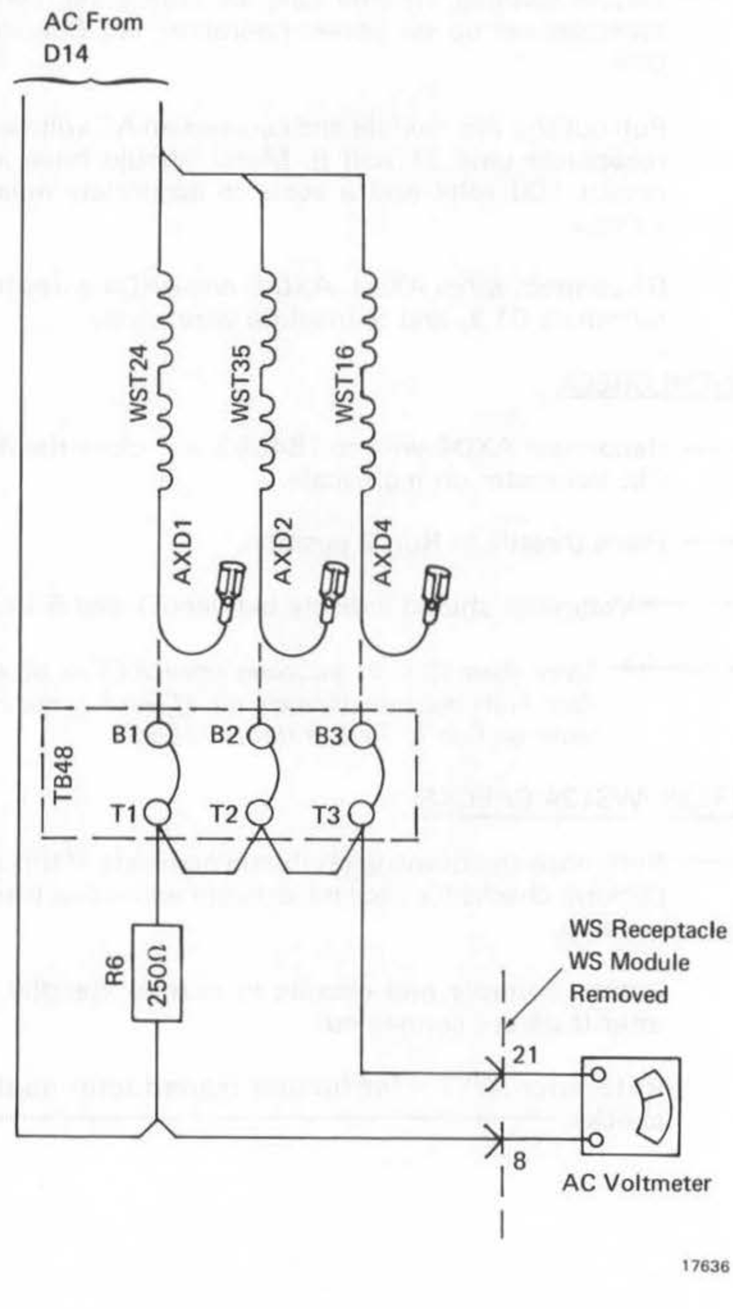
GENERAL TROUBLESHOOTING OUTLINE

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* —*	
	(Continued from WST24 check)	
	<u>WST35 CHECK</u>	
	→ Throttle idle; Open the AC Control CB. Disconnect the AXD1 wire from TB48B1. Insulate the end. Reconnect the AXD2 wire to TB48B2, RV2/L2 remains centered. 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*
	<u>WST16 CHECK</u>	
	→ 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 VAC.	
	→ *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

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
	(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.	
	Unless the voltage drop across one coil is approximately three times greater than the voltage drop across the second, no further testing is required.	
	→ *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)	

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

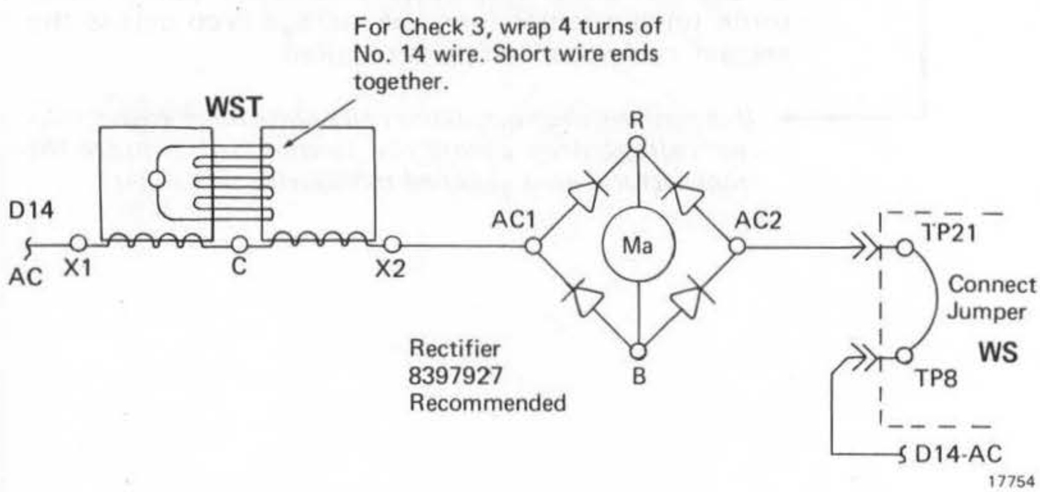
(WST characteristics checks continued)

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	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 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)

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
	(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.*	

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)	
	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)	

GENERAL TROUBLESHOOTING OUTLINE

Reference Symbol	TROUBLE – POSSIBLE CAUSE AND SYMPTOM	Instruction Reference

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 —**

(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. → WST-12
Immediately return throttle to idle.

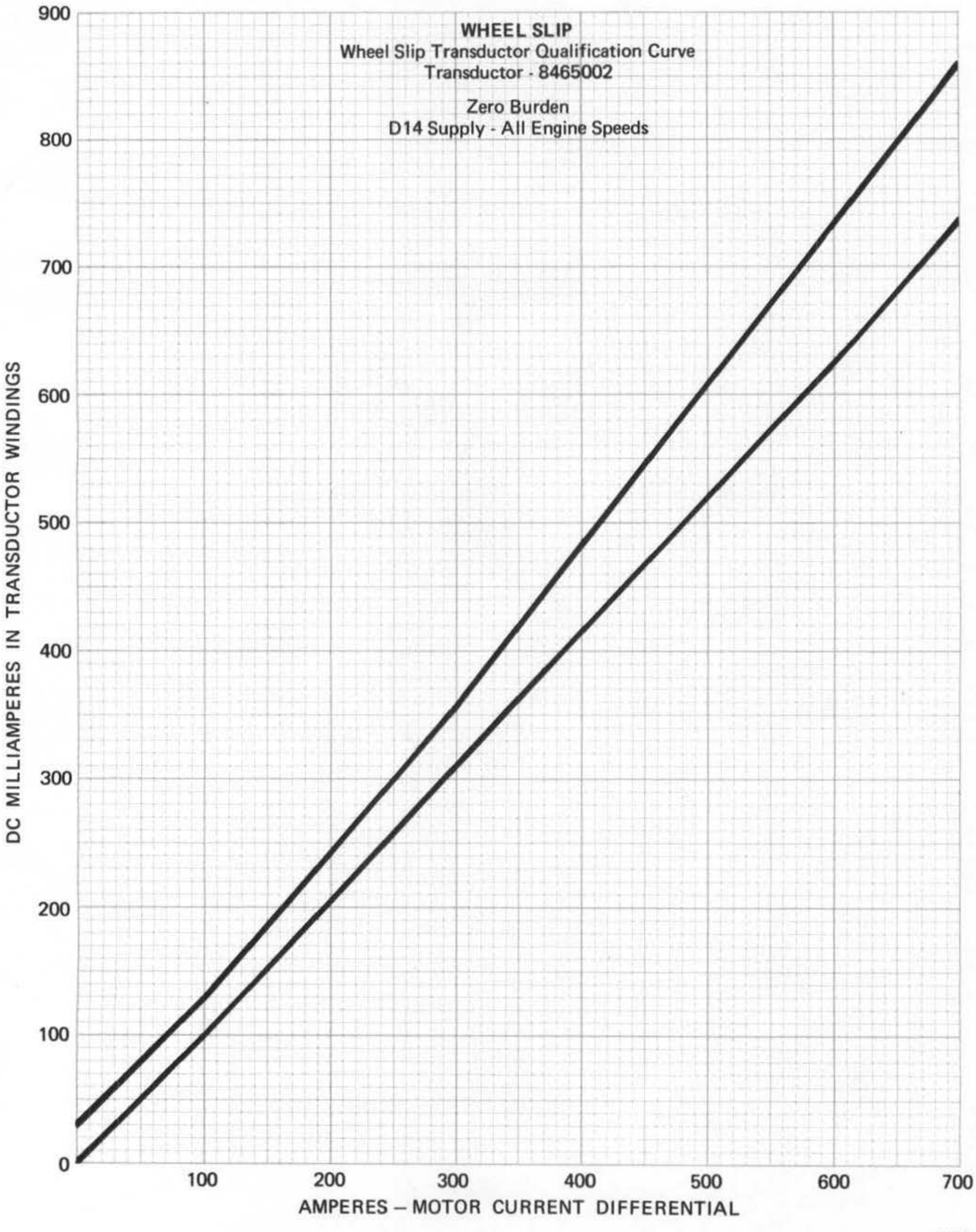
Operate reverser handle to reverse position, then while returning it to forward position, center transfer switch module RV1/L3. Open throttle to Run 1 position and compare current readings with previous check.

- - → Milliampere readings should fall within the tolerance band indicated on the transductor qualifilcation 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)

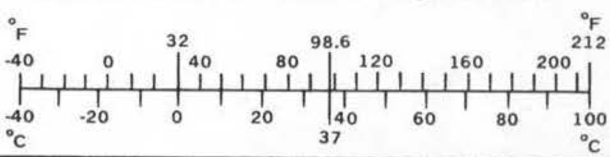


ELECTRO-MOTIVE

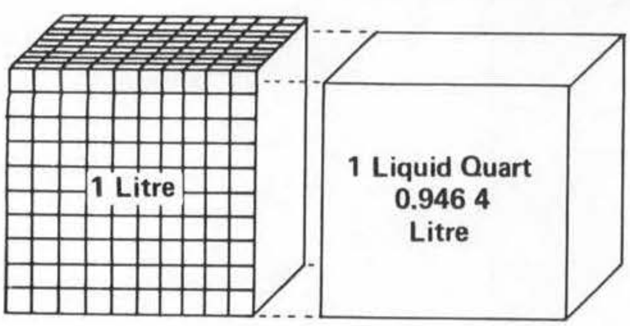
METRIC CONVERSION

TABLE OF FREQUENTLY USED UNITS

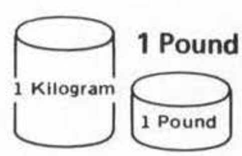
Multiply	by	to get equivalent number of:
LENGTH		
Microinch	.025 4	micron (μ)
Inch	25.4	millimetres (mm)
Foot	0.304 8	metres (m)
Yard	0.914 4	metres
Mile	1.609	kilometres (km)
AREA		
Inch²	645.2	millimetres² (mm²)
	6.45	centimetres² (cm²)
Foot²	0.092 9	metres² (m²)
Yard²	0.836 1	metres²
VOLUME		
Ounce	29.574	centimetre³ (cm³)
Inch³	16 387.	mm³
	16.387	cm³
	0.016 4	litres (l)
Ft³	0.028 3	metre³ (m³)
Quart	0.946 4	litres
Gallon	3.785 4	litres
Yard³	0.764 6	metres³ (m³)
MASS		
Ounce	28.350	grams (g)
Pound	0.453 6	kilograms (kg)
Ton	907.18	kilogram
Ton	0.907	tonne (t)
FORCE		
Kilogram	9.807	newtons (N)
Ounce	0.278	newtons
Pound	4.448	newtons
TEMPERATURE		
Degree Fahrenheit	(t° F-32)÷1.8	degree Celsius (C)



Multiply	by	to get equivalent number of:
ACCELERATION		
Foot/sec²	0.304 8	metre/sec² (m/s²)
Inch/sec²	0.025 4	metre/sec²
TORQUE		
Ounce-force-inch	0.007 06	newton-metre
	0.069 2	kilogram-metre
Pound-inch	0.112 98	newton-metres (N·m)
	0.011 52	kilogram-metres
Pound-foot	1.355 8	newton-metres
	0.138 25	kilogram-metres
POWER		
Horsepower	0.746	kilowatts (kW)
PRESSURE OR STRESS		
Inches of water	0.249 1	kilopascals (kPa)
Pounds/sq. in.	6.895	kilopascals
ENERGY OR WORK		
BTU	1 055.	joules (J)
Foot-pound	1.355 8	joules
Kilowatt-hour	3 600 000 or 3.6x10⁶	joules (J = one W's)
LIGHT		
Footcandle	10.764	lumens/metre² (lm/m²)
FUEL PERFORMANCE		
Miles/gal	0.425 1	kilometres/litre (km/l)
Gal/mile	2.352 7	litres/kilometre (l/km)
VELOCITY		
Miles/hour	1.609 3	kilometres/hr. (km/h)



The comparative dimensions of an inch and a millimeter, a litre and a quart, and a kilogram and a pound are shown.



1 Pound = 0.453 6 kg