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# EDUCATIONAL MANUAL

# MODEL U33
# DIESEL-ELECTRIC LOCOMOTIVE

GENERAL ELECTRIC

GEJ-3866

# EDUCATIONAL MANUAL

# MODEL U33
# DIESEL-ELECTRIC LOCOMOTIVE



GENERAL ELECTRIC

7-69 (3500)

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# LOCOMOTIVE DATA

## MAJOR EQUIPMENT

| | U33B | U33C |
|---|---|---|
| Air-brake System | 26L | 26L |
| Air Compressor (Gardner-Denver, if used) | WBO-9500 Series | WBO-9500 Series |
| Air Compressor (WABCO, if used) | 3 CWDL | 3 CWDL |
| Traction Motors | GE-752 | GE-752 |
| Main Alternator | GTA11 | GTA11 |
| Auxiliary Generator | GY-48 | GY-48 |
| Exciter | GY-48 | GY-48 |
| Fan-Gear Unit | GA-57 | GA-57 |
| Engine | 7FDL16 | 7FDL16 |
| Battery (Exide, if used) | MGD-19 | MGD-19 |
| Battery (Gould, if used) | 46.6T-19 | 46.6T-19 |

## SYSTEM CAPACITIES

| | | |
|---|---|---|
| Fuel Oil (Basic Locomotive Tank) | 1, 700 gal | 3, 000 gal |
| Fuel Oil (Modification Tank) | 3, 250 gal | 4, 000 gal |
| Lubricating Oil | 380 gal | 380 gal |
| Cooling Water | 350 gal | 350 gal |
| Engine Governor | 2 qt | 2 qt |
| Fan-Gear Unit | 12 qt | 12 qt |
| Compressor Crankcase (Gardner-Denver, if used) | 12 gal | 12 gal |
| Compressor Crankcase (WABCO, if used) | 12 gal | 12 gal |
| Sand | 60 cu ft | 60 cu ft |
| Main Air Reservoirs | 56, 000 cu in. | 56, 000 cu in. |
| Oil-bath Air Filters | 10 gal | 10 gal |

## BRAKE SYSTEM ADJUSTMENTS

| | U33B | U33C |
|---|---|---|
| Brake-cylinder Piston Travel (Minimum) | 2-1/2 in. | 3/4 in. |
| Brake-cylinder Piston Travel (Maximum) | 6 in. | 3 in. |
| Compressor Governor Switch (Dual Contact) | | |
| (Drop Out, Stage 1) | 129-130 psi | 129-130 psi |
| (Pick Up, Stage 1) | 140-141 psi | 140-141 psi |
| (Drop Out, Stage 2) | 134-135 psi | 134-135 psi |
| (Pick Up, Stage 2) | 145-146 psi | 145-146 psi |
| Compressor Intercooler Relief Valve | 60 psi | 60 psi |
| Main Reservoir Safety Valve | 150 ± 2 psi | 150 ± 2 psi |
| B. P. Regulating Valve | 70-110 psi | Variable |
| Independent Brake Valve (Full Independent) | 35-50 psi | Variable |
| Control-air Reducing Valve | 70 psi | 70 psi |
| Power-cutout Switch (PCS) | | |
| (Pick Up) | 58-62 psi | 58-62 psi |
| (Drop Out) | 44-46 psi | 44-46 psi |

## OPERATING SETTINGS

| | U33B | U33C |
|---|---|---|
| Diesel Engine (Idle) | 400 ± 15 rpm | 400 ± 15 rpm |
| Diesel Engine (Full Speed) | 1050 ± 4 rpm | 1050 ± 4 rpm |
| Overspeed-shutdown Trips | 1155 ± 10 rpm | 1155 ± 10 rpm |
| Diesel-engine Operating Temperature (In Tank) | 160-180 F | 160-180 F |
| Hot-engine Alarm (ETS) (Close) (Temperature at Flow Control $V_1$) | 208 ± 2 F | 200 ± 2 F |



## OPERATING SETTINGS

| | U33B | U33C |
|---|---|---|
| Hot-engine Alarm (ETS) (Open) (Temperature at Flow Control $V_1$) | 201 ± 2 F | 193 ± 2 F |
| Engine Lubricating-oil Header Pressure (Idle) | Approx 20 psi | Approx 20 psi |
| Engine Lubricating-oil Header Pressure (Full Throttle) | Approx 75 psi | Approx 75 psi |
| Engine Lubricating-oil Temperature (Normal) (Before Oil Cooler) | 160-180 F | 160-180 F |
| Engine Lubricating-oil Temperature (Maximum) (Before Oil Cooler) | 220 F | 220 F |
| Oil-pressure Shutdown (OPS) | | |
| (Engine at Idle) (40-second Delay) | 7-10 psi | 7-10 psi |
| (Engine 8th Notch) (No Delay) | 45-50 psi | 45-50 psi |
| Low Water Pressure Shutdown | | |
| (LWP) (1st Notch) | 0 psi | 0 psi |
| (LWP) (2nd Notch) | 0-3 psi | 0-3 psi |
| (LWP) (8th Notch) | 14-18 psi | 14-18 psi |
| Engine Temperature Deration Switch (ETDS) | | |
| (if used) (Close) | 195 ± 2 F | 195 ± 2 F |
| (Open) | 189 ± 2 F | 189 ± 2 F |

## DIESEL-ENGINE SYSTEMS PRESSURE VALVES

| | U33B | U33C |
|---|---|---|
| Fuel-oil Supply Line (Relief Valve) | 75 psi | 75 psi |
| Fuel Header to Metering Pumps (Idle) | 20 psi | 20 psi |
| Lubricating-oil-pump Pressure-relief Valve (Begins to Open) | 135 psi | 135 psi |

## WEIGHTS
(Approximate for Lifting Purposes Only)

| | U33B | U33C |
|---|---|---|
| Complete Locomotive (Fully Serviced) (Basic with 1700-gallon Fuel Tank) | 254, 500 lbs | - |
| Complete Locomotive (Fully Serviced) (Modified with 3250-gallon Fuel Tank) | 270, 000 lbs | - |
| Complete Locomotive (Fully Serviced) (Basic with 3000-gallon Fuel Tank) | - | 360, 000 lbs |
| Complete Locomotive (Fully Serviced) (Basic with 4000-gallon Fuel Tank) | - | 370, 000 lbs |
| One Truck (Complete) | 43, 000 lbs | 60, 000 lbs |
| One Truck Frame | 6, 050 lbs | 10, 200 lbs |
| One Truck Bolster | 1, 475 lbs | 5, 200 lbs |
| One Spring Plank | 390 lbs | - |
| One Motor, Wheel, and Axle Assembly | 11, 600 lbs | 11, 600 lbs |
| Traction Motor (Less Gear Case) | 7, 000 lbs | 7, 000 lbs |
| Air Compressor (Dry) (Gardner-Denver, if used) | 1, 590 lbs | 1, 590 lbs |
| Air Compressor (Dry) (WABCO, if used) | 1, 575 lbs | 1, 575 lbs |
| One Battery Tray | 300 lbs | 300 lbs |
| Engine Hood Assembly (Not Including Radiator Hood) | 4, 150 lbs | 4, 150 lbs |
| Fan-Gear Unit | 860 lbs | 860 lbs |
| Radiator Fan | 340 lbs | 340 lbs |
| Compressor Driveshaft and Hubs | 280 lbs | 280 lbs |
| Each Radiator Section | 400 lbs | 400 lbs |
| Equipment Blower | 1, 106 lbs | 1, 106 lbs |
| Lube-oil Cooler (Dry) | 850 lbs | 850 lbs |
| (Wet) | 1, 010 lbs | 1, 010 lbs |
| Engine and Alternator (Complete) | 63, 000 lbs | 63, 000 lbs |



| | U33B | U33C |
|---|---|---|
| Lube-oil Filter (Including New Element) (Dry) | 660 lbs | 660 lbs |
| (Wet) | 1, 060 lbs | 1, 060 lbs |
| Main Alternator with Auxiliaries | 17, 100 lbs | 17, 100 lbs |
| Auxiliary Generator and Exciter | 920 lbs | 920 lbs |
| Engine (Less Alternator) (Dry) | 43, 510 lbs | 43, 510 lbs |
| Engine Component Parts | | |
| Main Frame (Bare) | 11, 800 lbs | 11, 800 lbs |
| Crankshaft | 3, 950 lbs | 3, 950 lbs |
| Turbocharger | 1, 425 lbs | 1, 425 lbs |
| Intercooler (Dry) | 660 lbs | 660 lbs |
| Cylinder (Complete) | 760 lbs | 760 lbs |
| Piston and Master Rod Assembly | 207 lbs | 207 lbs |
| Piston and Articulating Rod Assembly | 94 lbs | 94 lbs |
| Oil Pump | 350 lbs | 350 lbs |
| Water Pump (with Gear) | 280 lbs | 280 lbs |
| Control Governor | 112 lbs | 112 lbs |
| Governor-Drive Assembly | 159 lbs | 159 lbs |
| Oil Pan | 1, 050 lbs | 1, 050 lbs |
| Free-end Cover | 1, 350 lbs | 1, 350 lbs |
| End Cover (Alternator End) | 80 lbs | 80 lbs |
| Exhaust Manifold | 630 lbs | 630 lbs |

# LOCOMOTIVE DESCRIPTION

## GENERAL

The General Electric, Model U33, diesel-electric locomotive is especially designed and built to meet the requirements of modern high-speed freight traffic. The design provides for high horsepower per axle, with a minimum of equipment and weight. With available modifications, the locomotive can be used in passenger service.

## POWER PLANT

### DIESEL ENGINE

The locomotive is powered by a 16-cylinder, 45-degree "Vee"-type, four stroke cycle, turbocharged, diesel engine with a 9-inch bore by 10 1/2-inch stroke. The engine has a unitized head and cylinder arrangement which can be removed singularly in a minimum of time. It is equipped with cast-iron pistons and a Bendix fuel-injection system. The cylinder liner is chrome-plated to give longer liner life.

### GOVERNOR

The Woodward PG engine governor is of the self-contained, electro-hydraulic type. It automatically regulates the horsepower at each throttle-speed setting.

### OVERSPEED PROTECTION

The engine is automatically shut down if the speed exceeds maximum rated rpm by 10 percent.

### COOLING SYSTEM

Water is circulated through the engine, turbosupercharger, intercooler, radiator, and lubricating-oil cooler by a gear-driven centrifugal pump, integral with the diesel engine. The water-storage tank is fitted with a sight glass and fill arrangement, and also a temperature gage. The tank is filled from ground through a four-way valve. The cooling system is pressurized, and a spring-loaded relief cap discharges overboard. Abnormally low water pressure automatically shuts down the engine.

### ENGINE TEMPERATURE CONTROL

Water temperature is controlled by an arrangement of thermostats and control valves which regulate the volume of water flow through the radiators.

### FUEL SYSTEM

A motor-driven pump transfers fuel from the main storage tank between the trucks, through a strainer and filter, to the injection pumps located on each cylinder. A short, uniform-length steel line carries the high-pressure fuel from the individual pump to the multi-hole injector located in the center of each cylinder head.

### LUBRICATION SYSTEM

Lubricating oil is circulated in a full-flow filtration system, by means of a pump.

The crankcase oil pan contains the volume supply of lubricating oil. Oil filters and a water-circulated heat exchanger maintain the desired characteristics of the system. A pressure-relief valve on the discharge side of the pump protects against abnormally high pressures. Abnormally low lubricating-oil pressure automatically shuts down the engine.

## ELECTRIC TRANSMISSION

### GENERAL DESCRIPTION
(See Fig. 2-1)

The Type GTA11 traction alternator is a salient-pole, three-phase, Y-connected, alternating-current generator which converts the mechanical energy of the locomotive diesel engine into the electrical power required for locomotive propulsion. The a-c output of the alternator is converted to d-c by means of a rectifier panel, and is used as the power supply for the d-c traction motors.



The Type GTA11 alternator is a single-bearing, separately-excited machine which is directly connected to the diesel engine. The engine crankshaft supports approximately half the weight of the alternator rotor. The other half is supported at the outboard end by means of a roller bearing which is splash-lubricated from the auxiliary-drive gear unit.

Excitation is supplied by an exciter (see Fig. 2-2) mounted on and driven by the alternator through the auxiliary drive gear system. Also shown in Fig. 2-2 is the auxiliary generator (which supplies power for the control system) and the power take-off unit.

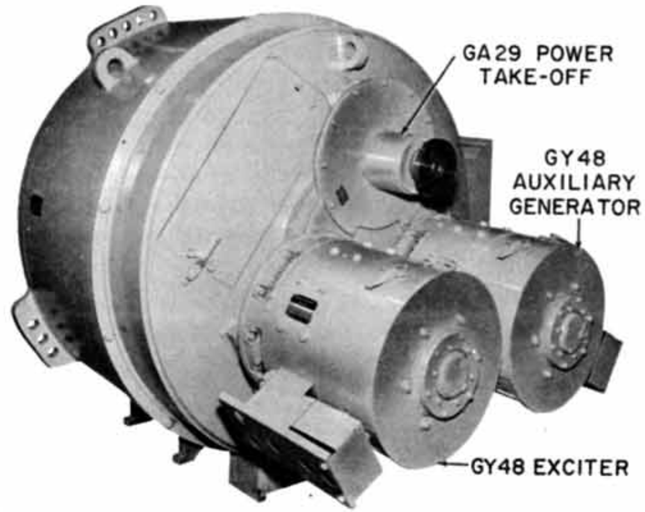



*Fig. 2-1 Model 5GTA11 alternator with auxiliaries*

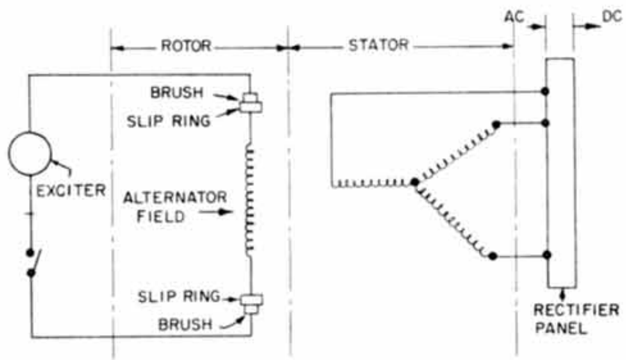



Fig. 2-2 (E-12762)

*Fig. 2-2 Schematic diagram, alternator*

## TRACTION MOTORS

Four GE-752, d-c traction motors are furnished with "B"-truck units, while units of "C"-truck design are supplied with six GE-752, d-c traction motors. These traction motors are series-wound, and are separately ventilated by the cleaned-air system. The armature is mounted in rolling-contact bearings.

Motors are driven through single-reduction spur gearing. They are supported by the axles to which they are geared, and by resilient nose suspensions on the truck transoms.

## CONTROL

Control devices are grouped in a pressurized, steel compartment, which is fitted with access doors. The reverser and line contactors are electro-pneumatically operated. Other contactors are magnetically operated. Circuit-breaker type switches are used in control circuits where overcurrent protection is required. Transition is automatic.



## EXCITER AND AUXILIARY GENERATOR

Two identical GY-48 machines are furnished; one as an exciter, the other as an auxiliary generator. Both of these machines are gear-driven from the traction alternator. The exciter furnishes the power to energize the alternator field windings on the rotor. The auxiliary generator furnishes power at regulated potential, for battery charging, lighting, and control.

## STORAGE BATTERY

A 32-cell, lead-acid type storage battery is furnished for starting the engine and to furnish power for lights and other auxiliaries when the engine is shut down.

## WHEEL-SLIP CORRECTION

Wheel slip is automatically detected by comparison of output signals from an alternator mounted on each axle. Initial slip correction also is automatic, through a reduction of power and the application of sand. If the slip persists, a light and/or a buzzer will be energized to signal the operator to take supplementary action.

## GROUND RELAY PROTECTION

If a ground occurs, a protective relay is actuated. This causes the engine speed to return to idle, and causes power to be removed. The picked-up relay also causes an audible and visual indication of the ground to be given to the operator.

The generator overload relay, in series with the alternator field, senses overloads (e.g., traction-motor flashover), and provides the operator with the same indication as the ground relay does.

## OPERATING CONTROLS

Controls and instruments for operating the locomotive are grouped at the operator's station, and at auxiliary panels in the operator's cab.

Operating Controls:

Controller with throttle and reverse/selector levers.

Engine Start push button. Engine Stop push button. Brake valves.

Sander valve. Bell ringer valve. Air horn valve.

Window wiper valves.

Circuit breakers and switches.

Emergency Engine Stop push button.

Emergency fuel shutoff.

Instruments:

Brake gages.

Load meter.

Speed indicator.

Warning Indicators:

Low engine-lubricating-oil pressure or low water – alarm bell and warning light.

High engine-water temperature – alarm bell and warning light.

Wheel slip – buzzer and warning light.

Ground relay – red indicator.

Engine shutdown – alarm bell.

No battery charge – alarm bell and warning light.

A number of accessories and modifications are available to suit customer needs.



## LOCOMOTIVE BRAKES

### AIR BRAKES

Schedule 26L with 26F control-valve air equipment is furnished.

Locomotive brakes may be operated either independently or with the train brakes. Connections for furnishing compressed air to the train brakes are provided at each end of the locomotive.

### COMPRESSOR

A three-cylinder, two-stage, water-cooled, engine-driven air compressor furnishes air for the locomotive and train braking systems.

Compressed air displacement (3 cylinder):

Idle engine speed . . . . . . . . . . . . . . . . 113 cfm
Full engine speed . . . . . . . . . . . . . . . . 289 cfm

### RESERVOIRS

A reservoir capacity of 56,000 cubic inches is furnished for storing and cooling the air for the air brakes.

### BRAKE EQUIPMENT

Brake cylinders are mounted on the truck frames, and operate fully equalized brake rigging which applies brake shoes to each wheel.

Brake rigging is furnished with hardened-steel bushings, and adjustment is provided to compensate for wheel and shoe wear. Cast-iron brake shoes are provided on the two-axle truck, and composition brake shoes are furnished on the standard three-axle truck.

## HANDBRAKE

A wheel-operated handbrake, located on the outside of the nose compartment, is provided for holding the locomotive at standstill.

# RUNNING GEAR

## TWO-AXLE TRUCK

The running gear of the locomotive consists of two four-wheel, two-axle, side-equalized, swing-motion swivel trucks.

The truck frame, bolster, and spring plank are of cast steel. The frame is supported by two equalizers on each side, with coil springs between the equalizer and frame. Elliptic springs are applied between the bolster and spring plank. The spring plank is supported by forged-steel swing-links pinned to the truck frame.

## THREE-AXLE TRUCK

The truck is a six-wheel, three-motor, floating-bolster type. Lateral or sidewise movement of the bolster is provided by having it rest on four curved, rubber and steel sandwich mounts. Wear plates, on the truck frame and bolster, limit longitudinal movement of the bolster.

The truck frame is a one-piece steel casting, and rests on coil springs which are seated on the journal housing.

## WHEELS

Solid, multiple-wear, rim-treated, rolled-steel, 40-inch diameter wheels have standard AAR tread and flange contour.



## AXLES

Axles are of forged, open-hearth steel, conforming to AAR material specifications.

## JOURNAL BOX

Journal boxes are equipped with sealed, grease-lubricated roller bearings.

Journal-box guides, housings, pedestal openings, and equalizer seats are lined with renewable, steel, wear-resistant plates.

## CENTER BEARINGS

Center bearings on "B"-trucks are equipped with hardened-steel liners, and are protected by dust guards. The bearings are arranged for lubrication. "C"-truck center bearings have composition liners which do not require lubrication between untruckings.

## SIDE BEARINGS

Side bearings, with renewable, wear-resistant steel plates, are provided.

## SAFETY HOOKS

Body and truck safety hooks are provided to prevent slewing in case of derailment, and to permit the trucks to be lifted with the superstructure.

# SUPERSTRUCTURE

The superstructure, of welded-steel construction, consists of a front hood, an operator's cab, an engine hood, and a radiator compartment. The engine hood is bolted to the underframe, and is removable.

## FRONT HOOD

The nose (short) hood contains a top-serviced sandbox. A door in the front bulkhead of the operating cab provides access to the inside of the hood.

## OPERATING CAB

The sides and roof of the operating cab are insulated and steel lined. The floor, raised above the underframe, is covered with heavy-duty Benelex.*

The cab has safety-glass windows in the front, rear, and on each side. Two-pane center windows, on each side of the cab, have sliding sashes equipped with latches. All other windows are fixed.

Doors, in diagonally opposite corners of the operating cab, provide access to walkways along the hoods. The doors have windows, weather stripping, and a provision for locking.

## WALKWAYS

Platform walkways, with handrails and non-skid treads, are provided at each end of the locomotive and along the hoods.

## ENGINE HOOD

The engine hood encloses the diesel engine and the traction alternator.

Full-height side-access doors, on both sides of this hood, extend the length of the engine and alternator. Doors in the roof provide access to the top of the engine. Detachable roof sections permit the removal of equipment. The air-compressor control panel is located on the right side, adjacent to the oil cooler.

*Registered trade-mark



## RADIATOR COMPARTMENT

The radiators are roof mounted. A reinforced screen over the air outlet opening is removable, to allow access to the radiators and fan and gear box. Dynamic-braking grids, when provided, are mounted along each side of the radiator compartment.

An end section holds a sandbox which is serviced from the roof. Rear headlights, classification lights, and number boxes are mounted on this section.

The engine air filters are located between the engine cab and the radiator cab. Access is through doors in the cab, located opposite the air filter. The air filter consists of an inertial-type pre-cleaner located on the cab floor and panel-bath air filters attached to a plenum inside the compartment.

## EQUIPMENT COMPARTMENTS

Main propulsion control equipment is located on the left side of the locomotive, beneath the operating cab. The compartment, maintained under positive air pressure to keep out dirt and water, contains contactors, reverser, braking switch, resistors, and auxiliary electrical devices.

All air-brake devices, air-operated equipment, and battery trays are located in easily accessible compartments along the right side of the locomotive.

## VENTILATION

Mechanically filtered air is provided by a centrifugal fan, driven off the alternator gearbox. The fan discharges into the platform air duct. The air is cleaned by inertial air cleaners which are installed near the equipment which requires cleaned cooling air. The air cleaners are accessible by removing the cover plates on the bottom of the platform just in front of and to the rear of the fuel tank.

## UNDERFRAME

The underframe is fabricated of low-alloy steel sections and plate. The centerplate bolster is also fabricated. Bolster side members and draft-gear housing are provided.

Hoods, cab, mechanical and electrical equipment, and tanks are supported by the main frame members. Space between these members is enclosed with plates, top and bottom, to form an air duct.

### WEARPLATES

Renewable, wear-resistant, hardened-steel plates are applied to the center bearing, side-bearing pads, and draft-gear housing. Composition wearplates are mounted on the center bearing of six-axle trucks.

### COUPLERS

AAR, Type E, top-operated couplers, with rubber-cushioned draft gear, are provided at each end of the locomotive.

### PILOTS AND SIDE STEPS

A pilot with footboards is provided at each end of the locomotive. Side steps provide access to the platform.

### LIFTING AND JACKING

Four jacking pads, in combination with lugs for cable slings, are integrally fabricated in the side bolsters.

### FUEL TANKS

A heavy-gage, welded-steel, fuel tank is bolted to the underframe between the trucks. Filler connections and fuel-level gages are furnished on each side of the locomotive. A full-depth sight gage is on both sides. An emergency electric push-button fuel-pump shutoff, baffle plates, clean-out plugs, and water drains are provided.



## COMPONENT LOCATION TERMS

The following terms will be used throughout this manual, in locating various components on the engine. (See Fig. 3-1.) The designation or explanation of these terms is as follows:

FREE END – The end of the engine where the turbocharger and intercoolers are mounted.

ALTERNATOR END – The end of the engine where the alternator is mounted.

Fig. 3-1 (E-10028B)

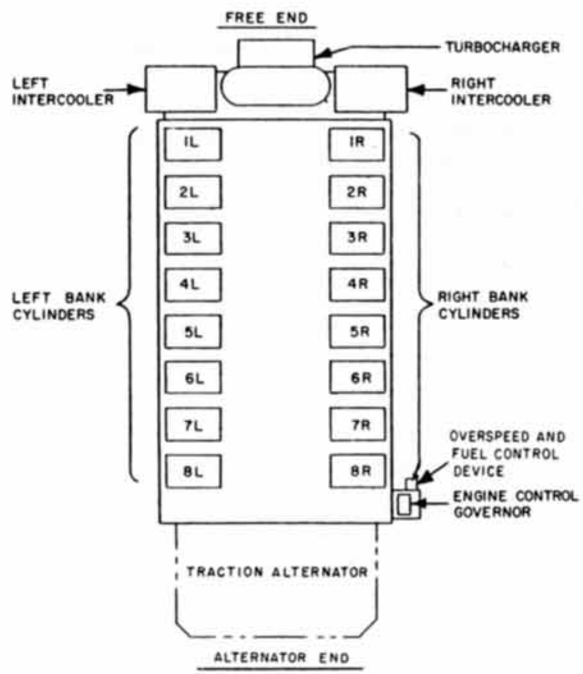



*Fig. 3-1. Schematic overhead view of engine*

RIGHT AND LEFT SIDE – The right side or left side of the engine is determined by viewing the engine while facing the alternator end.

CYLINDER LOCATION – The cylinders are numbered from the FREE END to the ALTERNATOR END. (Number 1 Right and 1 Left cylinders are nearest the turbocharger. Number 8 Right and 8 Left cylinders are nearest the alternator.)

CRANKSHAFT ROTATION – During engine operation, the crankshaft rotates clockwise when viewed from the FREE END, or counterclockwise when viewed from the ALTERNATOR END.

## ENGINE SPECIFICATIONS

| | |
|---|---|
| Model | 7FDL16 |
| Gross Horsepower | 3250 |
| Number of Cylinders | 16 |
| Stroke Cycle | 4 |
| Cylinder Arrangement | 45-degree V |
| Bore | 9 in. |
| Stroke | 10 1/2 in. |
| Compression Ratio | 12.7-1 |
| Firing Order | 1R - 1L - 3R - 3L - 7R - 7L - 4R - 4L 8R - 8L - 6R - 6L - 2R - 2L - 5R - 5L |
| Turbocharger | Single |
| Engine Dimensions | |
| Height (Overall Including Stack) | 9 ft 1 in. |
| Length (Overall Including Alternator) | 21 ft 8 7/16 in. |
| Width (Overall) | 5 ft 8 1/2 in. |
| Weight (Including Alternator) | 60,410 lbs |



## DESCRIPTION

The engine lubricating-oil system provides pressure lubrication to bearings within the engine, and carries away heat produced by friction and combustion.

The lubricating-oil system is of the full-flow type, in that all of the oil used must circulate through the lube-oil filter. There is no oil-filter bypass valve, and no provisions of any kind which would permit unfiltered oil to circulate through the system should the filter become obstructed.

This system is used to prevent unfiltered oil, and the harmful foreign materials it might contain, from contaminating the engine and its components. A fail-safe low-oil-pressure engine-shutdown mechanism is provided in the governor. Should the lube oil pressure be reduced to the point where it is inadequate to serve the system, the engine shuts down automatically. (See LUBRICATING-OIL PRESSURE.)

The lubricating-oil system consists of the following components in their order of oil flow. (See Fig. 4-9.)

1. Engine crankcase
2. Pump
3. Relief valve
4. Filter
5. Cooler
6. Regulating valve (where used)
7. Engine supply system

An oil pan is bolted to the main frame to enclose the bottom of the crankcase and to hold the oil supply. An oil-fill opening is sealed by expandable plugs. A dipstick is used to measure the crankcase oil level.

### OIL FLOW OUTSIDE THE ENGINE

Oil discharged from the pump is piped to the lube-oil filter. A relief valve protects the system against excessive pressure. The oil flows through the filter and then to the lower end of the oil cooler. The water flowing down through the tubes inside the cooler removes heat from the oil.

Oil is discharged from the top of the cooler and is piped to the engine free-end cover.

In a very few applications, an oil-pressure regulating valve, also mounted in the cover at the strainer inlet, controls engine-oil header pressure and discharges excess oil to the crankcase. In most cases, the regulator is used.

## OIL FLOW INSIDE THE ENGINE

The main engine supply header and branch passages within the main frame conduct oil to all main bearings and to four of the camshaft bearings (No. 1 and No. 9 bearing, each bank). Oil enters the crankshaft from the main bearings and flows through angularly drilled passages in the shaft to the crank-pin bearings.

The oil passes from the crank pin to the articulation pin. It lubricates the articulation pin and passes through the drilled passage in the main and articulated rods to lubricate the piston pins. The oil then passes to the pistons. It is shaken around in the chamber under the piston crown. It cools the whole piston head and then flows out through an orifice back to the cylinder.

The oil entering the four camshaft bearings is conducted lengthwise through the drilled camshafts. Holes drilled radially into the shafts supply oil to each of the other shaft bearings.

The camshaft bearings contain annular grooves connecting to drilled passages in the engine main frame. Oil flows through these passages to the valve and fuel push-rod crossheads.

The oil then flows upward through the valve push rods to supply lubrication to the valve operating parts at the top



of the cylinder. Oil return is through the valve push-rod cavities to lubricate the cams and cam rollers, and then to the crankcase.

The free-end cover bearing and the idler-gear bushings are lubricated through a passage from the oil header to an annular groove around the cover bearing. Another drilled passage connects the annular bearing groove to a drilled passage in the idler-gear shaft. The auxiliary drive gear, located on the crankshaft next to the vibration damper, is lubricated internally by oil flowing through a passage within the shaft and through the gear hub. Oil from these bearings returns by gravity to the crankcase.

The turbocharger bearings receive lubrication through an external line, flange-connected to the oil header at the free-end cover. From the turbocharger, the oil is returned to the crankcase through a pipe that is also flange-connected to the cover.

Lubricating oil is piped to the governor-drive assembly and to the low-pressure shut-down device located on the engine control governor. This pipe is flange-connected to the engine oil header at the generator end. The oil from the governor drive returns to the crankcase internally.

The oil supply for the overspeed governor is maintained in a small reservoir built into the governor-drive gear case. The reservoir is kept filled with oil by a drilled passage in the gear case.

The camshaft gears are splash-lubricated through an orifice and pipe from the engine oil header.

The bearings and drive gears of the oil and water pumps are lubricated by running partially submerged in lube oil contained within the free-end cover reservoir.

## LUBRICATING-OIL PRESSURE

Oil pressure must be maintained at all times during engine operation. Insufficient oil pressure will cause extensive damage to the bearings, pistons, cylinders and other moving parts within the engine.

The low-lube-oil pressure device will stop the engine and turn on a yellow indicating light in the operator's cab if a condition of insufficient oil pressure exists. For further information, see ENGINE CONTROL GOVERNOR.

During engine starting, a time delay built into the low-oil-pressure shutdown device allows time for the engine oil pressure to build up. If the pressure fails to build up within the time allowed, the low-oil-pressure device will trip and prevent the engine from starting.

## FILLING, DRAINING, AND CHANGING OIL

### FILLING

To service the lubricating-oil system, proceed as follows:

1. Check that drain valves A, B and C are closed. (See Fig. 4-9.)

2. Fill the crankcase, through the oil fill pipe or through a crankcase inspection opening, with the correct quantity of new lubricating oil. The oil must conform to the required specifications. See FUEL AND LUBRICANT SPECIFICATION. Fill the crankcase to the FULL level mark on the dip-stick.

3. With the engine idling, the oil level must be between the FULL and LOW marks on the dip-stick.

### DRAINING (See Fig. 4-9)

The lubricating-oil system is drained by the use of three valves which are identified as Valve A, Valve B, and Valve C. The following list identifies the valve, or combination of valves, which must be opened to drain the various portions of the system.



1. Valve A (the crankcase drain valve) is opened to drain the main oil supply from the engine crankcase.

2. Valve B (the end-cover drain valve) drains the oil filter and oil cooler overboard.

3. Valve C (the filter drain-back valve) drains the oil filter and oil cooler back to the crankcase.

4. With Valves B and C both open, the oil filter, oil cooler, and front end drain overboard.

### CHANGING OIL (See Fig. 4-9)

1. With the engine stopped, remove the pipe cap from the drain pipe. The pipe extends below the platform over the fuel tank on the right side of the engine.

2. Arrange barrels on a drain-hose system to catch the used oil.

3. Open the crankcase drain valve (A), end-cover drain valve (B), and filter drain valve (C).

4. Remove the vent plug on the filter cover.

5. When old oil is completely drained, close valves A, B, and C. Replace the vent plug in the filter cover and reapply the cap to the drain pipe.

### CHANGING FILTER ELEMENTS

To renew the filter elements, proceed as follows:

> *NOTE: Remove the oil-filter vent plug when draining the filter. Replace it tightly when through draining. Filter draining may be expedited by applying air pressure (not over 50 psi) at the filter vent. Observe applicable safety precautions.*

1. Drain the filter by opening Valve C and removing the filter vent plug. The oil level in the filter will drop by gravity to the level in the crankcase. Alternately close Valve C and open Valve B to drain overboard the residue in the bottom of the filter tank.

*NOTE: Further lowering of the level of dirty oil in the filter may be accomplished by using 10 or 20 pounds of air pressure to force the oil back into the crankcase and closing Valve C.*

2. Be sure no pressure remains in the tank. Loosen the filter cover clamps and open the hinged cover after the oil has been drained from the filter tank.

3. Remove the wing nuts and the element hold-down plates.

4. Remove the used elements and place them in a suitable container to catch the drippings.

5. Clean any sludge deposits from the filter shell.

6. Install new filter elements. (See the Renewal Parts Catalog for the correct replacement part.)

*NOTE: Do not use cotton waste filters.*

7. Install the element hold-down plates and wing nuts. Tighten the nuts evenly. HAND TIGHTEN ONLY. Be sure the filter elements are all seated and clamped securely.

8. Inspect the filter cover gasket for possible damage and replace it if necessary. Close the filter cover and tighten the clamping bolts evenly.

9. Replace and tighten the vent plug.



## RELIEF AND REGULATING VALVES

The pressure and flow within the lube-oil system is automatically controlled by two pressure-operated valves.

1. Pump relief valve
2. Engine pressure regulating valve (where used)

These valves are held closed by adjustable spring pressure. When sufficient oil pressure is developed, it will overcome the spring pressure causing the valve to open and pass oil.

The function of each of the two valves within the system should be thoroughly understood before any attempt is made to change their settings. Normally, these valves do not get out of adjustment. However, they may fail to function properly due to leakage caused by a damaged seat, by dirt which holds the valve off its seat, or by dirt wedged around the valve stem which causes erratic valve operation. When disassembling a valve for cleaning, always mark the adjustment so that it may be returned to its correct setting without removal from the system.

## PRESSURE RELIEF VALVE

The pressure relief valve, located near the outlet of the lube-oil pump, protects the system against excessive oil pressure which may develop should the system become restricted or if the filters become dirty. If the pump discharge pressure exceeds the valve operating pressure, the valve will be forced open, permitting oil to flow to the free-end cover, thus limiting the pressure. The oil-pump relief valve can best be set by removing it from the locomotive and setting on a test stand similar to the one illustrated in Fig. 4-1. Instructions for setting the valve are as follows:

1. Start pump with A open.

2. Close A until the set pressure is reached.

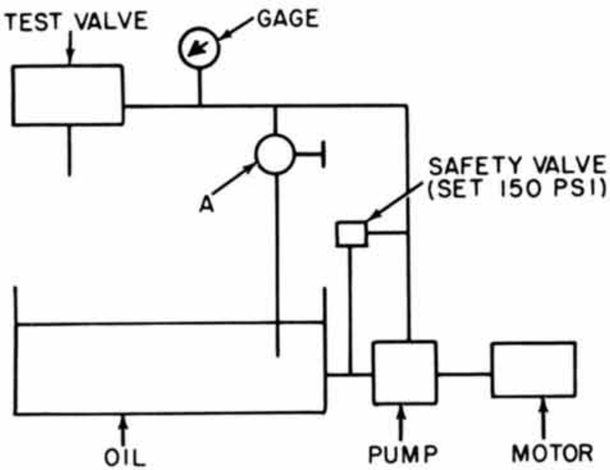



Fig. 4-1 (E-13210)

*Fig. 4-1. Test arrangement for adjusting valves*

3. Adjust the valve until oil starts to flow. If the pump flow is 20 gpm or less, the valve can be set with A closed completely.

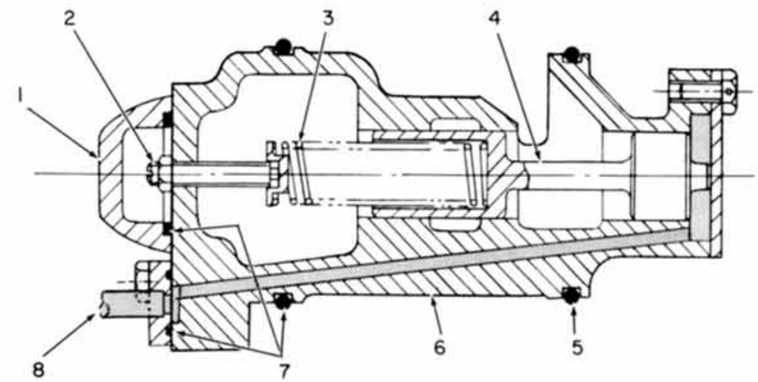
## PRESSURE REGULATING VALVE
(Where Used) (See Fig. 4-2)

The main lube-oil header-pressure regulating valve is a self-contained device located inside the left-bank camshaft access opening in the free-end cover. The valve body is sealed to the end-cover oil passages by "O" rings and is held in place by bolts. Access to the pressure adjustment screw is obtained by removing the cap.

This valve maintains a relatively constant engine-oil header pressure although the volume of oil flowing



Fig. 4-2 (E-11969A)




1 Cap
2 Adjustment screw with lock nut
3 Piston spring
4 Regulating piston
5 "O" ring
6 Valve body
7 "O" ring
8 Oil pressure connection from engine lube-oil header

*Fig. 4-2. Lube oil pressure regulating valve*

through the system continues to change as a result of the engine speed change.

Oil pressure from the engine header is applied to the inner end of the valve regulating piston in opposition to the spring force. Therefore, as the engine-oil header pressure tends to drop due to plugging of the filter, the spring force becomes more effective thus raising the pressure setting of the valve to compensate for the increased pressure drop across the strainer.

## ADJUSTMENT

The regulating valve may be adjusted as follows:

1. Warm the engine to normal operating temperature.

2. Remove the bolted cover from the valve; then, operate the engine at throttle notch eight. Loosen the lock nut and turn the adjustment screw in or out to set 75 psig on the cab gage. Allow sufficient time for the pressure readings to stabilize between adjustments. Turning the adjustment screw IN will raise the pressure.

3. Tighten the lock nut securely and replace the cap.

### LUBE-OIL FILTER (See Fig. 4-3)

The lube-oil filter is a fabricated, cylindrical, steel shell. It has a hinged and gasketed cover which is clamped to hold maximum system pressure. The filter shell is supported by a fabricated-steel frame which is part of the filter assembly.

Internally, the filter is arranged with two separate cavities. Oil flowing into the filter shell passes inward through the eight elements located in the upper cavity, downward through the element centers into the lower cavity, and out through the outlet pipe.

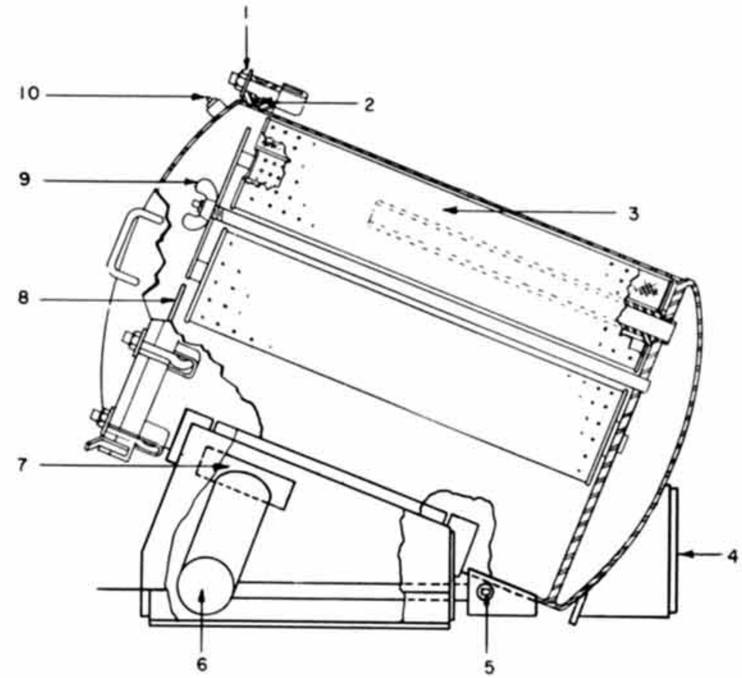
### LUBE-OIL COOLER (See Fig. 4-4)

The lube-oil cooler is a fabricated-steel shell containing vertical water tubes.

The cooler is mounted in a vertical position with its top flange bolted directly to the underside of the water storage tank. Water from the tank flows downward through the tubes to the bottom header which is connected to the suction side of the water pump.



Fig. 4-3 (E-9993B)




1 Cover clamp bolt
2 "O" ring
3 Filter element
4 Oil outlet to cooler
5 Pipe plug
6 Oil inlet from pump
7 Baffle
8 Hold-down plates
9 Hold-down-plate wing nut
10 Vent plug

*Fig. 4-3. Lube-oil filter*

Oil from the filter enters at the bottom of the cooler and flows upward around the tubes to the oil outlet which is connected to the engine free-end cover. Internal baffles direct the oil flow back and forth across the tubes to produce maximum cooling.

The tubes are secured to their end sheets by expansion rolling. The upper tube sheet is clamped and sealed between the upper cooler flange and the water tank. The lower tube sheet is free to move vertically in the shell to compensate for thermal expansion. A seal, consisting of two packing rings and a packing ring spacer, located at the lower header flange, prevents leakage between oil and water sections but allows movement of the tube sheet at its lower end. Compression of the rubber packing rings is controlled by a spacer and adjusting shims at each clamping bolt. (See enlarged view in Fig. 4-4.)

The packing-ring spacer has several "weep" holes drilled through it. Failure of either packing ring will be indicated by oil or water leakage at the flange. This will also prevent leakage of oil into the water and vice versa.

## CRANKCASE BREATHER

The crankcase breather, located within the upper portion of the free-end cover, is a closed, shallow, flat cavity cast into the cover. (See Fig. 4-5.) The cavity is open to the crankcase and has a cast cover at its top, which is sealed with a gasket and bolted in place. A fine wire-mesh screen panel is mounted within the cover and is held in place by a bolted metal frame. (See Fig. 4-6.) The breather is vented into the side of the exhaust stack above the turbocharger by an extension pipe.

Suction developed by the engine exhaust draws the oily vapor from the crankcase through the breather screen and out the stack. As the vapor passes through the screen, the oil is caught and drains back to the crankcase.

Fig. 4-4 (E-13211)

1 Shell
2 Tube bundle
3 Bonnet
4 Stud
5 Hex nut
6 Lockwasher
7 Packing ring
8 Gland ring
9 Gasket
10 Shim
11 Spacer
12 Hex bolt

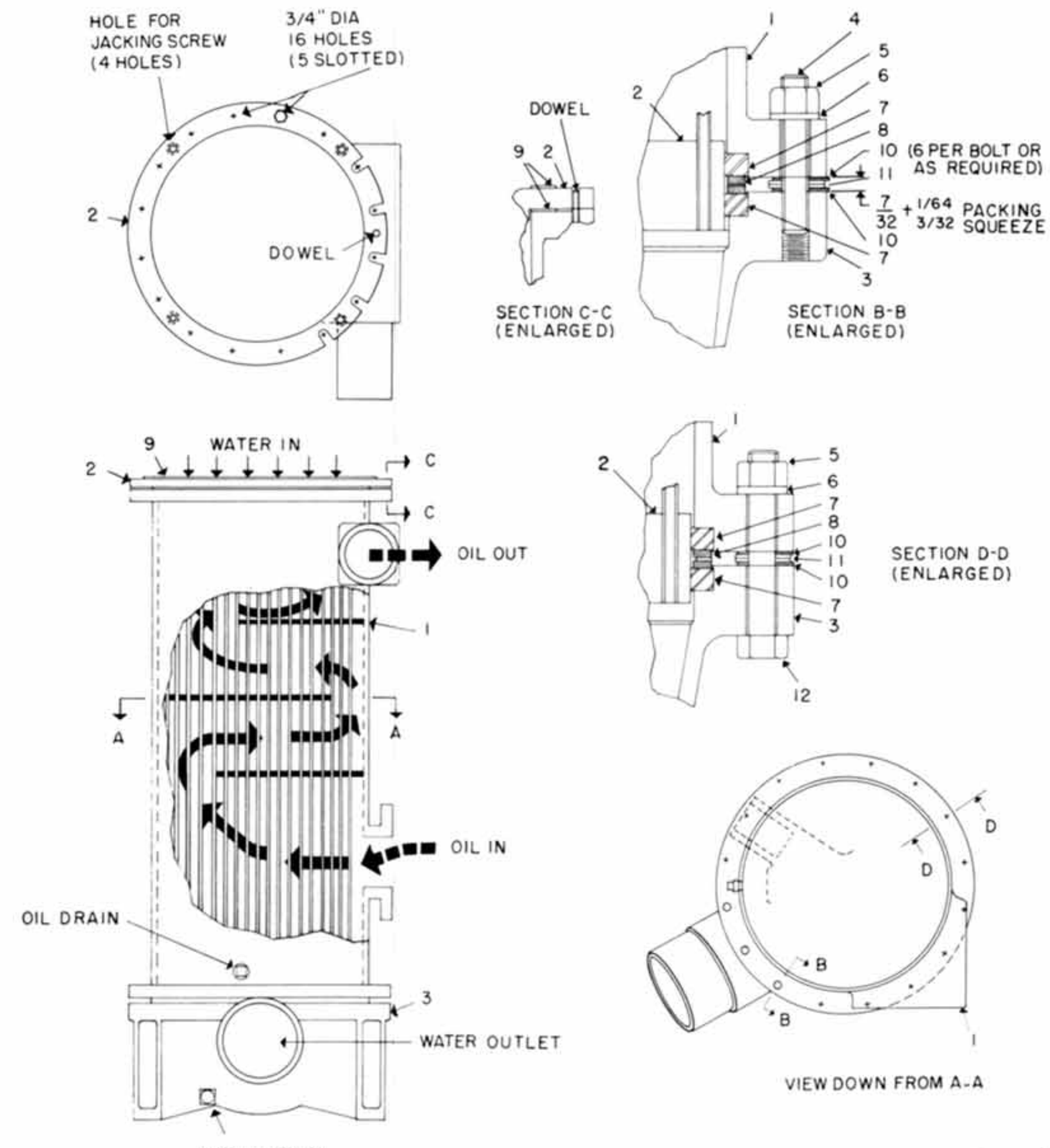



*Fig. 4-4. Lube oil cooler*

Fig. 4-5 (E-9990)

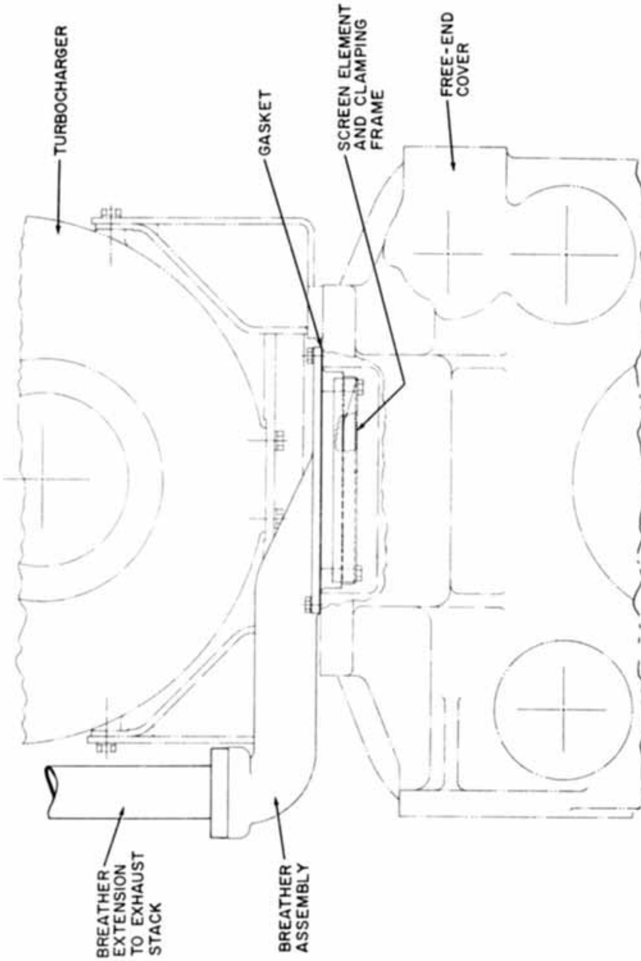



*Fig. 4-5. Lube-oil breather*

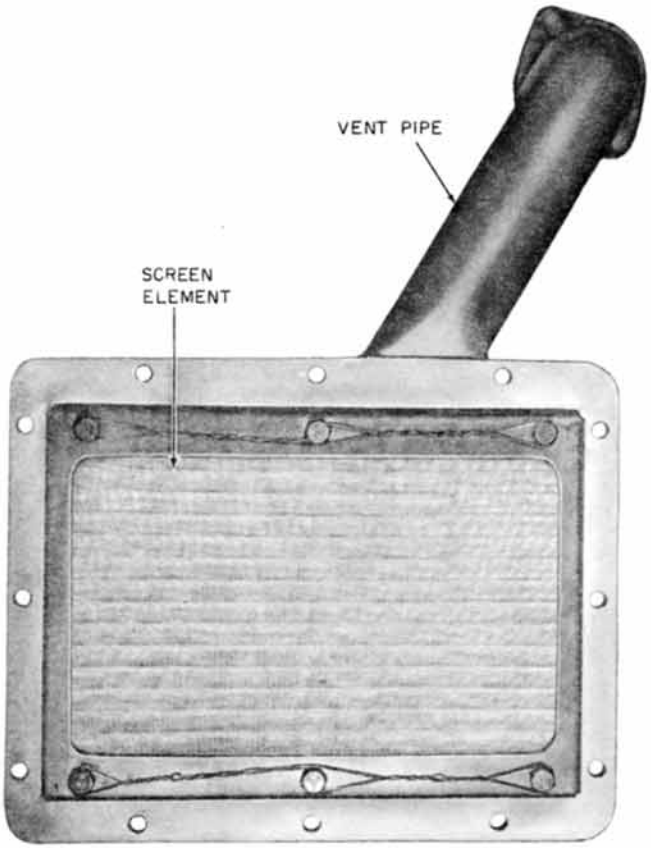



Fig. 4-6 (E-9940)

*Fig. 4-6. Crankcase breather cover assembly*



Fig. 4-7 (E-9927)

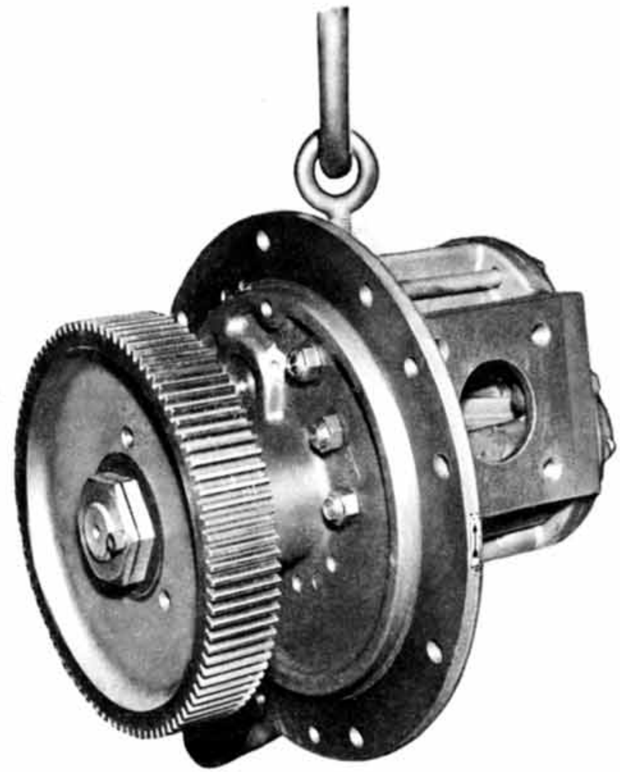


*Fig. 4-7. Lubricating-oil pump*

LUBE-OIL PUMP (See Figs. 4-7 and 4-8)

The lubricating-oil circulating pump is of the positive-displacement type, using a pair of helical gears as rotors. It is mounted on a flanged mounting plate and is driven by the pump idler gear. The pump body has a flanged outlet opening for external discharge piping.

1 Bushing (marked 21F)
2 Nut
3 Dowel pin
4 Drive gear and shaft
5 Back plate
6 Dowel pin
7 Bushing (21B)
8 Lock nut
9 Bushing (10)
10 Dowel pin
11 Casing
12 Idler gear and shaft
13 Dowel pin
14 Nut
15 Bushing (9)
16 Face plate

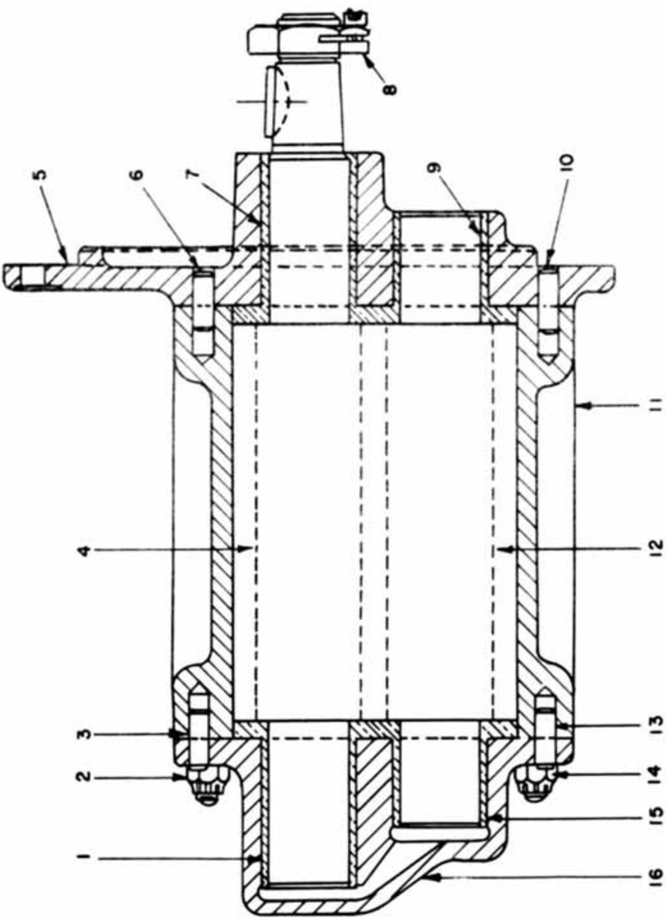



*Fig. 4-8. Cross section of lube-oil pump*

Fig. 4-8 (E-13161)

1 Overspeed and fuel-control oil pressure
2 Water line
3 Cast-in header
4 From main oil header
5 Oil supply to governor drive gear box
6 Cab gage line
7 Drain line from overspeed governor
8 Pump suction line
9 Pressure relief valve
10 Test point
11 Pump
12 Pressure regulating valve
13 Cooler
14 Filter
15 Vent

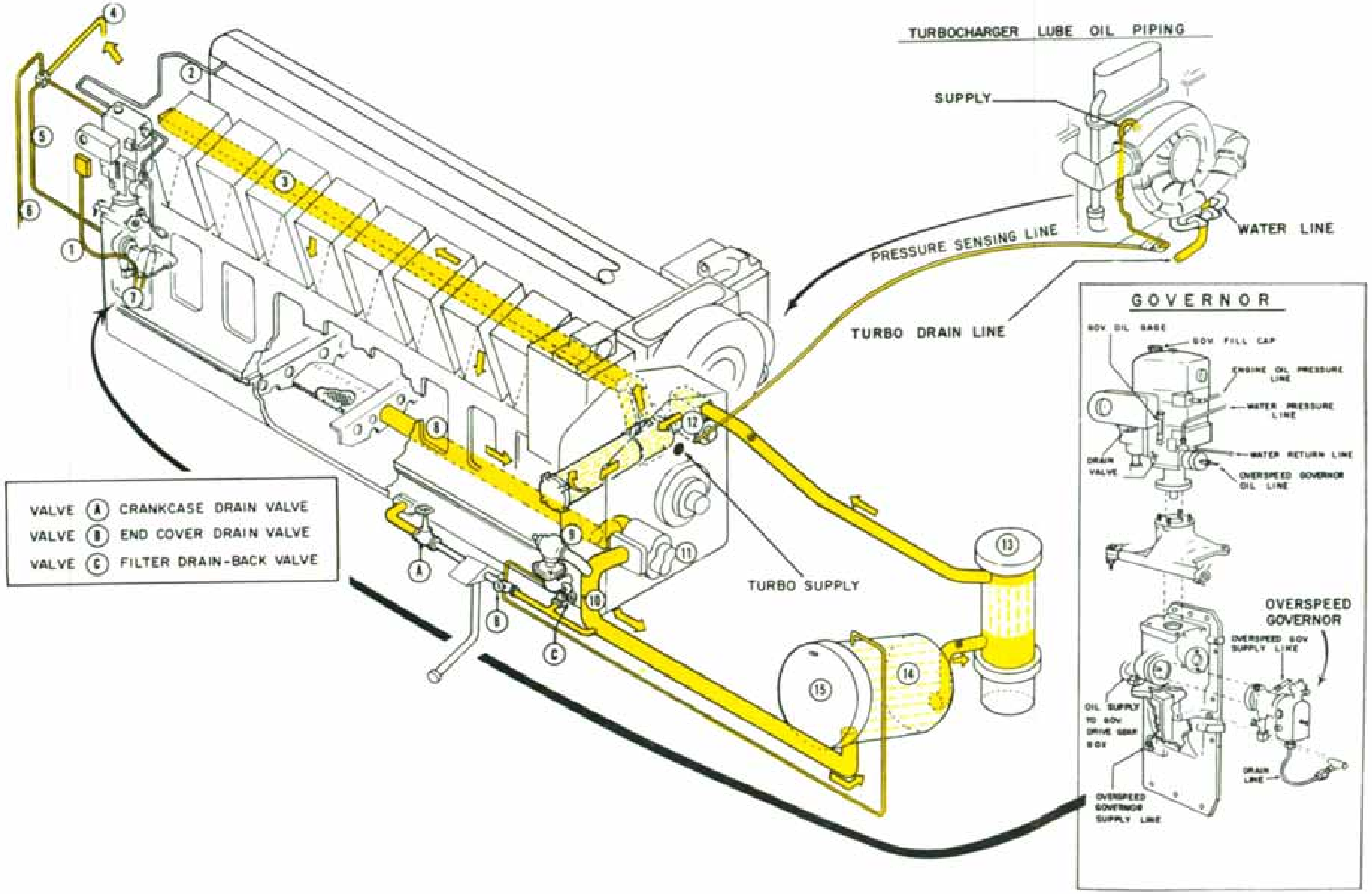



*Fig. 4-9. Lubricating-oil system*

# FUEL OIL SYSTEM

## DESCRIPTION

The engine fuel supply is contained in a fuel tank located below the locomotive platform. Fuel is drawn from the tank by the electric-driven fuel-booster pump and is circulated through the system. (See Fig. 5-1.)

The fuel system consists of the following components, listed in order of fuel flow from the fuel tank through the system:

1. Fuel tank
2. Fuel heater (optional)
3. Single element fuel strainer
4. Fuel-booster pump
5. Relief valve
6. Primary filter
7. Engine fuel header
8. Injection equipment
9. Regulating valve
10. Fuel drain headers

The suction side of the system is between the tank and the fuel-booster pump. Fuel is drawn through a fuel heater (optional), and through a single-element fuel strainer before reaching the pump.

The pressure side of the system is located between the booster pump and the pressure regulating valve which discharges excess fuel back to the tank. Fuel discharged by the booster pump flows to a single-element fuel filter. A relief valve is also connected to the pump discharge and protects the booster pump from overloads caused by flow restrictions in the pressure side of the system. Fuel is then conducted through a pipe to the engine fuel header.

Individual flexible hoses connected between the injection-pump inlet fittings make up the engine fuel header. The fuel header first supplies fuel to the injection pumps on the left bank, and then crosses over by the turbocharger and supplies the injection pumps on the right bank.

1 Cylinder drain
2 Fuel heater (if used)
3 Fuel strainer
4 Fuel pressure gage
5 Tank sight gage
6 Fuel-level gage (if used)
7 Tank fill
8 Test points
9 Pressure regulating valve
10 Pressure relief valve
11 Booster pump
12 Condensate drain valve
13 Drain plug
14 Fuel tank
15 Tank vent
16 Fuel header
17 Primary fuel filter

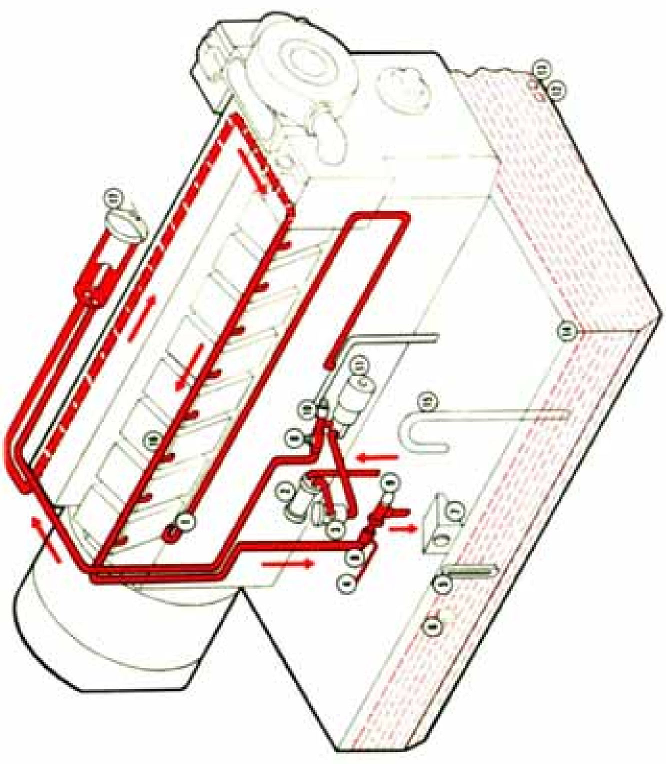


*Fig. 5-1. Fuel-oil system*

Fig. 5-1 (E-16054)



Excess fuel returns to the tank through a regulating valve which is adjusted to maintain pressure in the engine fuel header.

Two fuel drain headers, one on each side of the engine frame, collect fuel leaking back from the injectors and high-pressure pumps, and direct it back to the fuel tank.

## FUEL TANK

Units are equipped with a single fuel-supply tank centrally located below the platform. The tank is equipped with two fill openings, one on each side of the tank. Two fuel-level sight gages, one near each fill opening, are standard equipment on the tank. Fuel-level dial gages may be applied to the tank as optional equipment. One sump, located lengthwise at the bottom of the tank, is equipped at both ends with a condensate drain valve and a larger drain opening which contains a plug. A vent pipe vents the tank to atmosphere.

## ELECTRIC EMERGENCY FUEL CUT-OFF SYSTEM

The electrically operated, emergency fuel cut-off system is arranged with three emergency trip switches. Momentarily depressing any one of these switches will cause the fuel-booster pump to stop, thus stopping the flow of fuel to the engine. At the same time, a signal to the governor stops the engine. Once tripped, the system is restored to normal by depressing a "reset" button in the operator's cab or, upon starting the engine, the system will be reset automatically.

## FILLING AND DRAINING

### FUEL OIL

The fuel oil recommended for the engine is distilled fuel and should conform to the American Society for Testing Materials (ASTM) Specification D-975 No. 2-D. For extreme low temperatures, or for engines operating at high altitudes, number 1D fuel with a minimum cetane value of 45 may be used. For further information, see FUEL AND LUBRICANT SPECIFICATIONS.

### FILLING

Fuel filling may be done from either side of the locomotive by applying the fuel hose to the fill opening (fill fittings may differ depending on customer preference). Observe the upper sight gage periodically during filling to determine when the tank is full.

The fuel supply may be determined at any time by observing the upper and lower sight gages or the fuel dial gage (if used) for the indicated fuel level.

### DRAINING

The fuel tank should be periodically drained of accumulated water condensate by the use of the drain valves at each end of the tank sumps. These valves are made with a straight-thread screw which contains a drilled passage and has an internal stop to limit the number of turns they can be opened. If an excessive amount of water is found in the fuel tank, a check of the engine fuel filters, fuel heaters (if used), system, and fuel supply should be made immediately. Also check the possibility that leakage from a cylinder injector tube may be getting to the tank through the fuel return headers. If water is permitted to enter the fuel system, it can cause extensive damage to the system parts.



Large quantities of fuel may be quickly drained from the tank by removing the drain plug from each end of the tank sumps. The sump end-covers may be removed to gain access to the tank when internal cleaning becomes necessary.

## DATA

### FUEL TANK CAPACITY

U33B . . . . . . . . . . . . . . . . . . . . . . . . . . . 1700 Basic
3250 gal. (Option)

U33C . . . . . . . . . . . . . . . . . . . . . . . . . . . 3250 Basic
4000 gal. (Option)

# COOLING WATER SYSTEM

## DESCRIPTION

### COMPONENTS

The locomotive pressurized cooling system (see Fig. 6-7) maintains an essentially constant engine operating temperature throughout its load range and with wide variations in ambient temperature. The system also supplies heat to the cab heater, and cooling to the water-cooled air compressor.

The principal components in the system are as follows:

1. Water storage tank
2. Lube-oil cooler
3. Water pump
4. Water inlet headers
5. Water discharge header
6. Flow control valve
7. Radiator sections
8. Cab heater
9. Valves and interconnecting pipes

### SYSTEM OPERATION

The water storage tank, located just forward of and slightly below the radiator panels, contains the supply of "working coolant" in the system. A fill opening, equipped with a spring-loaded cap, is located near the top of the water-storage tank on the "A" side.

Water leaving the storage tank is drawn downward through vertical tubes in the lubricating-oil cooler, and is then conducted to the suction side of the engine-driven centrifugal water pump. To simplify piping and system draining, the lubricating-oil cooler is bolted directly to the storage tank at its lowest point. The cooler is supported from the locomotive platform by three adjustable feet.

Water discharged from the pump enters a lateral passage in the free-end cover of the engine where it is distributed to the inlet-water header pipes, the turbocharger, and the intercoolers.

The inlet water headers, one along each side of the engine, distribute cooling water to the cylinders. These headers are made up of eight sections which are individually removable. Each section is bolted to its cylinder and connected to adjacent sections by Dresser couplings.

The cylinders contain wet-type liners surrounded by vertical passages. Cool incoming water flows through these passages and upward and out through additional passages in the cylinder head.

The engine intercoolers, which remove heat from combustion air, are constructed with a fabricated-steel case enclosing a fin and a tube-type radiator core. Cooling water, from the free-end cover, enters at the bottom of each intercooler, passes vertically three times through the core, and is then discharged at the top of the cooler. Water flow through each intercooler is limited by an orifice in the cooler discharge opening.

The turbocharger located at the free-end of the engine receives its cooling water through two openings in the top surface of the free-end cover. These openings are aligned with openings in the base of the turbocharger bracket, and the mating connections are sealed by "O" rings.

Water is discharged from the turbocharger at three openings near the top on its exhaust-gas inlet side. These openings are in turn connected to the discharge pipe from the left intercooler.

Water is supplied to the cab heater by a pipe connected to the outlet water header on top of the engine, and is returned to the system through a pipe which extends along the right side of the engine and which is connected to the bottom header on the lube-oil cooler. If desired, a fuel heater, which is optional equipment, may be connected into this line. The compressor is supplied from a pipe connected to the flow control valve and discharged into the radiator return pipe.





The discharge water header is centrally located lengthwise over the engine, with its discharge opening connected to a junction box at the top of the right intercooler. Branch pipes welded into the header are connected to individual cylinders by Dresser fittings. Water flowing from the intercoolers, turbocharger, and discharge water header combines at the junction box and is conducted to the flow control valve.

The flow control valve is mounted at the forward left corner of the water storage tank and regulates the temperature of the system by routing the water flow from the engine as follows (see Fig. 6-7):

1. Directly to the water storage tank – when minimum engine cooling is required.

2. To the forward two radiator sections – when partial cooling is required.

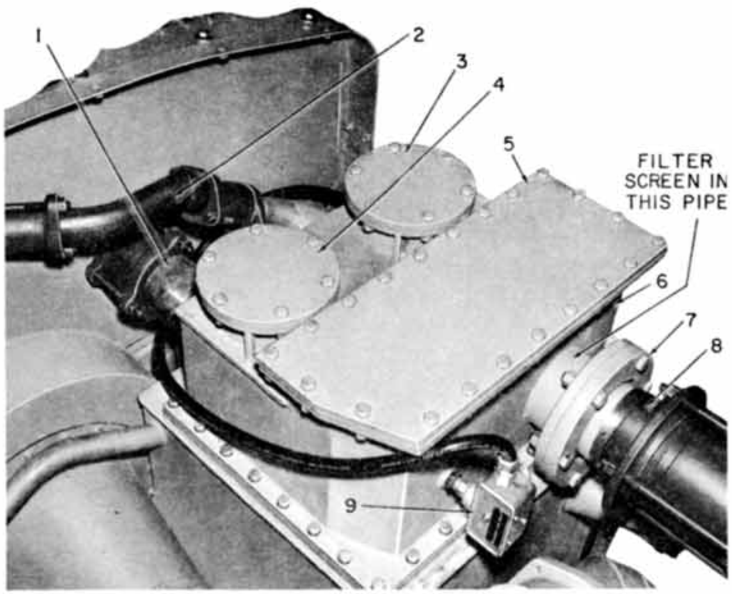
3. To all radiator sections – when full engine cooling is required.

Water cooled in the radiators is then returned to the storage tank. For minimum engine cooling, the flow of water to the radiators is cut off by the flow control valve and the water left in the radiator sections and piping is quickly drained to the storage tank by gravity flow.

## FLOW CONTROL VALVE

(See Fig. 6-1)

The flow control valve has no manual adjustments. The valve is made up of eight thermostats, two piston-type valves, and a filter screen, all housed in a fabricated-steel case. The valve case is mounted over an




1 Outlet to radiator sections 3-4-5-6
2 Outlet to radiator sections 1-2
3 $V_1$ valve cover
4 $V_2$ valve cover
5 Thermostat housing cover
6 Flow control valve
7 Collar
8 Discharge water header
9 Engine high-temperature switch

*Fig. 6-1. Overhead view of flow control valve and associated piping*

Fig. 6-1 (E-11810)



opening in the water-storage tank and is connected to the engine by a single pipe, and to the radiator sections by two pipes. (See Fig. 6-1.) Three removable covers permit access to the control valve's internal parts. A rectangular cover is over the eight thermostat units, and two circular covers are over the $V_1$ and $V_2$ piston-type valves. A 1/2-inch pipe boss is provided in the cover to permit installation of a temperature test gage.

## VALVES WITHIN THE CASE

### Thermostat Valves

The eight thermostats, which are identical, function as two-way valves. When water temperature is below their operating point, as in Fig. 6-2(A), they pass the water directly through their cylindrical bodies to the water tank below.

When the water temperature increases, the temperature-sensitive compound in the bulb (located on top) expands, overcoming spring pressure and forcing the skirt downward. (See Fig. 6-2(B).) As this skirt moves, the opening at the bottom becomes more and more restricted, while the previously closed opening at the top of the skirt (increasing in size) permits the water pressure to start building up in the adjacent chamber.

### Piston-type Valves

Conditions of flow through the radiator are controlled by the two "snap action" piston-type valves, $V_1$ and $V_2$. (See Fig. 6-3.) Vertically mounted within the case, the valves each consist of an upper and a lower piston connected by a stem. These valves are identical and interchangeable. The center portion of each valve is hollow to permit water which leaks past the upper piston to return through the valves to the storage tank; thus, leakage has no effect on the operation of the system. To assure accurate operation, the weight of each valve is held within close limits during manufacture.

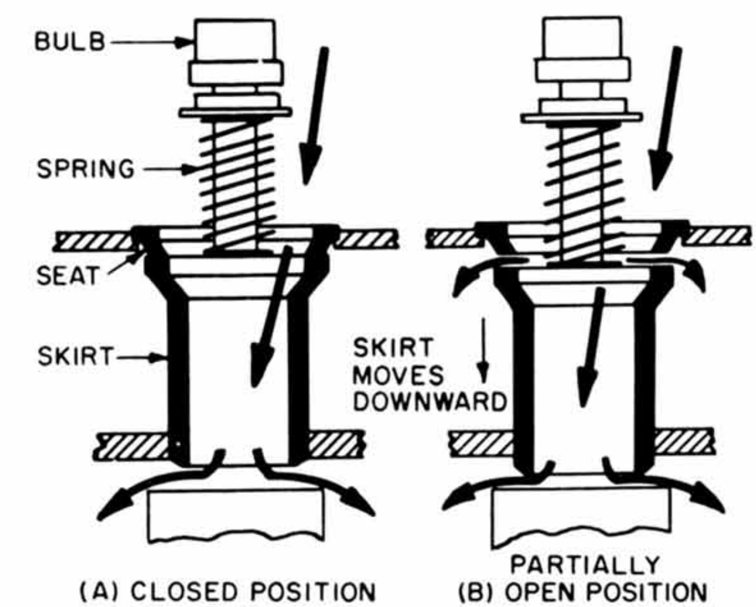



Fig. 6-2 (E-9989)

*Fig. 6-2. Operation of thermostats*

Successful operation of the system during freezing weather depends upon water flow through the radiator sections being either at a high rate or completely off. If trickles of water are permitted to pass through the radiators, ice would form in the tubes. The "snap action" of the piston-type valves accomplishes this purpose.

## COMBINED OPERATION

The flow control valve regulates the temperature of the cooling system by directing the water flow in the following manner:



### When Minimum Engine Cooling Is Required
(See Fig. 6-3)

Water discharged from the engine enters Chamber A to flow downward through the thermostats. Since the thermostats are below operating temperature, water passes through their lower openings to the tank.

### When Partial Engine Cooling Is Required
(See Fig. 6-4)

As the engine discharge water temperature rises, the thermostats begin to operate. The downward movement of the skirts partially restricts water flow to the tank. At the same time, openings at the top of the skirts allow water to enter Chamber B.

Pressure now begins to develop in Chamber B. When the thermostats have moved their skirts enough to cause this pressure to reach approximately 4 psi, valve $V_1$ "snaps" upward to the limit of its travel.

Chamber B is now open to Chamber C, and Chamber C is closed to the storage tank by the lower piston of valve $V_1$. Water flows from Chamber C through the pipe connection to the radiator sections 1 and 2.

At the moment valve $V_1$ opens, water pressure in Chambers B and C falls somewhat below 4 psi; thus, valve $V_2$ does not open. Valve $V_1$ remains up, however, because the area of the bottom of its upper piston that is exposed to pressure is still large enough to hold $V_1$ up, even with reduced pressure.

If the cooling demands are now satisfied, and the water temperature remains approximately constant, no changes in the valve position take place. Small variations in the cooling requirements are satisfied by a slight opening or closing of the thermostats to modulate the flow.

If the cooling requirements should fall off, the thermostats will close the opening at the top of the skirt (and open the exit to the tank) sufficiently to lower the pressure in Chambers B and C to the point that gravity will pull valve $V_1$ down to its closed position, resulting again in the situation depicted in Fig. 6-3. Air from the storage tank enters Chamber C to vent the radiator, permitting it to drain quickly.

## When Full Engine Cooling Is Required (See Fig. 6-5)

If, with valve $V_1$ open, the engine discharge water temperature continues to rise, the thermostats will still further restrict water flow to the storage tank, and at the same time allow increased flow to Chambers B and C. Pressure in these chambers again begins to increase. When it reaches approximately 4 psi for the second time, valve $V_2$ will "snap" upward to the limit of its travel.

Chamber C is now open to Chamber D, and Chamber D is closed to the storage tank by the lower piston of valve $V_2$. Water flows from Chamber D through the pipe connection to radiator sections 3, 4, 5 and 6.

Water is now flowing to all the radiator sections, resulting in a maximum cooling by the system. As before, small variations in the cooling requirements are satisfied by a slight opening or closing of the thermostats to modulate the flow.

## When Engine Cooling Requirements Decrease

When the cooling requirements decrease sufficiently, the sequence of operation previously described will reverse. The thermostats will gradually reduce the water flow and thus reduce the pressure in Chambers B, C and D. Because of the higher rate of flow, the greater decrease in pressure will occur in Chamber D, causing valve $V_2$ to close first. When valve $V_2$ closes, the flow of water to

Fig. 6-3 (E-9946A)

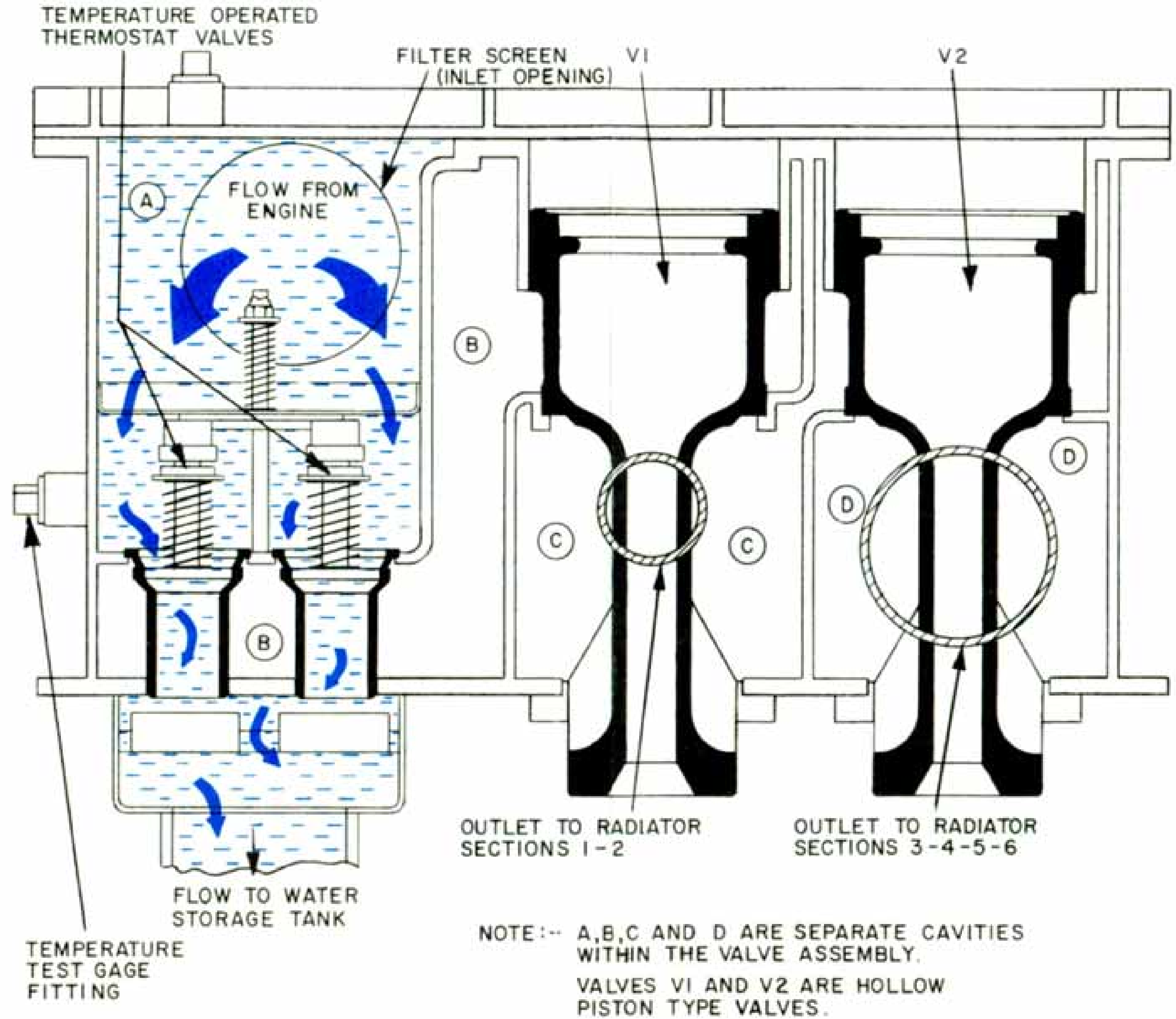



*Fig. 6-3. Flow control valve operation, minimum engine cooling required*

Fig. 6-4 (E-9947A)

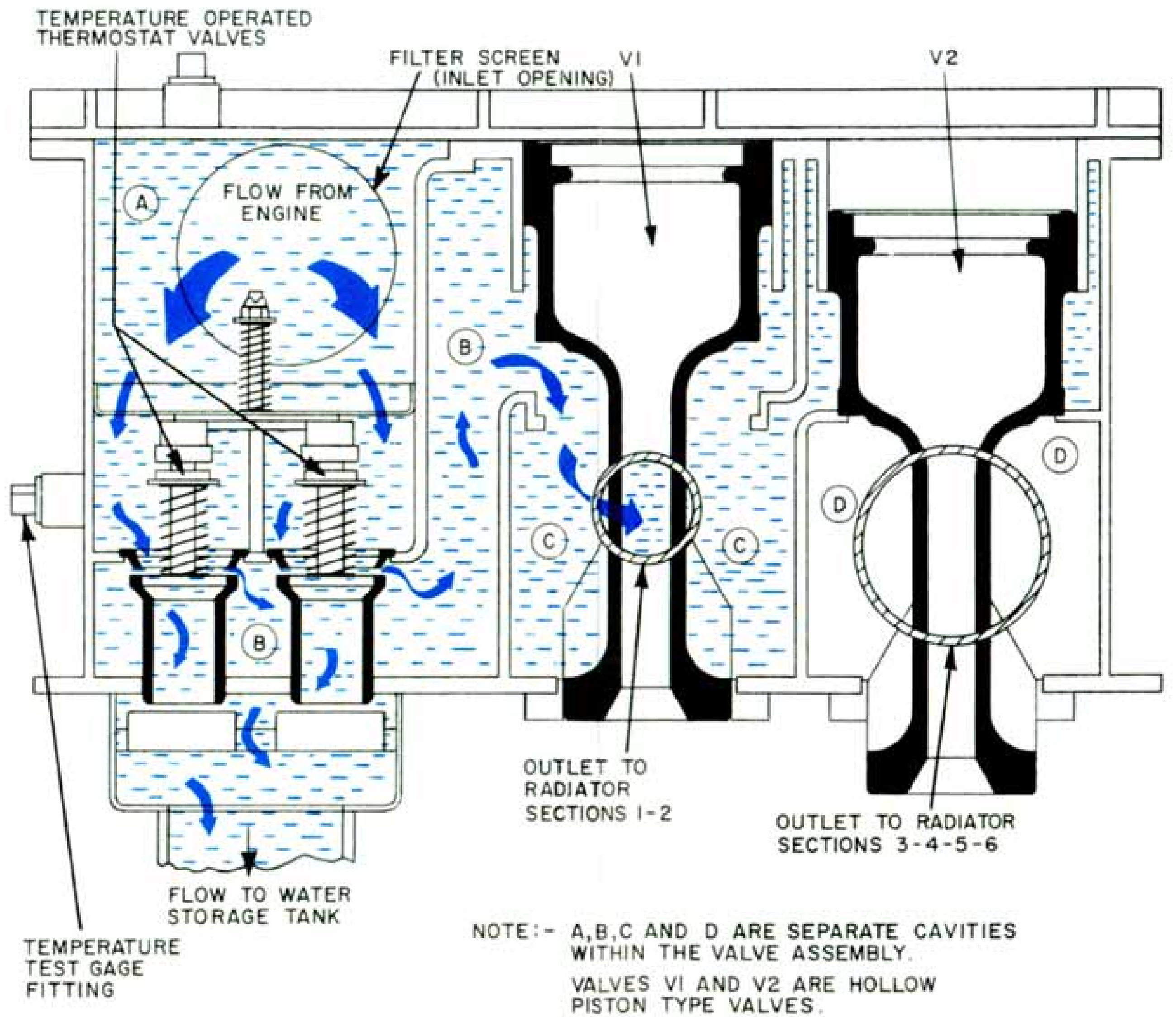



*Fig. 6-4. Flow control valve operation, partial engine cooling required*

Fig. 6-5 (E-9948A)

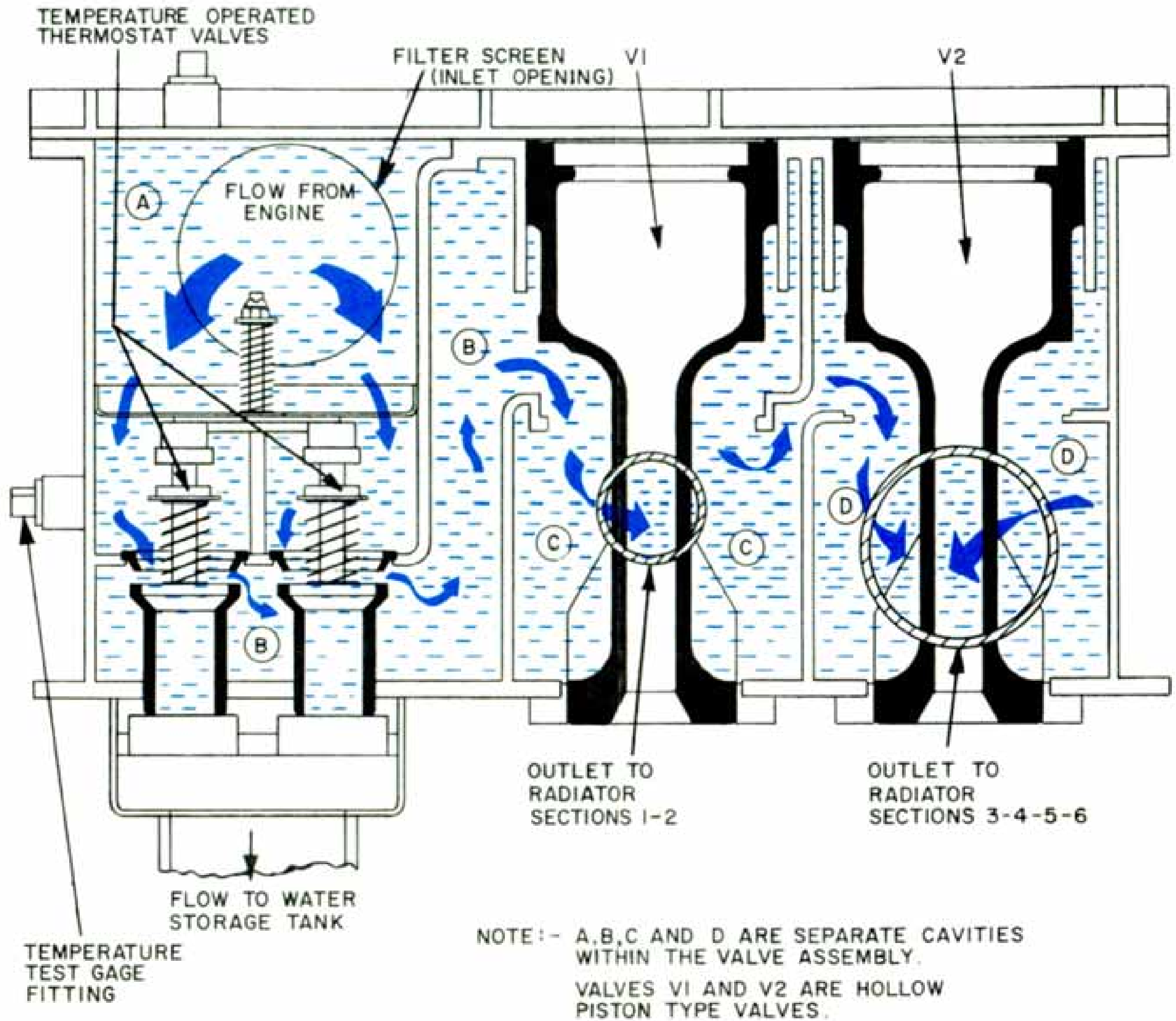



*Fig. 6-5. Flow control valve operation, full engine cooling required*

the radiator sections 3, 4, 5 and 6 will be shut off. At the same time, the radiator sections will be vented to the storage tank by the lower piston on valve $V_2$, thus permitting the water remaining in the sections to quickly drain to the tank.

Water pressure in Chambers B and C will be increased somewhat by the closing of valve $V_2$; thus valve $V_1$ will remain open.

If cooling requirements continue to decrease, the thermostats will further reduce pressure in Chambers B and C. When the pressure in Chamber C becomes sufficiently low, valve $V_1$ will close, shutting off the flow of water to the radiator sections 1 and 2. As with valve $V_2$, the radiator sections are vented to the storage tank through the lower piston-valve $V_1$, thus permitting the water remaining in these sections to quickly drain to the tank.

## SAFETY DEVICES

### ENGINE HIGH-TEMPERATURE SWITCH

The engine high-temperature switch, mounted on the flow control valve, is a thermal-electrical safety device that functions to alert the operator should the engine temperature become excessive. When the temperature of the water discharged from the engine reaches the temperature setting of the switch, its electrical contacts will close, energizing a light and/or bell in the operator's cab.

To assure proper operation, the switch should be inspected and tested in a hot pot.

With the switch in place, remove the cover plate and check to make certain the electrical connections are secure and the contacts are in good condition. The contacts, if burned or pitted, may be dressed (with the circuit de-energized) by using a small, fine, flat file.

*CAUTION: DO NOT SET THE SWITCH ON THE LOCOMOTIVE BY COVERING THE RADIATOR INLET SCREENS. DO NOT COVER THE ENGINE AIR INLET. THIS CAN DAMAGE THE ENGINE AIR FILTER SYSTEM.*

*CAUTION: WHEN CONDUCTING THIS TEST, DO NOT ALLOW THE TEMPERATURE OF THE COOLING WATER DISCHARGED FROM THE ENGINE TO EXCEED 215 F.*

Should the switch require an adjustment, its closing and opening settings can be raised or lowered simultaneously by turning the external adjustment screw on the switch case. The differential setting of the switch can be adjusted by changing the magnetic air-gap of the movable contact. However, this adjustment is quite difficult to make and should not be tampered with when adjusting the switch on the locomotive.

When checking an engine high-temperature switch, immerse the switch tube in a pot of agitated water. Slowly raise the water temperature until the switch contacts close. Lower the water temperature until the contacts open.

### LOW-WATER-PRESSURE SHUTDOWN

The low-water-pressure shutdown is an automatic safety device used to shut down the engine in the event of cooling-water pressure failure.

This device is mounted on the left side of the engine control governor and is piped to the engine cylinder inlet water header.

If the pressure of the cooling water supplied to the engine cylinders drops below that required for safe operation of the engine, the water pressure device will function to shut down the engine. (For operating and adjustment details refer to ENGINE CONTROL GOVERNOR.)



## COOLING WATER TREATMENT

In order to maintain the efficiency of the diesel engine cooling-water system and to protect against corrosion or erosion of the various metals in contact with the fluid, the water used should be kept clean and within proper limits of alkalinity, hardness, and inhibitor concentration.

## FILLING THE SYSTEM

(See Fig. 6-6)

The locomotive cooling-water system may be filled through three openings. One fill is located on the "A" side near the top of the storage tank. The other two fills are located on each side of the locomotive, beneath the platform. One of these serves as a vent when the other is used as a fill. A two-way valve, mounted on the tank, must be opened to fill or vent the system.

The water-level sight gage is located on the water storage tank and is marked to indicate the normal water levels which occur throughout the various operating conditions of the cooling system. When the locomotive is operating, large fluctuations will occur in the level of the water in the sight gages and the storage tank. This is normal and is caused by water in varying amounts being diverted from the storage tank to the radiators during intervals of cooling.

When filling the system from a completely drained condition, adjust the water to the proper level with the engine idling to allow trapped air to vent from the system.

*NOTE: Water will be forced out of the fill pipes by the pressure in the system if the fill caps are removed when the water level is above the "FULL AT IDLE" mark on the gage or if the system is excessively hot. Before removing the caps, drain some water from the system or allow the system to cool down. In either case, slowly turn the fill caps to allow the system pressure to be vented before removing the caps.*

## DRAINING THE SYSTEM

(See Fig. 6-7)

The cooling system is equipped with three manually operated valves: a main system drain valve (A), located near the base of the lubricating oil cooler, and two cab heater shut-off valves (B) and (C), located in the operator's cab near the cab heater.

*NOTE: Because this is a pressurized system, draining time will be greatly reduced if the system is vented to atmosphere by removing one of the fill caps.*

The system can be completely drained by opening valves A, B and C. In freezing weather, the 1/4-inch drain plug must also be removed from the water pump impeller casing.

*CAUTION: TO PREVENT THE CAB HEATER CORE FROM FREEZING DURING EXTREMELY COLD WEATHER, HEATER VALVES B AND C MUST REMAIN FULLY OPEN AT ALL TIMES. IF, IN AN EMERGENCY, THE VALVES MUST BE CLOSED, THE PIPE CONNECTIONS TO THE HEATER CORE MUST BE LOOSENED TO PERMIT*



Fig. 6-6 (E-11809A)

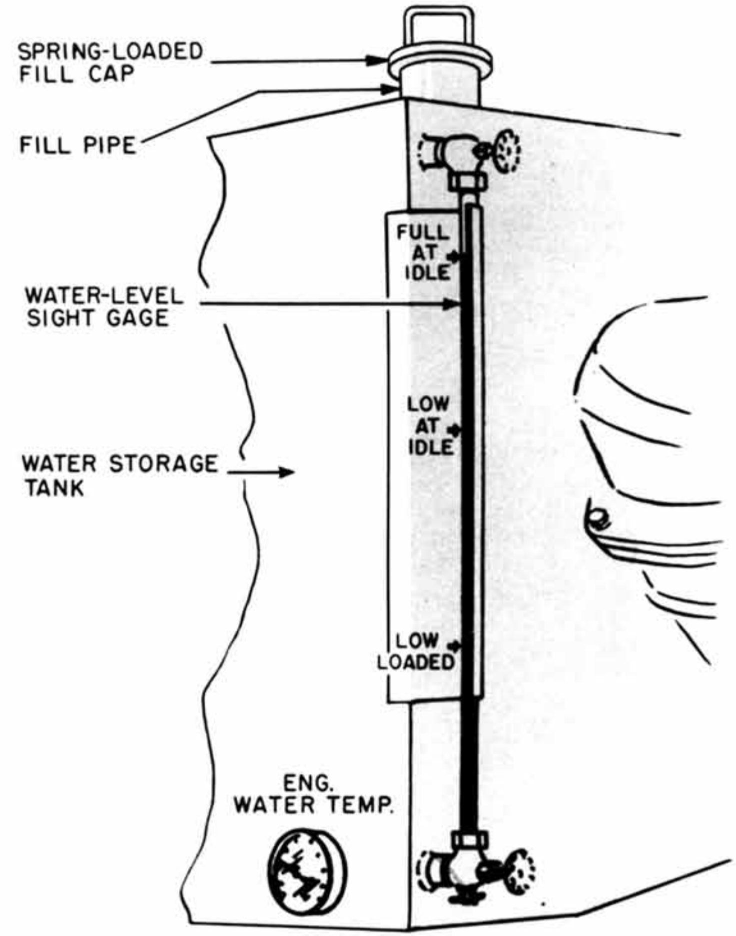



*Fig. 6-6. Water-level sight gage*

*THE CORE TO DRAIN. IF THE LOCOMOTIVE IS SHUT DOWN DURING EXTREMELY COLD WEATHER, DRAIN ALL WATER FROM THE TOILET RESERVOIR TO PREVENT IT FROM FREEZING.*

## RADIATORS

(See Fig. 6-7)

The radiator is made up of six individual sections, three on each side of the locomotive, mounted to slope downward from the locomotive centerline to the outer sides. Wire screening is mounted over the upper side of the radiators to protect them from damage.

Radiator sections are alternately numbered, starting at the water storage tank. The odd numbers are on the right side of the locomotive and the even numbers are on the left.

A pipe connects Chamber C of the flow control valve to the inlets of the radiator sections 1 and 2. Another pipe connects Chamber D of the flow control valve to the inlets of radiator sections 3, 4, 5 and 6. Pipe connections at the radiator sections are made by Dresser fittings to permit easy removal.

Cooled water flows from the radiator sections through their respective drain header pipes to the water storage tank. A small pipe, connected parallel to the large drair header pipe, assures complete draining when the locomotive is not on level track.

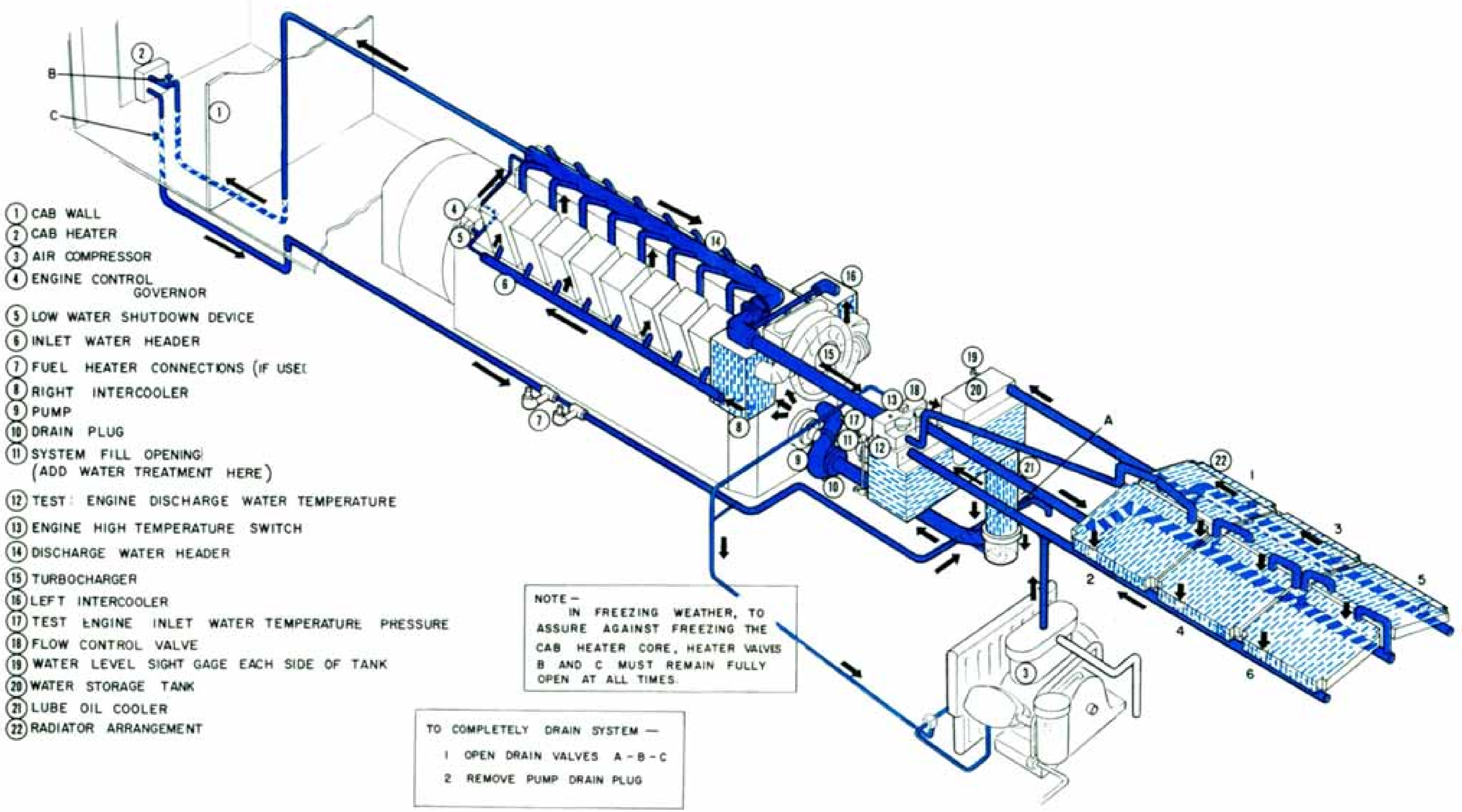



*Fig. 6-7. Locomotive pressurized-cooling water system, cutaway view*

AIR SYSTEMS

## EQUIPMENT AIR SYSTEM (See Fig. 7-3)

### DESCRIPTION

Air enters the front end of the locomotive through a screened inlet. The incoming air passes first through the equipment blower and then down into the platform. Part of the air moves to the front of the locomotive, passing through an air cleaner. The bleed air is discharged out the bottom of the locomotive. The cleaned air is supplied to the control compartment, a cab heater, and the front traction motors. The air also moves in the platform toward the rear of the locomotive and is cleaned by another air cleaner. This cleaned air ventilates the back traction motors and extended-range dynamic braking compartment, if used. In the platform directly below the alternator, air cleaners supply cleaned air to the alternator, to the auxiliary generator, and to the engine cab for pressurization. Clean air is supplied to the rectifiers by air cleaners located in the platform below the rectifiers.

As shown in Fig. 7-1, the equipment air cleaner is made up of 14 panels, each panel having 54 individual tubes. The air flow in the individual tube is shown in Fig. 7-2. Each tube acts as a miniature cyclonic dirt separator. Incoming air enters the vanes in the tubes, causing the air to swirl. Dirt particles, being heavy, go to the outside, and eventually leave the far end of the outer tube. The cleaned air swirling in the central portion is discharged out of the cleaner. The bleed air carries the dirt out of the cleaner.

As shown in Fig. 7-1, an opening at the bottom of each panel permits the separated dirt and bleed air to escape. It is continuously discharged from the locomotive through outlets beneath the underframe.

Test results show that all dirt particles eight microns or larger are removed by this cleaner. (A micron is one-millionth of a meter or approximately 1/25,000 of an inch.)

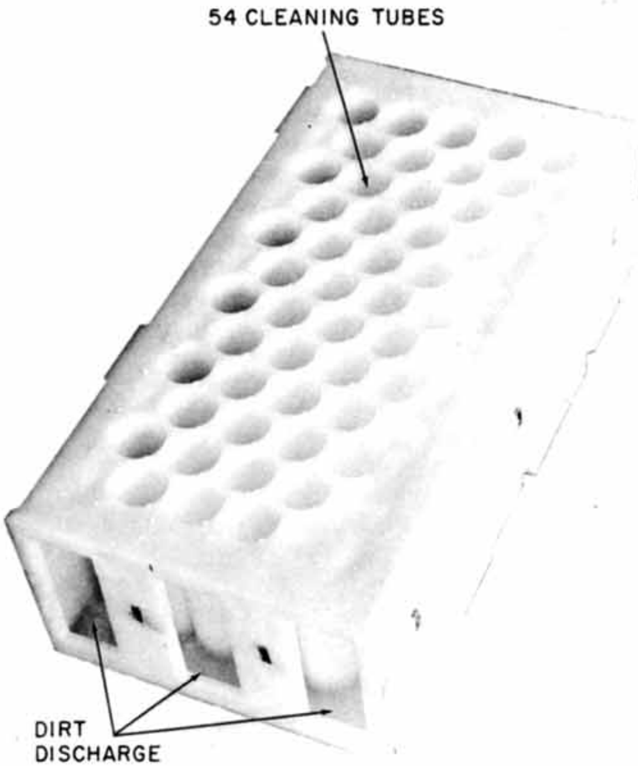



Fig. 7-1 (E-14921)

*Fig. 7-1. Air cleaner*

## ENGINE AIR SYSTEM
## (EQUIPPED WITH PANEL-BATH FILTERS)
(See Fig. 7-3)

### DESCRIPTION

The engine-air primary air cleaner consists of a "V" type inlet screen and three GE air cleaners installed in a door. One door is located on each side of the locomotive,



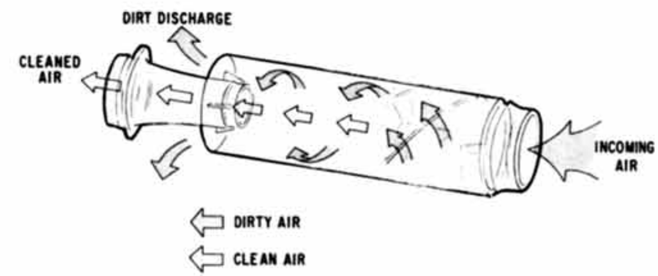



Fig. 7-2 (E-13565)

*Fig. 7-2. Equipment and engine air cleaner tube air flow*

just forward of the water tank and below the radiator. The semi-cleaned air is discharged into a plenum. The power for the bleed-air system is obtained with an engine exhaust gas aspirator. An air duct between the air cleaner bleed-air discharge and aspirator continuously discharges the dirt from the locomotive.

The final engine air cleaner consists of six oil panel-bath-type air filters mounted onto the engine air plenum as shown in Fig. 7-3.

When the diesel engine is running at low speed, all air entering the oil-bath-filter assembly is deflected downward through the oil. Due to the high velocity of the air as it passes across the surface of the oil pool, droplets of oil are picked up and carried upward to wet the screen of the filter panel. It is this oil, draining back down into the reservoir at the bottom, that carries away dirt particles trapped by the filter screen. The quantity of this dirt is comparatively small due to the cleaning action of the primary air cleaners.

As the engine speed increases, the spring-loaded baffle in the front of the oil-bath filter will be deflected by the pressure of the air stream, and permit most of the air to go directly to the filter. However, a portion of the air is deflected downward and across the oil pool to maintain the self-cleaning action of the filter.

## ENGINE AIR SYSTEM (EQUIPPED WITH PAPER AIR FILTERS) (See Fig. 7-8)

### DESCRIPTION

The engine air-cleaner system is located between the engine cab and radiator cab. Ambient air enters the locomotive through a screened air inlet which contains three GE air cleaners, located just above the platform walkway on each side of the locomotive. The cleaned air is collected in the cleaned air plenum and is delivered up through the secondary air filter to the inlet of the turbo through a 14-1/4-inch inside-diameter pipe.

The engine air-filtering system consists of an inlet screen, a primary air cleaner, a secondary air cleaner, and an exhaust stack aspirator. See Fig. 7-4.

The bleed air is discharged out two holes on the end of each primary cleaner and then into an air duct. The bleed air then is discharged out the stack, utilizing an exhaust stack aspirator. See Fig. 7-5. A check valve is used to prevent engine exhaust gases from entering the cleaned air system through the bleed air duct.

Two safety or protective devices are provided to ensure against improper operation of the engine air system. These devices are as follows:

1. A service indicator which indicates when the air-cleaner system needs servicing. See Fig. 7-6.

2. A pressure switch that returns the engine to idle, actuates the trainline alarm, and illuminates a red ENGINE

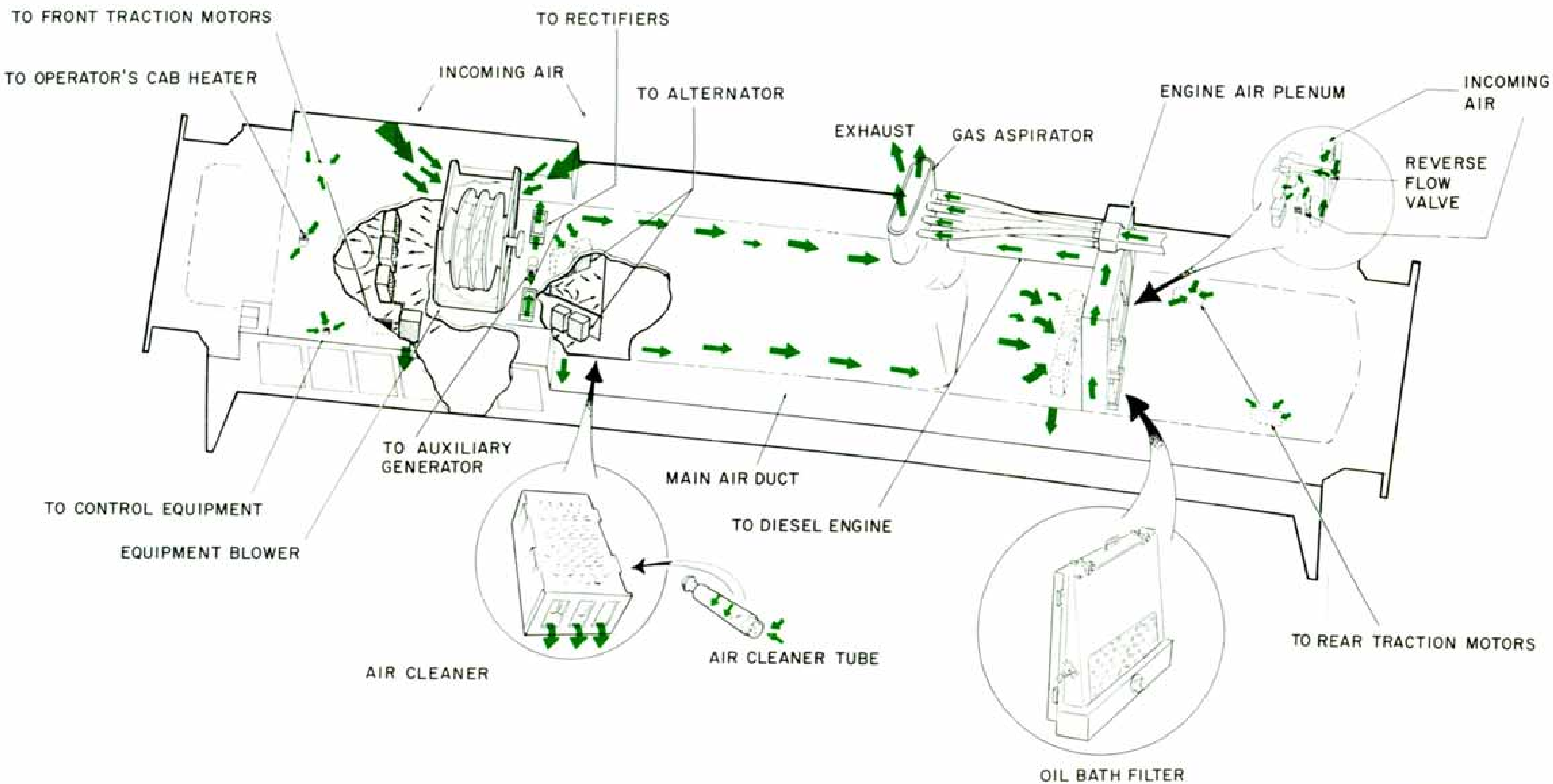



*Fig. 7-3. Locomotive air system*

Fig. 7-4 (E-15051)

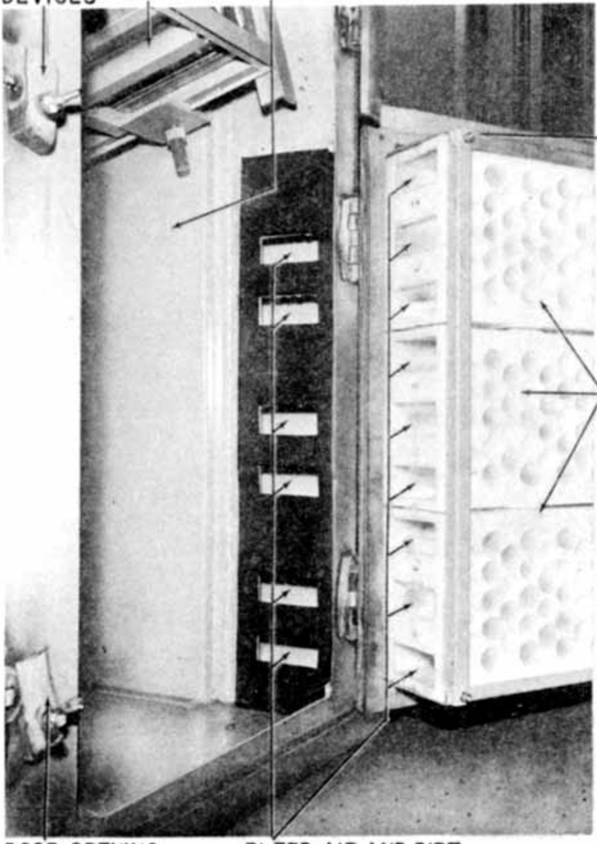



*Fig. 7-4. Engine air cleaner assembly*

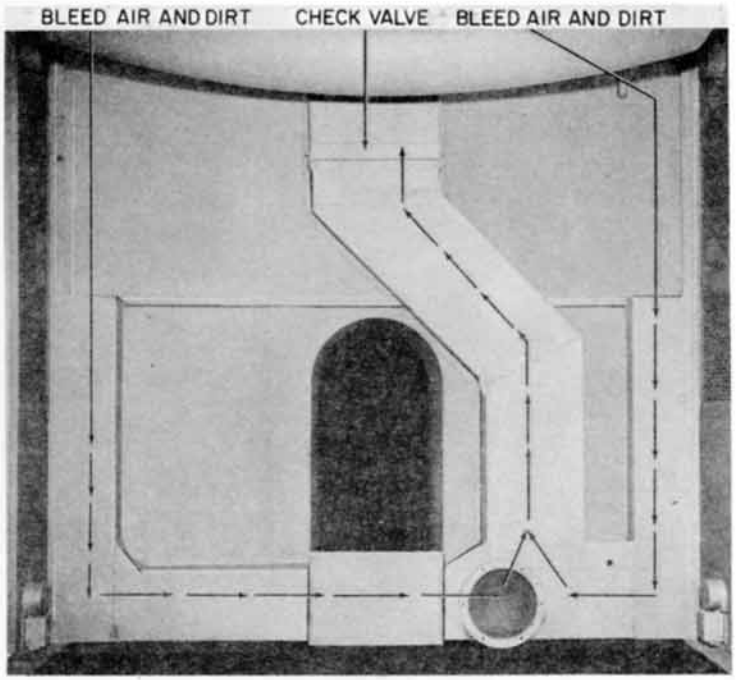



*Fig. 7-5. Bleed air discharge*

AIR FILTER light on the engine control panel. This prevents diesel engine operation with plugged air filters. See Fig. 7-7.

Two U-tube manometer air-pressure taps are located in the vicinity of the service indicator, for use in determining the condition of the air system. See Fig. 7-6.

## SAFETY DEVICES

Two safety or protective devices are provided to ensure against improper operation of the engine air system. Two of these devices operate from the vacuum in the cleaned air plenum. Dirt accumulation on the secondary

Fig. 7-5 (E-15052)

Fig. 7-6 (E-15054)



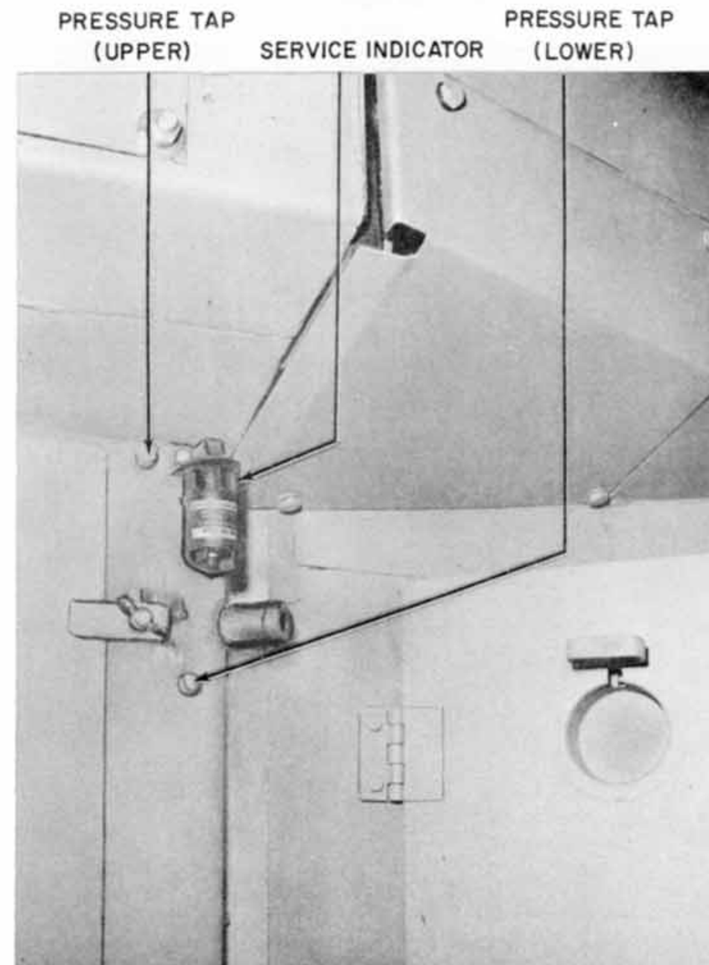



*Fig. 7-6. Service indicator*

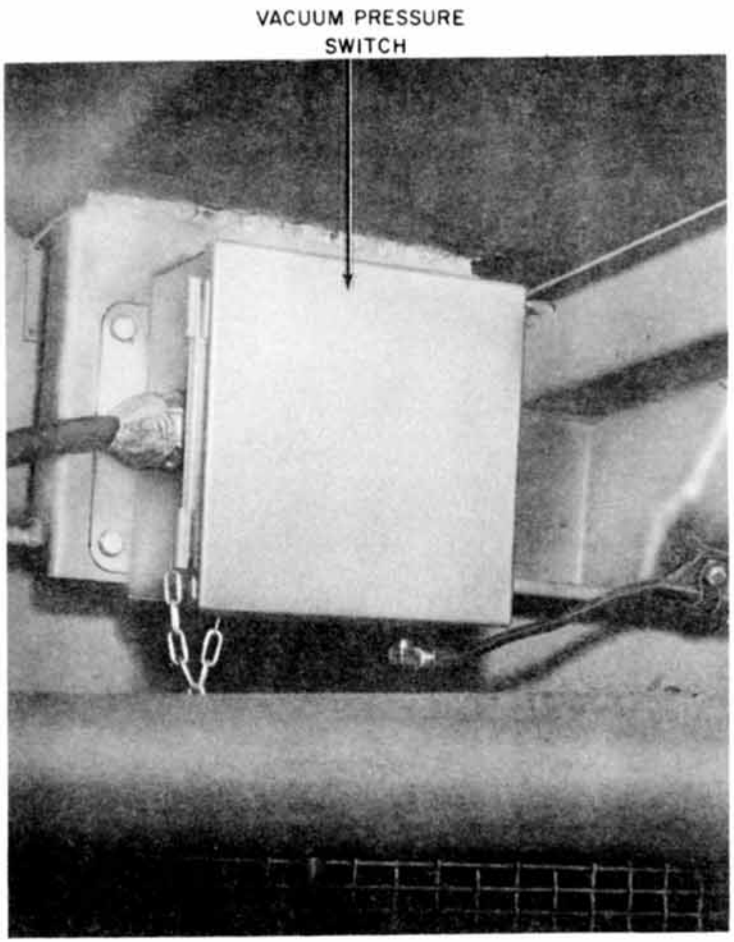



Fig. 7-7 (E-15053)

*Fig. 7-7. Vacuum switch*

air filter or primary air cleaner gradually increases the vacuum in the cleaned air plenum. One of these devices is the service indicator located high on the outside of the right side of the locomotive cab. As the vacuum increases, the red band gradually rises in the service indicator window. See Fig. 7-6. When the pressure reaches minus



12 inches of water, the red band will lock in place and no longer drop when the engine is at idle. This will occur only with the diesel engine in "eighth notch full-load." The filter cartridges must be changed. To reset the service indicator, push the reset button located on the bottom of the indicator.

Should the filter cartridges not be changed, the vacuum in the cleaned air plenum will increase at an accelerated rate. At minus 14 inches of water vacuum, the second safety device, consisting of a vacuum pressure switch located in the back left upper corner of the radiator cab (see Fig. 7-7), energizes the EFR relay and returns the engine to idle. A trainline alarm rings and a red ENGINE AIR FILTER light illuminates on the engine control panel. This circuit can be reset by using the trainline ground-relay reset. If the shutdown was a true indication, the engine will again go to idle as soon as the engine is advanced to "eighth notch full-load."

> *CAUTION: THIS CIRCUIT MUST NOT BE JUMPERED OUT BECAUSE THE RAPID BUILDUP OF PRESSURE DROP ACROSS THE SECONDARY AIR FILTER WILL REDUCE THE AIR TO THE DIESEL ENGINE AND RESULT IN CATASTROPHIC FAILURE OF THE DIESEL ENGINE.*

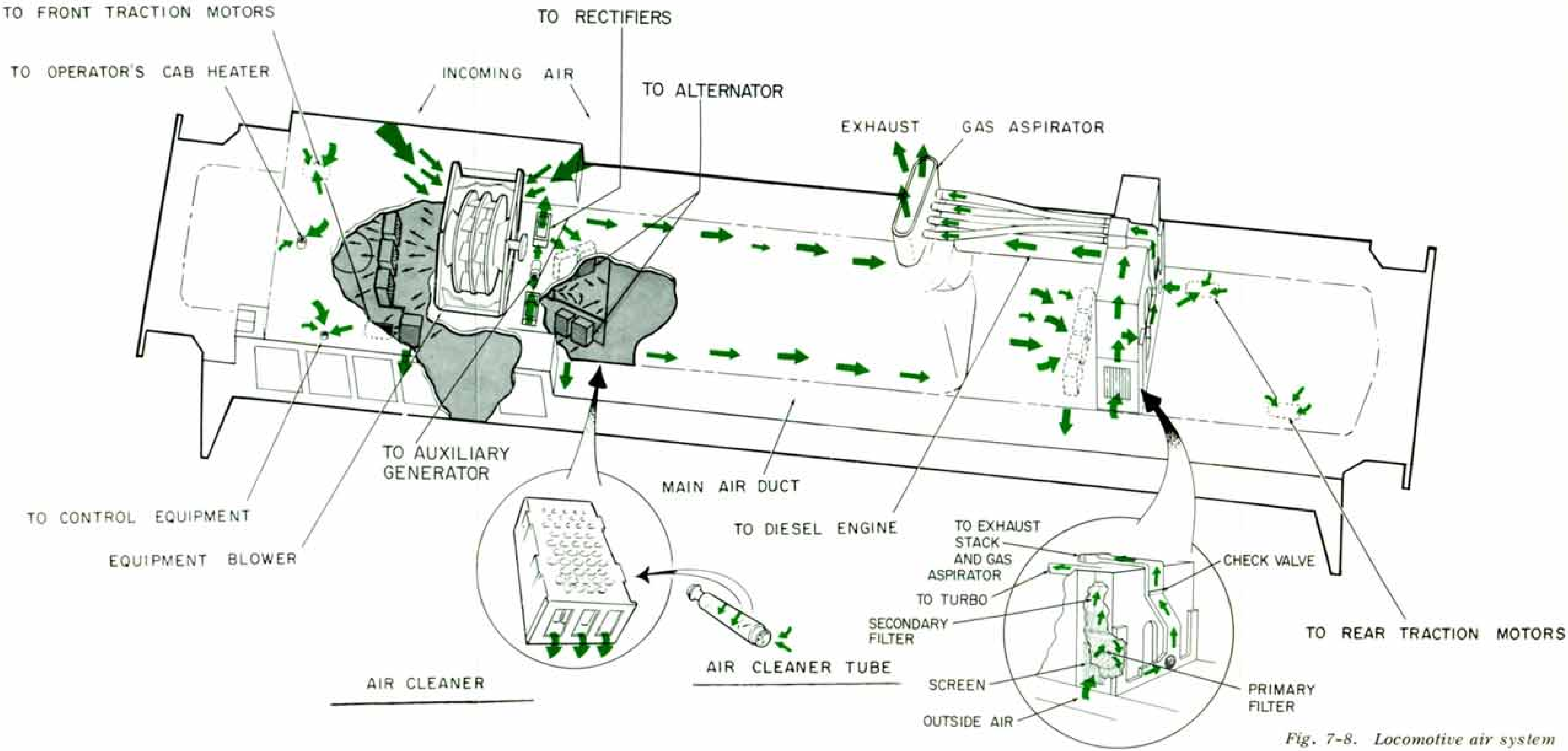



*Fig. 7-8. Locomotive air system*

# OVERSPEED SYSTEM

## OVERSPEED AND FUEL-CONTROL DEVICE

The overspeed and fuel-control device assembly provides automatic control of the diesel engine in the event of an engine overspeed or excessive intake air temperature condition.

### DESCRIPTION

The overspeed and fuel-control device assembly is comprised of two cast-steel cylindrical casings (see Fig. 8-1). The outer casing is a cylinder which is open at one end and is closed at the other end by means of a steel, recessed cover secured by a spring-steel retaining (snap) ring. The inner casing is a cylinder, which is cast with one open end and one closed end. The inner casing also contains an inner-casing actuator assembly cup (see Fig. 8-1) which contains three wax-filled thermal actuators and an actuator spring which is located in the space between the outer face of the assembly cup and the inside face of the inner casing. The outside circumference of the inner ring has two machined, annular grooves into which "O" ring seals are fitted to provide a sliding, close-tolerance fit to the inside surface of the outer casing. The skirt of the inner casing is machined so as to provide an oil space, or recess, between the inner and outer casings. A guide rod locates and centers the assembly cup to the inner casing, and the inner casing to the outer casing (see Fig. 8-1).

Engine intake manifold air is supplied, through a fitting in the outer casing top cover, to the thermal actuators mounted inside the inner casing. Oil from the engine overspeed governor is fed, through a fitting located on the side of the outer casing, into the space between the inner and outer casings (see Fig. 8-1). The device forms an expanding link between the control-governor power piston and the linkage which controls the operation of the fuel-injection pumps (see Fig. 8-2).

1 Top cover
2 Outer casing
3 Thermal actuators (3)
4 Inner casing "O" ring (upper
5 Actuator cap
6 Actuator piston
7 Inner casing "O" ring (lower)
8 Actuator piston lock nut
9 Inner casing cover
10 Inner casing cover bolt
11 Inner casing actuator assembly cup
12 Inner casing
13 Spring
14 Top cover snap ring
15 Guide rod

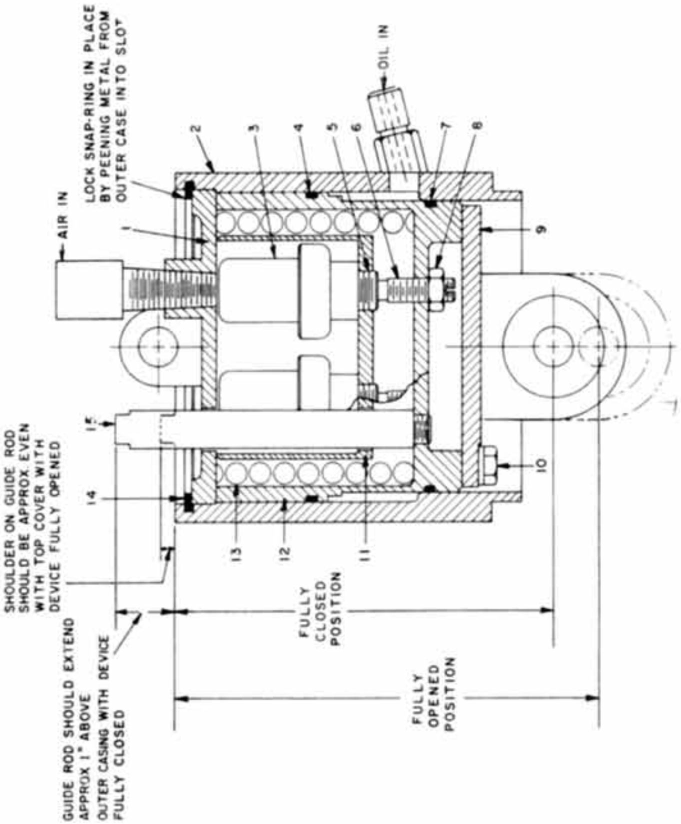



*Fig. 8-1. Cutaway view of overspeed and fuel-control device*

Fig. 8-1 (E-14949)

Fig. 8-2 (E-14950)



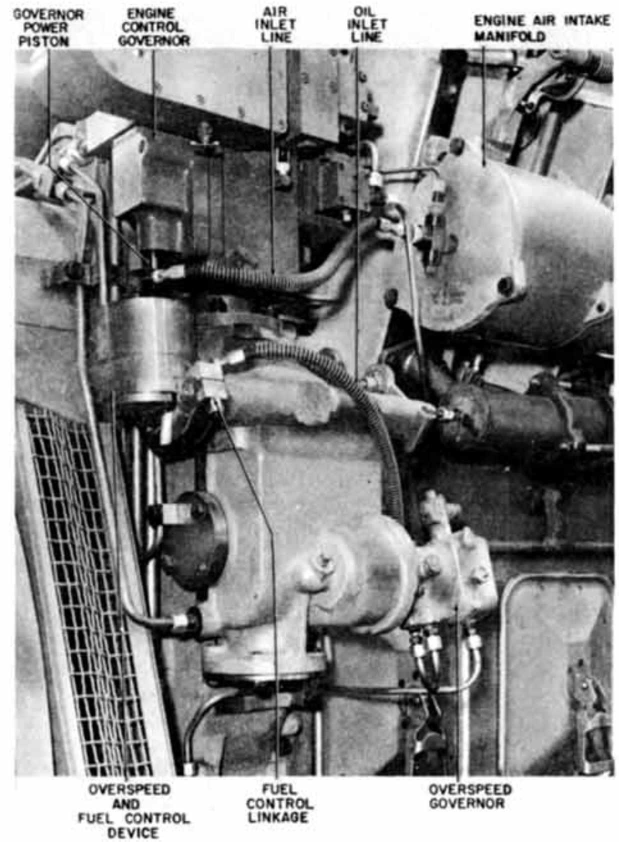



*Fig. 8-2. View of overspeed and fuel-control device mounted on engine*

## OPERATION

In normal engine operation, oil pressure from the overspeed governor pump is supplied to the device during the engine cranking cycle. The oil pressure being opposed to, and greater than, the pressure exerted by the compressed spring (see Fig. 8-1) causes the device to move to, and remain in, the CLOSED position. In its CLOSED position, the device acts as a solid link in the fuel control linkage during the entire period of normal engine operation.

## Engine Overspeed Condition

In the event of an engine overspeed, the oil pressure from the overspeed governor pump is removed. This removal of oil pressure from the device allows the spring to decompress, thus forcing the inner casing out, or to its OPEN position. This action of the inner casing, regardless of the position of the governor power piston, moves the fuel control linkage so as to force the injection pumps to shut off fuel to the cylinders.

## Excessive Intake-Air Temperature Condition

A line from the engine air intake manifold supplies intake air samplings to the inner-casing actuator assembly (see Fig. 8-1). If the engine intake air exceeds 180 degrees F, the three thermal actuators start to expand, vertically, in direct proportion to the amount of increase in air temperature above 180 degrees F. The expansion of the actuators exerts pressure against the inside face of the outer casing cover. This thermal actuator pressure, combined with the pressure of the compressed spring, is sufficient to overcome the overspeed-governor oil pressure, and thereby forces the inner casing to move toward its OPEN position. This movement of the inner casing, regardless of the position of the governor power piston, moves the fuel control linkage to force the injection pumps to reduce the amount of fuel to the cylinders.

# OVERSPEED GOVERNOR

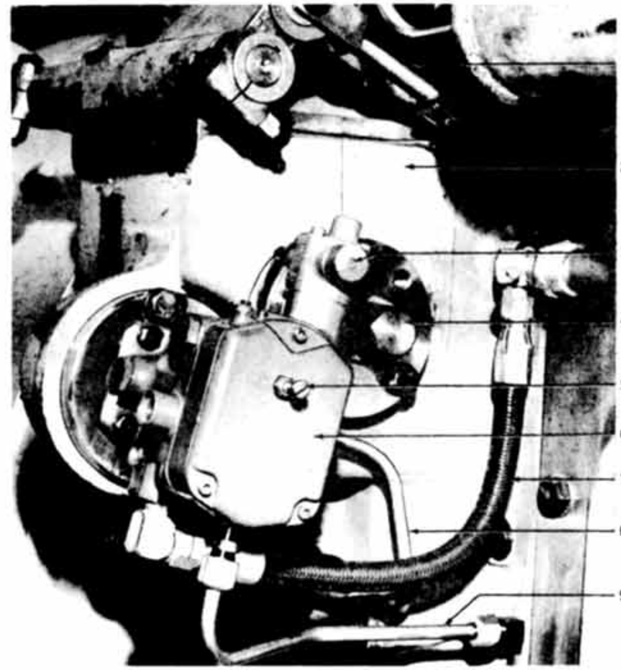
## DESCRIPTION

The overspeed governor contains the following components (see Fig. 8-3):

1. A pilot valve plunger with speeder spring and linkage.



Fig. 8-3 (E-13455A)




1 Engine control governor linkage
2 Governor-drive gear case
3 Overspeed governor reset button
4 Tachometer drive (capped)
5 Overspeed trip adjustment
6 Overspeed governor
7 Oil line to overspeed device
8 Overspeed governor oil supply line
9 Overspeed governor oil drain line

*Fig. 8-3. Typical overspeed governor arrangement*

2. A pair of flyweights mounted on the end of the drive shaft.

3. A power piston, at the end of which is mounted the terminal lever.

4. An oil-pressure relief valve mounted in the side of the governor case.

The base portion contains a positive-displacement gear pump. The outer case portion contains the lockout and latching mechanism. (See Fig. 8-4.)

## OPERATION

### Engine Running at Normal Speed Range (See Fig. 8-5)

*NOTE: In Fig. 8-5 and Fig. 8-6 the governor is shown with the drive shaft vertical. (On the FDL engines, it is horizontal.) The following text refers to the governor as it is shown in the FIGURES, NOT as it is mounted on the engine.*

1. The reset spring and overspeed lockout rod will position the terminal lever to hold the power piston down in its bore (lockout latch released).

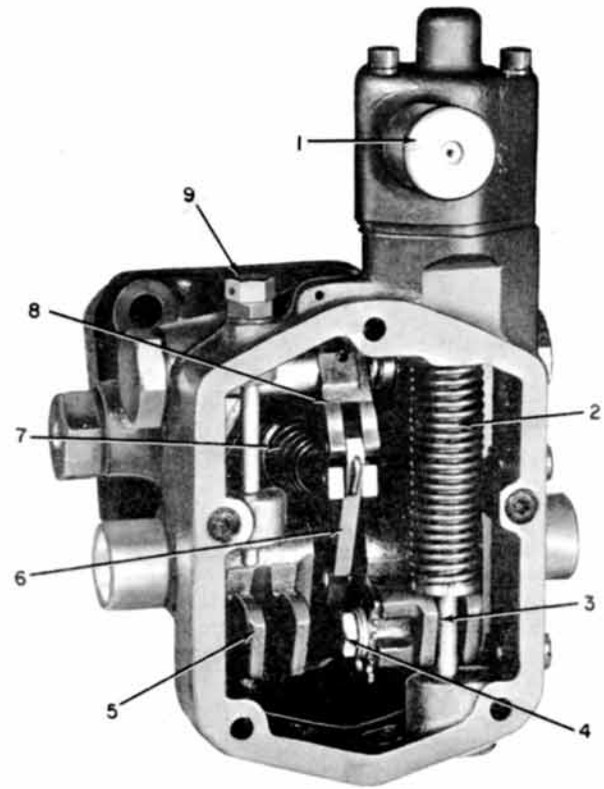
2. Downward pressure of the speeder spring, as set by adjustment of the trip-speed setting screw, will hold the flyweights in and the pilot plunger down.

3. In these positions, the bottom of the power piston is connected to drain to the engine sump, through ports in the pilot valve bushing, to a groove in the pilot valve plunger, and through a slanting hole drilled from the groove to the lower end of the pilot valve plunger.

4. Oil under pressure (200 psi) from the pump is delivered through porting in the pilot valve bushing, around



Fig. 8-4 (E-9725B)




1 Reset button
2 Reset spring
3 Overspeed lockout rod
4 Speed droop adjustment (set at 50% position)
5 Terminal lever
6 Floating lever
7 Speeder spring
8 Speed adjusting lever
9 Terminal lever stop screw

*Fig. 8-4. Overspeed governor with cover removed* the pilot valve plunger, and out to the power piston. With the piston down, the oil can flow around the lower groove and out of the governor case through a connecting line to the overspeed device.

Note that the upper groove in the power piston will also contain oil under pressure by means of drilled holes connecting to the lower groove. Also, a slot in the pilot valve plunger, below the port connecting to the power piston, is connected to the pressurized oil in the pilot valve bushing through a second diagonally drilled hole.

Engine Overspeeding Tripping Action (See Fig. 8-6)

1. As engine speed increases to the overspeed setting, the flyweights will move outward and raise the pilot valve plunger, bringing the pressurized oil slot in line with the port connected to the power piston.

2. Pressurized oil flowing under the power piston will force the piston up to close off the supply of pressurized oil to the overspeed device. This will position the upper groove in the piston above the top of the power piston bore.

3. This allows oil from the overspeed device to flow back through the holes connecting the two grooves in the power piston, over into the flyweight head cavity in the governor case, and down through a drain hole to the engine sump.

4. Removal of oil pressure from the overspeed device causes the latter to shut down the engine. (See OVERSPEED DEVICE for details.)

5. Upward movement of the power piston to the tripped position also rotates the terminal lever, raising the end of the floating lever at the speed droop bracket pin. This reduces the pressure of the speeder spring and allows flyweights to move out quickly. Rotation of the terminal lever also pushes the lockout rod back until the lockout latch engages and raises the reset button.



## TRIP INDICATOR AND RESET

Visual indication that the unit is in tripped position is provided by a red band below the reset button, visible when the button is up. To reset the governor following an overspeed trip, push down on the reset button.

*NOTE: Before resetting, attempt to find the cause of tripping and take the necessary corrective action.*

## ADJUSTMENTS

*CAUTION: ONLY QUALIFIED PERSONNEL SHOULD BE PERMITTED TO MAKE ADJUSTMENTS TO THE OVERSPEED GOVERNOR.*

The governor has two points for adjustment:

1. The speed droop bracket (located inside the governor on the terminal lever) must be set at mid-position.

2. The trip-speed setting screw in the governor cover must be adjusted to provide trip action at the specified overspeed for the engine.

1 Trip indicator
2 Reset button (press to reset)
3 Trip-speed setting screw
4 Reset spring
5 Overspeed lockout rod
6 Speed droop bracket (set at 50% position)
7 Floating lever
8 Terminal lever
9 Power piston (down)
10 Gear pump
11 Relief valve
12 Pilot valve plunger (down)
13 Flyweight head
14 Flyweight
15 Speeder spring
16 Speed adjusting lever
17 Lockout latch (released)

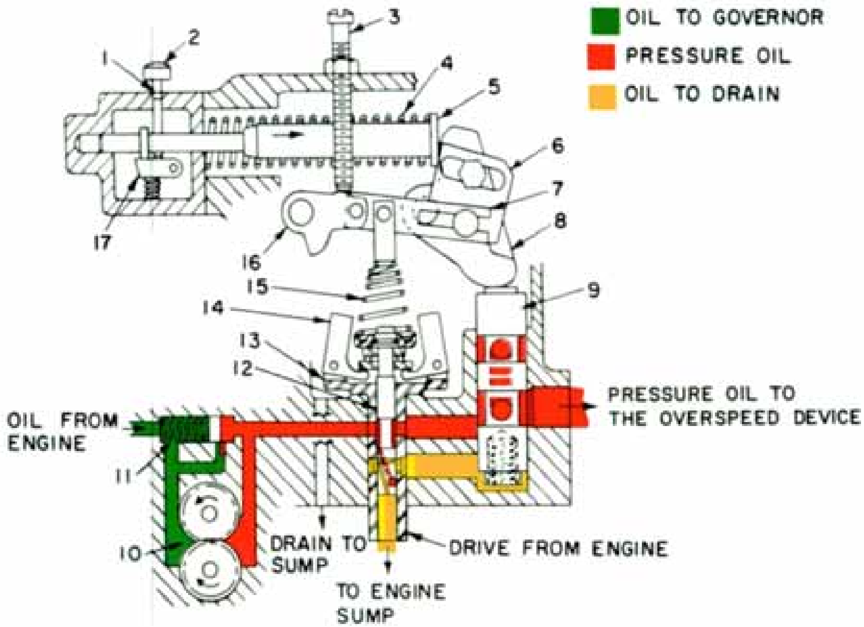



*Fig. 8-5. Operating condition—engine running at normal speeds*

1 Trip indicator
2 Reset button (press to reset)
3 Trip-speed setting screw
4 Reset spring
5 Overspeed lockout rod
6 Speed droop bracket (set at 50% position)
7 Floating lever
8 Terminal lever
9 Power piston (up)
10 Gear pump
11 Relief valve
12 Pilot valve plunger (up)
13 Flyweight head
14 Flyweight
15 Speeder spring
16 Speed adjusting lever
17 Lockout latch (engaged)

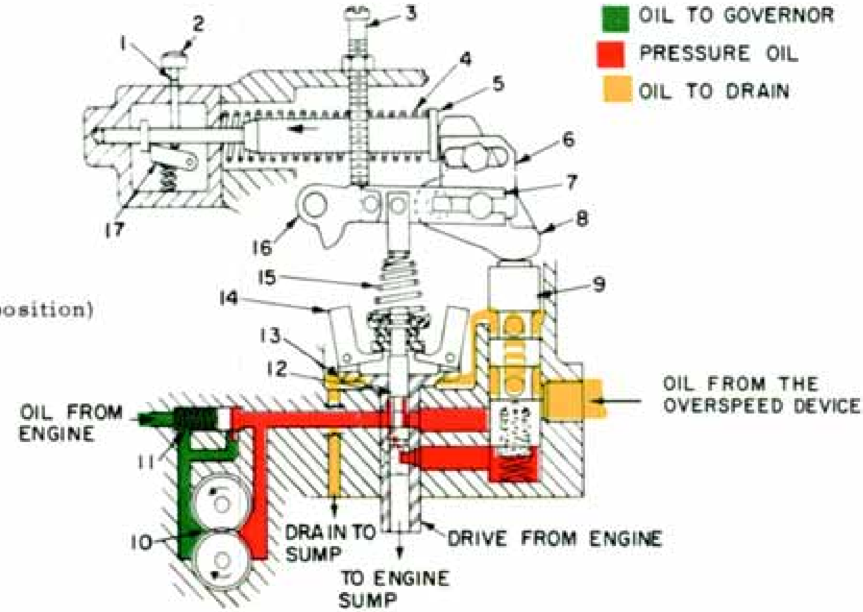



*Fig. 8-6. Trip condition as a result of overspeed*

# OPERATING INFORMATION

## INTRODUCTION

All of the operating devices, manual and visual, normally used by the engineman during locomotive operation are located near the operator's position. Most of these devices are located either on the master controller, on the air-brake stand, or on the engine control panel.

*NOTE: Customer equipment requirements often differ from one railroad to another. Therefore, physical locations and appearance of some devices illustrated in this manual may not agree entirely with the equipment furnished to any particular railroad.*

## MASTER CONTROLLER

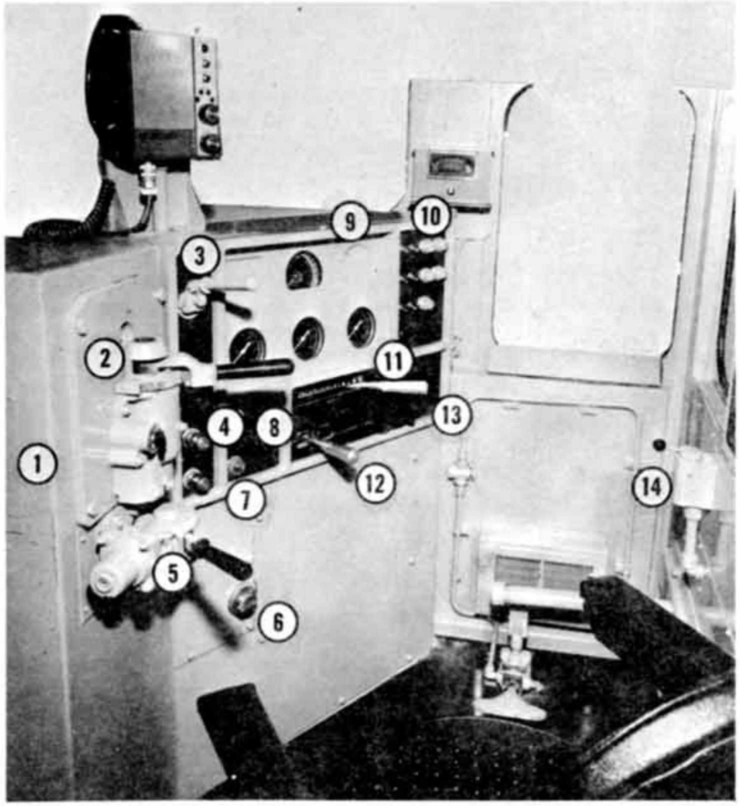
The master controller is a set-up switch used by the operator to control the locomotive. It has a throttle handle and a selector handle. These handles control motoring and dynamic braking (if used). Various control switches, circuit breakers, and indicating lights are mounted on the housing of the controller.

Mechanical interlocking between the handles prevents improper operation of any handle. (See INTERLOCKING BETWEEN HANDLES.)

### SELECTOR HANDLE (See Figs. 9-1 and 9-2)

The selector handle is a five-position switch which is used to set up the direction of locomotive movement and the type of operation desired, motoring or dynamic braking.

The mid-position is OFF. Handle movement to the two positions beyond OFF, away from the operator, sets up FORWARD MOTORING then FORWARD DYNAMIC BRAKING. Movement of the handle to the two positions beyond OFF, in the opposite direction, sets up REVERSE MOTORING then REVERSE DYNAMIC BRAKING.



1 Regulating valve
2 Automatic brake valve
3 Horn valve
4 Bell ringer and window wipers
5 Independent brake valve
6 MU-2A valve (or two-position cock)
7 Emergency switch and reset buttons
8 Generator-field circuit breaker
9 Instrument panel
10 Toggle switch and indicating light panel
11 Throttle handle
12 Selector handle
13 Selector switch panel
14 Sander control

*Fig. 9-1. Operator's position*

Fig. 9-1 (E-14937)



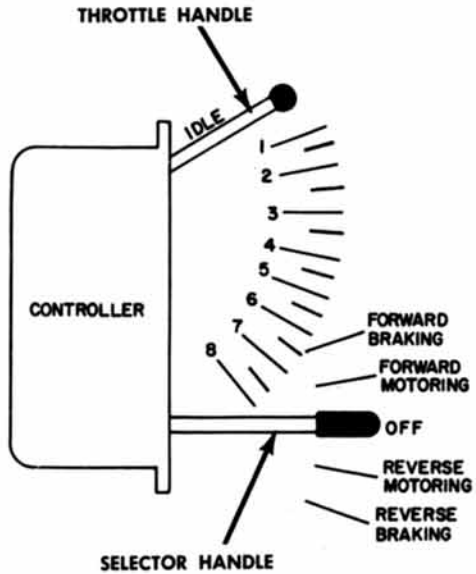



*Fig. 9-2. Master controller handle positions*

Fig. 9-2 (E-14903)

*WARNING: MAKE SURE THAT THE PROPER SELECTOR HANDLE SETTING HAS BEEN MADE BEFORE ADVANCING THE THROTTLE HANDLE; OTHERWISE, SEVERE EQUIPMENT DAMAGE AND POSSIBLE PERSONAL INJURY COULD OCCUR.*

## THROTTLE HANDLE (See Figs. 9-1 and 9-2)

The throttle has an IDLE position and eight major and eight intermediate positions or notches. Major notches are registered by a numbered scale on the face of the controller housing, just above the opening for the throttle handle. This handle controls tractive effort when motoring, and controls braking effort when dynamic braking is being used.

## INTERLOCKING BETWEEN HANDLES

Interlocking between handles of the master controller is governed in the following manner:

1. The selector handle can be taken out only when in the OFF position. The throttle handle must also be in the IDLE position.

2. The selector handle cannot be moved unless the throttle handle is in the IDLE position.

3. The throttle handle can be moved with the selector handle in any position.

## DEVICES ON MASTER CONTROLLER HOUSING
(See Fig. 9-1)

The following operating devices are located on the master controller housing:

### M.U. Emergency Shutdown Switch

This switch has two positions, STOP and RUN. The normal position is RUN. When this switch is turned to STOP, the diesel engines on all units in multiple-unit locomotive consist will shut down.

This switch is provided for emergency use only. Normal shutdown should be made by moving the throttle to IDLE, the engine control switch (EC) to START, and depressing the STOP button on the engine control panel.

After an emergency shutdown, the engine control switch (EC) must be turned to START and the engine(s) must be restarted in the normal manner.

### Power Limit Switch

This switch has two positions, NORMAL and NOTCH 7. When locomotive units of the same horsepower are oper-



ated in the locomotive consist, this switch is ordinarily in the NORMAL position.

When the leading unit is slipping excessively, the power limit switch can be moved to NOTCH 7 to reduce power while the trailing units are operating at full power. This will reduce the tractive effort on the leading unit and will usually improve the ability of the locomotive to hold the rail under bad rail conditions.

When other locomotives of lower horsepower ratings are operated in the consist, under certain conditions, this switch must be moved to the NOTCH 7 position unless the locomotives are equipped with automatic power matching control.

### Other Switches

1. Front headlight
2. Rear headlight
3. Step lights
4. Gage lights and dimmer control

### Call Button

The call button is used to sound an alarm bell in all locomotive units.

### Wheel-slip Light

The wheel-slip light indicates when a pair of wheels is slipping.

### "PCS OPEN" Light

The "PCS open" light indicates that the PCS switch is "open" and has not been reset.

## Generator-field Circuit Breaker

The generator-field circuit breaker is ON whenever the locomotive is powered and operating as a lead unit. The breaker may also be used to keep the main generator de-energized when it is necessary to run the engine at speeds higher than idle.

## Other Controls and Devices

Depending on customer requirements, other controls and devices such a hump control, Mars headlight, flow-control gage, etc., may also be located on the controller housing.

# ENGINE CONTROL PANEL

The engine control (EC) panel is located on the rear wall of the operator's cab (see Fig. 9-3). Mounted on this panel are various other switches, circuit breakers, and operating devices used during locomotive operation.

## ENGINE CONTROL SWITCH (See Fig. 9-3)

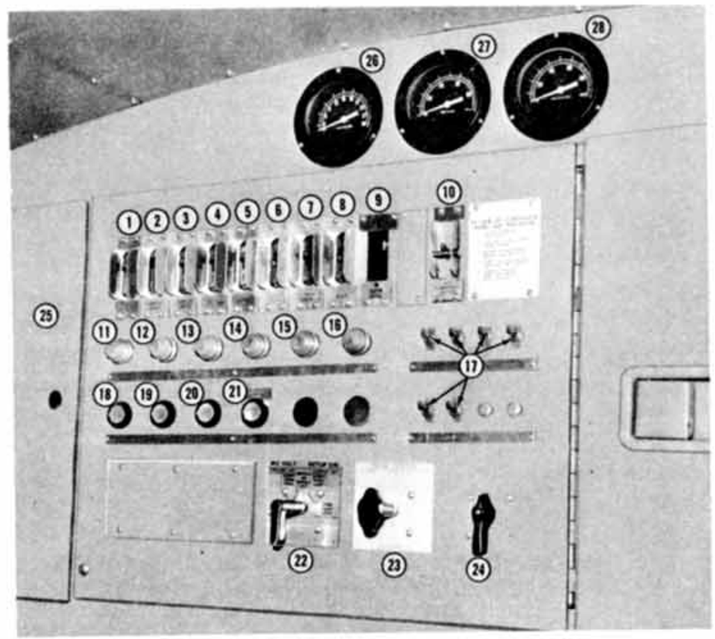
The engine control switch has two positions, START and RUN. The engine start button is effective only when the engine control switch is in the START position.

When the engine is running and the engine control switch is in the START position, engine speed is held at idle and power cannot be applied to the locomotive. The power plant is said to be "off the line".

When the engine is idling and the locomotive is to be operated, the engine control switch (EC) must be moved to the RUN position.



Fig. 9-3 (E-13527)




1 Engine run
2 Charging circuit
3 Running lights
4 Headlights
5 Control
6 Fuel pump
7 (Optional equipment)
8 (Optional equipment)
9 (Optional equipment)
10 Slip suppression cutout
11 Ground relay trip
12 Hot engine
13 Low oil
14 No battery charge
15 Low water
16 (Optional equipment)
17 Light switches
18 Ground reset
19 Fuel pump reset
20 Engine start
21 Engine stop
22 M.U. headlight set-up switch
23 Engine control switch
24 Motor cut-out switch (optional)
25 Battery switch compartment
26 Turbo (intake manifold) air pressure
27 Fuel-oil pressure
28 Lube-oil pressure

*Fig. 9-3. Engine control panel*

## ENGINE START AND STOP BUTTONS
(See Fig. 9-3)

To start the diesel engine, depress the ENGINE START button firmly and hold it in until the engine starts. To stop the engine, depress the STOP button momentarily.

The engine start button is effective only when the engine control switch (EC) is in the START position.

## M.U. HEADLIGHT SET-UP SWITCH (See Fig. 9-4)

The M.U. headlight set-up switch has five positions. Positioning of this switch is determined by the location of the locomotive unit in the consist and whether the front of the locomotive unit is leading or trailing. Switch positions are as follows:

SINGLE OR MIDDLE UNIT: Place the switch in this position on any locomotive unit operated singly or on all units, except the leading or trailing unit, when the locomotive consist is made up of more than one unit.

SHORT HOOD LEAD - LEADING UNIT: Place the switch in this position when the leading unit is operated with the short hood forward.

LONG HOOD LEAD - LEADING UNIT: Place the switch in this position when the leading unit is operated with the long hood forward.

SHORT HOOD TRAIL - TRAILING UNIT: Place the switch in this position when the final trailing unit is connected so its short hood trails.

LONG HOOD TRAIL - TRAILING UNIT: Place the switch in this position when the final trailing locomotive is connected so its long hood trails.



Fig. 9-4 (E-11960)

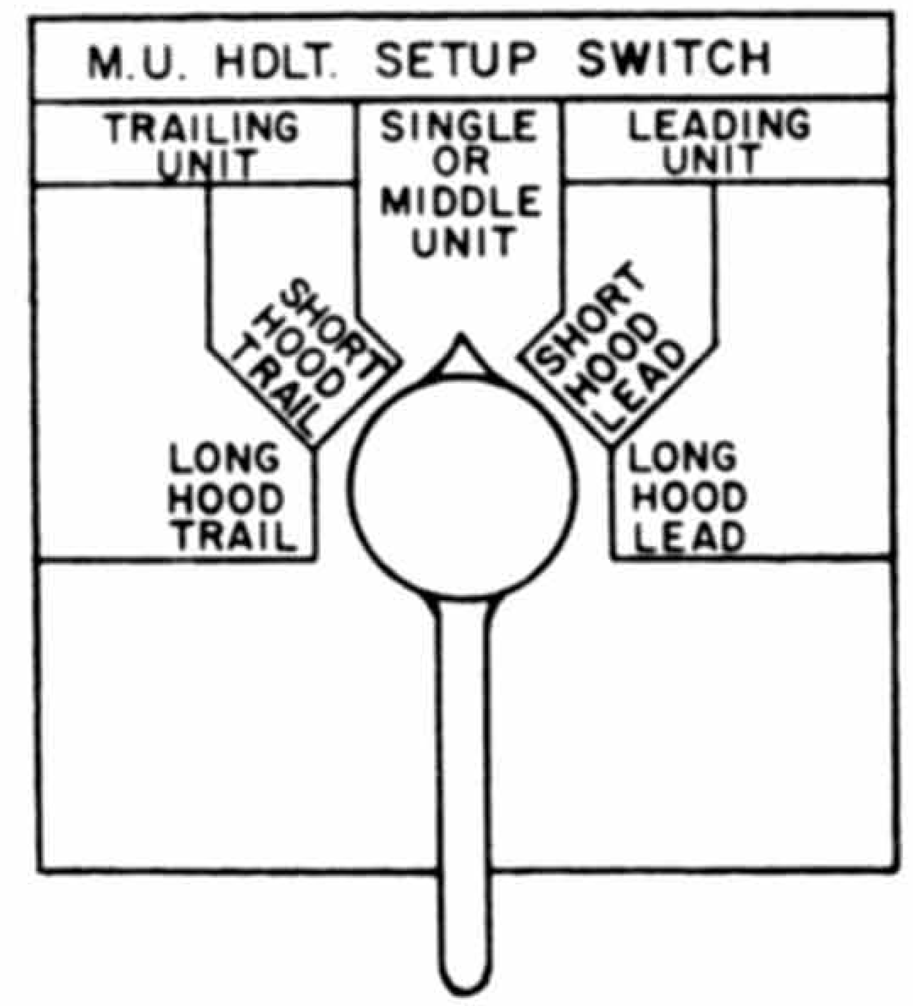



*Fig. 9-4. M.U. headlight set-up switch*

## M.U. BRAKING SELECTOR SWITCH

The M.U. dynamic-braking selector switch (when installed) is furnished in several styles, depending on the request of a railroad. Position the selector switch according to the directions on the nameplate and according to railroad rules.

The selector switch must be positioned before leaving the terminal and must not be changed even if the engine is isolated enroute.

## MOTOR CUT-OUT SWITCH (See Fig. 9-3)

The motor cut-out switch (if installed) can be used to cut out one or more traction motors. At the same time, the power output of the locomotive will be reduced. Operation of the motor cut-out switch does not eliminate a ground fault in a power circuit.

Under emergency conditions, the locomotive may be operated for a short period of time with one or more motors cut out. Refer to railroad rules for specific details of operation.

CIRCUIT BREAKERS ON ENGINE CONTROL PANEL (See Fig. 9-3)

The following circuit breakers are located on the engine control panel:

1. Charging Circuit - Isolates the battery-charging generator from the control system.

2. Running Lights (all lights except headlights)

3. Headlights

4. Control (NOTE: On some arrangements, this breaker may be located on the master controller switch panel.)

5. Fuel Pump

SWITCHES ON ENGINE CONTROL PANEL (See Fig. 9-3)

The following switches are located on the engine control panel:

1. Hood-Engine-Control Compartment Lights

2. Rear Classification Lights

3. Front Classification Lights

4. Front Number Lights

5. Rear Number Lights



6. M.U. Walkway Lights (if equipped)

7. Slip Suppression Cutout or Wheel Slip Cutout - Normally, this switch is sealed in the "UP" (closed) position. The switch should only be opened as directed by railroad regulations.

GROUND RELAY (See Fig. 9-3)

The ground relay is furnished to protect the power and control circuits. An indicating light will come on and the bell will ring when the relay has tripped. The reset button must be pushed to reset the relay.

MISCELLANEOUS CONTROLS

In addition to the previously described operating devices, the following additional controls are used by the engineman during locomotive operation:

1. Bell Valve - Mounted on the engineman's brake stand. (See Fig. 9-1.)

2. Horn Valve - Mounted on the brake stand. (See Fig. 9-1.)

3. Sander Control - Mounted on the right wall, at the engineman's position. (See Fig. 9-1.)

4. Windshield Wiper Valves - Located on the brake stand and over the fireman's positions.

5. Hand Brake - Located on the outside of the nose compartment (low-nose locomotive).

6. Emergency Brake Valve - The handle is located on the helper's side of the brake stand. Pulling this handle

causes an EMERGENCY brake application and dropping of power.

7. Emergency Fuel Cut-off System – In an emergency, any one of three electric push buttons may be depressed momentarily to cut off fuel delivery and shut down the engine. One of these buttons is located on each side of the locomotive platform near the fuel tank. The third button (Engine Stop) is located on the engine control panel and is also used for normally shutting down the engine.

*NOTE: The emergency cut-off button is used to shut down the engine on the local unit only. The emergency shutdown switch on the master controller will shut down the engines on all units of the consist simultaneously.*

8. Fuel-trip Reset Button – This button on the engine control panel must be depressed before depressing the engine start button for engine starting and after any emergency fuel cut-off button has been depressed.

9. Cab Heater – Cab heat is regulated by turning the regulating valve, behind the brake stand, to give the desired heat. Adjust the louver control at the base of the heater for suitable air deflection.

*CAUTION: TO PREVENT THE HEATER FROM FREEZING IN COLD WEATHER, LEAVE THE VALVES OPEN AT ALL TIMES.*

10. Window Defrosters – The heat for window defrosting is controlled by the same regulating valve which controls cab heat.

11. Cab Ventilation – Cab ventilation is controlled by positioning the hand-operated lever at the base of the cab heater as desired.



## CIRCUIT BREAKERS (See Fig. 9-3)

Circuit breakers are operated like a toggle switch, to open the circuit manually.

An overload in a breaker circuit causes the breaker to open the circuit automatically, and the toggle moves into the center position indicating that the breaker has tripped.

The breaker is reset by moving it to OFF, and then to ON, after allowing a few minutes for the thermal element in the breaker to cool. The breaker should only be reclosed if there is no visible reason for the automatic opening of the circuit. If it trips after reclosing, it should be left open unless instructed otherwise.

## COLORED LIGHTS AND BELL

During normal locomotive operation, the bell and all colored lights are off. In locomotive consists of more than one unit, colored lamps will light on the affected unit only. The bell will sound on all units.

*NOTE: If troubles occur on two or more units at the same time which cause the alarm bell to ring, turn the engine control switch on all affected units to the START position before attempting to restart any unit. With the throttle handle on the lead unit beyond the IDLE position, it is impossible to start any unit while the alarm bell is ringing.*

## LOW-OIL AND LOW-WATER LIGHTS (YELLOW) (See Fig. 9-3)

A yellow light on the engine control panel will light when either the engine lube-oil supply or the cooling water pressure is low.

1. If the engine lubricating-oil pressure drops to between 7 to 10 psi at 400 rpm, or between 45 to 52 psi at 1050 rpm, the engine shuts down and a yellow LOW-OIL indicating lamp lights. After the engine shuts down, the alarm bell will sound as long as the engine control switch (EC) is in the RUN position. A yellow LOW-WATER indicating lamp will also come on if the water supply is low.

2. After the engine shuts down, move the engine control switch to the START position to silence the alarm bell. Check the lubricating-oil supply on the dip-stick. Check for broken or cracked oil lines. Also, check the water supply at the storage tank and check for water piping leaks.

3. To restart the diesel engine after the fault is corrected:

a. Depress the shutdown plunger on the engine governor until it clicks and stays in.

*NOTE: The engine governor is equipped with two shutdown plungers, one for low oil and one for low water. Be sure both plungers are reset.*

b. Depress the engine start button.

c. After the engine is running, recheck for any signs of distress.

d. If the condition is normal, put the locomotive "on the line" and recheck for any signs of distress.

4. If the engine fails to start due to the Low-oil Pressure Reset button tripping, do not repeat cranking.

5. If the locomotive units are being operated in multiple, the engine on affected unit only will shut down.



## CRANKCASE OVERPRESSURE SWITCH

A crankcase overpressure switch is mounted on the side of the engine near the starting motors. The switch will shut down the engine in case a serious engine fault occurs.

When the switch trips, the engine shuts down automatically, the alarm bell rings, and an indicating light comes on in the operator's cab and on the housing of the switch.

When such a fault occurs, take the locomotive off the line and leave the engine shut down. Proceed as directed by railroad rules.

Before the engine is restarted, the cause of the shutdown must be determined and the fault corrected.

## HOT ENGINE LIGHT (RED)

(See Fig. 9-3)

1. If the engine water temperature becomes excessive, the alarm bell sounds and the HOT ENGINE indicating lamp (red) lights.

*NOTE: On some locomotive models, the engine speed will return to idle for the duration of the Hot Engine alarm.*

At first opportunity, investigate for the cause. When the cooling water temperature returns to normal, the alarm bell will stop ringing. Turning the engine control switch to START will not stop the ringing of alarm bell or will not turn off the HOT ENGINE light. If the cooling water temperature does not return to normal in a reasonable length of time, shut the engine down.

## NO BATTERY CHARGE (BLUE)
(See Fig. 9-3)

If the engine is running and the engine control switch is in the RUN position and the battery-charging equipment fails, then the NO BATTERY CHARGE lamp (blue) will light and the alarm bell will sound. The light will also come on if the engine is not running, but the battery switch is closed. Under this condition, a fault does not necessarily exist.

## POWER RECTIFIER PANEL

The power rectifier panel is mounted on the bulkhead near the alternator. When a number of rectifiers have failed in any one panel, traction power will be automatically reduced. When this occurs, proceed as directed by railroad rules.

## ALTERNATOR OVERLOAD RELAY

A surge relay (GOLR) is provided to detect power faults which could cause alternator overloading and go to ground. The fault detection also prevents excessive equipment damage caused by an inoperative ground relay.

*NOTE: After the alternator overload relay (GOLR) or ground relay (GR) has tripped, check for blown power-rectifier fuses.*

## GROUND RELAY
(See Fig. 9-3)

If a ground occurs in the main power circuits, the ground relay operates to reduce the engine speed automatically to IDLE, removes power from the traction motors, and sounds the alarm bell.



An indicating light (Ground Relay Tripped) on the Engine Control Panel will light, indicating that a fault has occurred.

If a ground occurs in the control circuits, the ground relay may operate during the engine cranking cycle. Report this condition.

To reset the relay:

1. Take engine "off the line";

2. Push in the ground-relay reset button on the engine control panel;

3. Advance the throttle handle. If the ground relay stays in, continue normal operation.

*NOTE: On locomotives equipped with a trainline ground-relay reset, a tripped relay is indicated by a warning light. To reset the relay, return the throttle handle to IDLE. Wait 15 seconds; then, press the reset button. The same reset button is pressed and the same resetting procedure applies when an alternator overload relay (GOLR) has tripped.*

If the ground relay immediately operates a second time, the affected unit must not be operated. The unit must either be shut down or, if necessary, the engine can be left running by turning the engine control switch to START. This takes the unit "off the line."

*NOTE: When the ground-relay cut-out switch (GRCO) is opened, the unit will shut down. This is to prevent running the locomotive without electrical protection.*

## PCS SWITCH

The pneumatic control switch (PCS) is operated from the air-brake system.

During a safety control "penalty" or emergency air-brake application, this switch opens. The engine speed is reduced to IDLE and the power is removed. The "PCS OPEN" ("PC OPEN") light at the engineman's position will light.

To reset the PCS switch automatically:

1. Move the throttle handle to the IDLE position.

*NOTE: If the PCS switch has tripped while in dynamic braking, the selector handle must be returned to OFF to reset the circuit.*

2. Move the automatic brake valve handle to the SUPPRESSION position.

3. Depress the safety control foot pedal (if used). (When the application pipe builds up to normal pressure, the PCS switch will reclose.)

4. Move the automatic brake valve handle to the RELEASE position.

## WHEEL SLIP
## (WITHOUT AUTOMATIC BRAKING)

If any wheels slip during locomotive operation, normally the following occurs:

1. A reduction in excitation and immediate sanding occurs automatically on the locomotive that is slipping.



2. If the wheels continue to slip for more than two or three seconds, the wheel-slip lamp (on the Master Controller) lights.

3. Excitation continues in a reduced state.

4. When the wheel slip is corrected (wheel speed under control), the excitation will return to normal and the sanding tapers off.

## ENGINE OVERSPEED SHUTDOWN
(See Fig. 9-5)

In the event that the engine overspeeds to 1130 rpm, the engine is shut down automatically. After an overspeed shutdown of the engine, move the engine control switch to the START position. Reset the overspeed mechanism by pushing in the knob of the engine overspeed governor (Fig. 9-5), located on the left side of the engine under the engine control governor. Proceed to start the engine as described under STARTING ENGINE. If it overspeeds again, do not restart the engine. If troubles occur on two or more units at the same time which causes the alarm bell to ring, turn the engine control switch on all affected units to the START position before attempting to restart any unit. With the throttle handle on the lead unit beyond the IDLE position, it is impossible to start any unit while the alarm bell is ringing.

*NOTE: During freezing weather, protect the engine cooling system according to railroad instructions.*

## SAFETY-CONTROL FOOT PEDAL

A safety-control foot pedal (if equipped) is located at the operator's position. The pedal must be depressed at all times during locomotive operation. If the operator's foot is removed from the pedal for more than five seconds, brakes will apply at the SERVICE rate. For a further description, see SAFETY CONTROL.

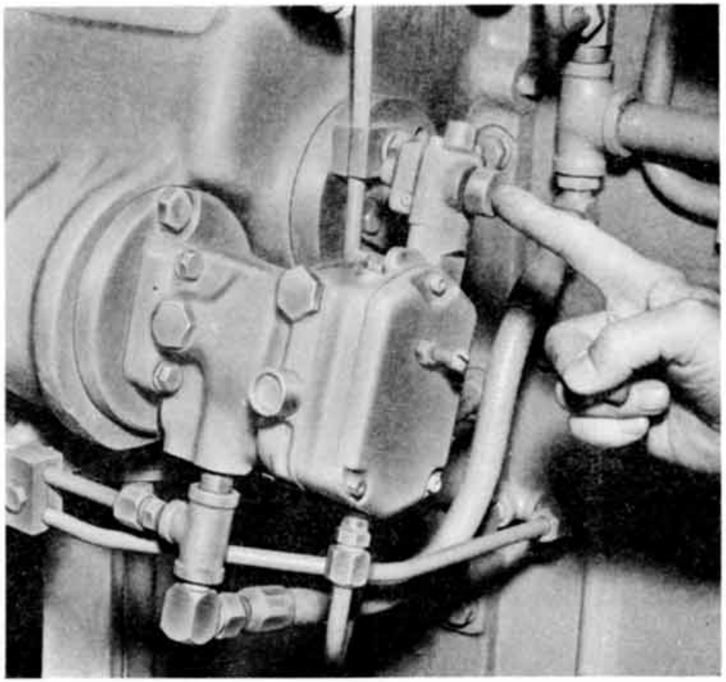


Fig. 9-5 (E-13028)

*Fig. 9-5. Engine overspeed governor and reset*

## EMERGENCY SANDING

Emergency sanding (if installed) is automatically applied in the forward and reverse directions during all emergency brake applications, for a sufficient time to stop the train. In multiple-unit operation, emergency sanding is applied to all units, regardless of whether they are equipped with pneumatic or electro-pneumatic sanding equipment.



## LOCOMOTIVE OVERSPEED

When a locomotive equipped with overspeed protection exceeds the maximum permissible speed, an overspeed application is initiated.

1. The overspeed whistle blows.

2. In about five seconds, a penalty brake application is initiated if the train speed has not been reduced sufficiently. See AIR BRAKE REGULATION for the proper procedure.

## PRESSURE AND TEMPERATURE GAGES

1. Control Air – Usually located in the air-brake compartment. Normal air pressure is 70 psi.

2. Intake Manifold Air-pressure Gage – Located above the engine control panel in the operator's cab. (See Fig. 9-3.) Normal reading at FULL ENGINE SPEED and FULL LOAD is 16.5 to 21.0 psi.

3. Fuel Pressure Gage – Located above the engine control panel in the operator's cab. (See Fig. 9-3.) Normal fuel pressure at IDLE is 35 psi and at FULL LOAD is 25-30 psi.

4. Lube-oil Pressure Gage – Located above the engine control panel in the operator's cab. (See Fig. 9-3.) Normal lube pressure at IDLE is 20 psi and at FULL LOAD is 75-95 psi.

5. Water Temperature Gage – Located on the right side of the water storage tank. (See Fig. 9-6.) Normal operating temperature is 170-180 F.

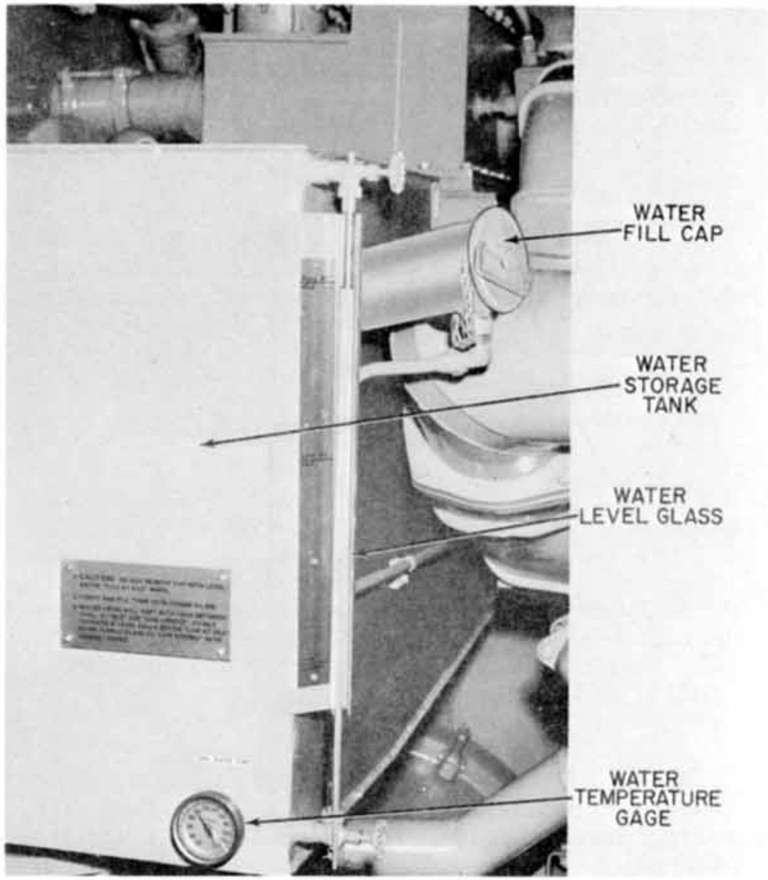



Fig. 9-6 (E-13529)

*Fig. 9-6. Water storage tank details*

## OTHER GAGES

1. Engine Lubricating-oil Dip-stick - One located on each side of the engine, near the lube-oil fill. The stick is marked HIGH and LOW. Proper level with the engine idling is between HIGH and LOW.



Fig. 9-7 (E-11826)

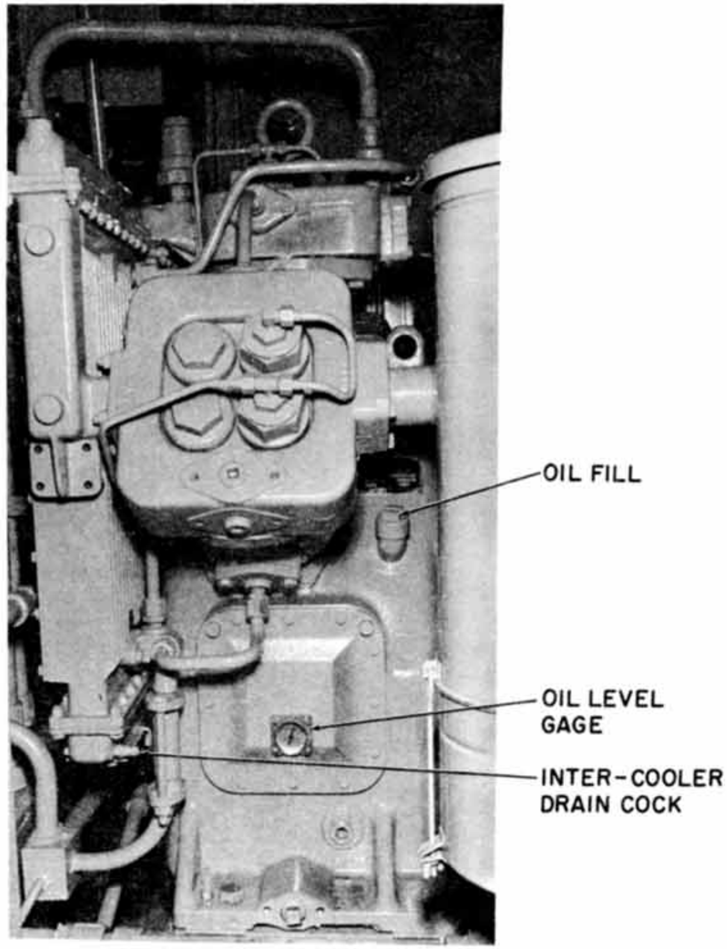



*Fig. 9-7. Air compressor (WABCO)*

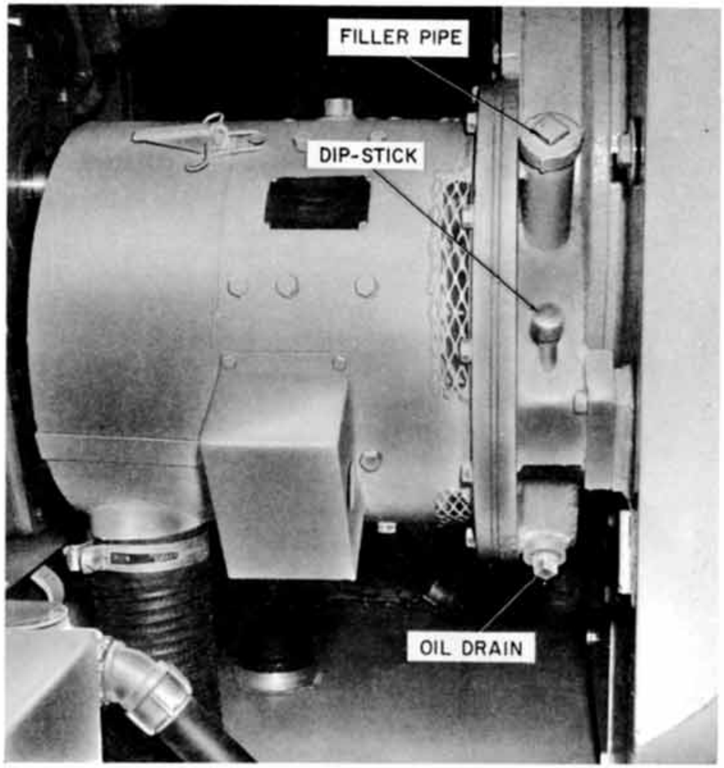



Fig. 9-8 (E-13029)

*Fig. 9-8. Traction-alternator gear unit*

2. Fuel-oil Sight Glasses – Mounted on both sides of the main fuel tank, to indicate the level of fuel in the tanks.

3. Cooling Water – A sight glass, mounted on side of cooling water supply tank, indicates the level of the cooling water in the system. Markings on the tank indicate the proper level for conditions (See Fig. 9-6.)



Fig. 9-9 (E-13530)

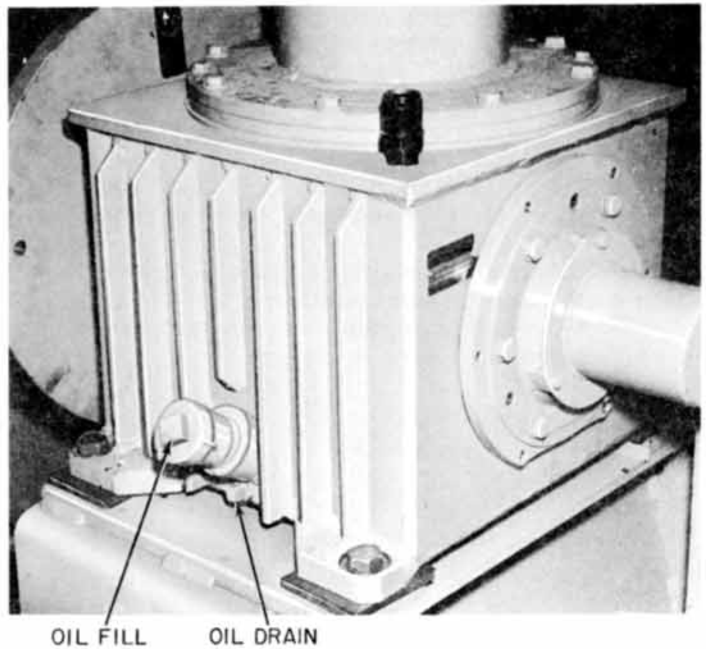



*Fig. 9-9. Fan-gear unit*

*WARNING: TO AVOID PERSONAL HARM FROM WATER BURNS, NEVER REMOVE THE WATER FILL CAP WHEN THE WATER LEVEL IS ABOVE THE "FULL AT IDLE" MARK.*

4A. Compressor Lube Oil (Gardner-Denver Compressor) – A gage, mounted on the compressor frame, indicates the oil level. The gage scale is marked ADD (lower red scale), RUN (green scale), EXCESSIVE (upper red scale).

4B. Compressor Lube Oil (Westinghouse Compressor) – Maintain to the RUN level on the oil-level indicator gage. (See Fig. 9-7.)

5. Traction-alternator Gear Box – A dip-stick marked EMPTY -ADD - FULL indicates the oil level. Proper level is between ADD and FULL with the engine stopped. (See Fig. 9-8.)

6. Fan-gear Unit Oil Level – Maintain the oil level near the spill-over of the fill pipe. (See Fig. 9-9.)

7. Governor Oil-level Sight Glass – Located on left side of engine near the traction alternator. (See Fig. 9-10.) The oil level must be visible between the marks on the sight glass when the engine is running.



Fig. 9-10 (E-13296)

Fig. 9-10 (E-11828)

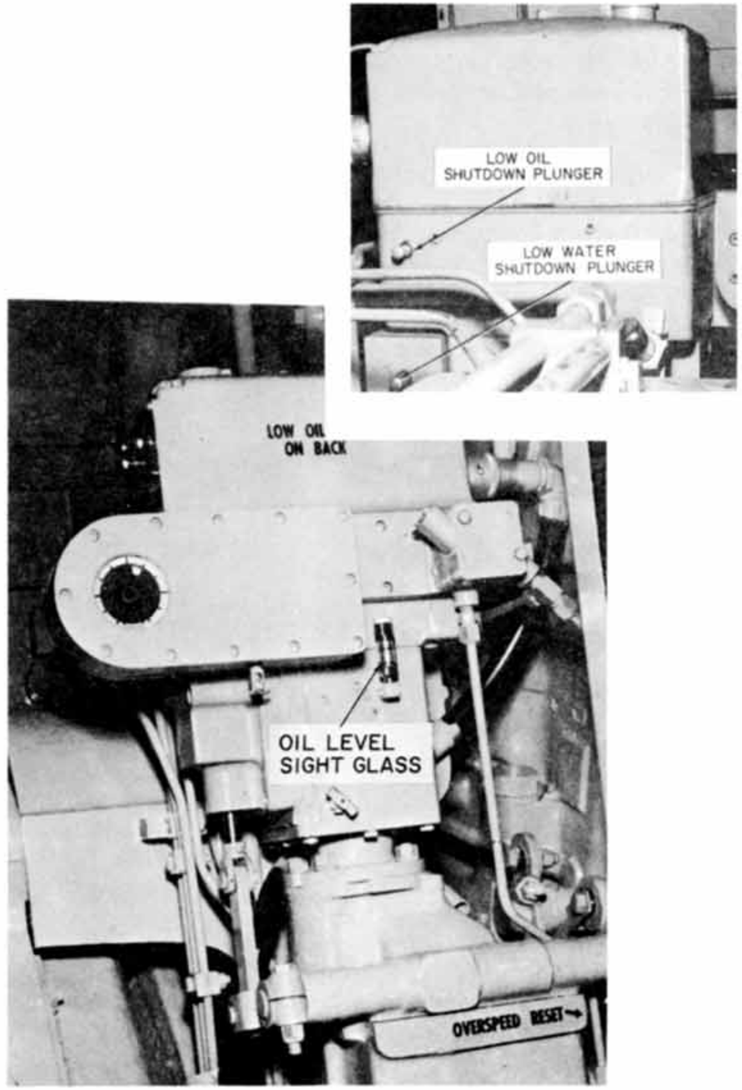



*Fig. 9-10. Engine control governor and low-oil and low-water resets*

The following checks and inspections should be made in accordance with railroad rules.

## BEFORE BOARDING THE LOCOMOTIVE

1. Inspect for broken, worn, loose, or dragging parts (brake rigging, brake shoes, wheels, traction-motor commutator covers, etc.).

2. Check for leaks from the outside piping.

3. Properly position all drain and cut-out cocks.

4. Check the proper connection of the air hoses and jumper cables (if in multiple with other units).

5. Check the fuel supply on the fuel-tank sight glass.

## AFTER BOARDING THE LOCOMOTIVE

1. Remove rags, tools, etc., from moving parts and electrical equipment.

2. Check the diesel-engine lubricating-oil supply. The oil level should indicate FULL on the measuring gage with the engine shut down. A measuring gage (dip-stick) is located on each side of the engine and is marked LOW – FULL.

3. Check the governor oil supply. The sight glass on the governor should be full of oil. After the engine is started, oil must be visible between the marks on the sight glass. (See Fig. 9-10.)

4. Check the air-compressor lubricating-oil supply. On the Gardner-Denver compressor, the proper level is indicated when the pointer registers on the green portion of the scale of the oil-level indicator. The lower red



scale indicates that oil must be added. The upper red scale indicates excessive oil. (See Fig. 9-7.)

On the WABCO air compressor, maintain the oil supply to the RUN level on the gage.

5. Check the cooling water supply. Be sure that the water drain valves are closed.

6. Check that the fan-gear-unit oil level is up to the spill-over of the fill pipe.

7. Check the lubricating oil of the generator-gear unit. The dipstick is marked EMPTY – ADD – FULL. Proper level is between the ADD and FULL marks. (See Fig. 9-8.)

8. Check that the diesel-engine overspeed device is reset (Fig. 9-5).

9. Check that the engine barring-over device is removed from the engine.

10. Check that the following air cut-out cocks are open:

a. Air-compressor governor

b. Control air

c. Safety control (if used)

d. Bell, horn, and window wiper

e. Overspeed control (if used)

11. Check that the brake-pipe angle cock is "cut in" (vertical position).

12. The brake-valve pilot cut-out cock (double-heading cock) on the 26L air-brake system should be properly positioned.

13. The MU-2A valve or double cut-out cock must be positioned according to the location of the unit in the locomotive consist and the type of brake equipment in the lead locomotive.

14. Check the positions of the Automatic and Independent brake valve handles. The Automatic brake valve handle should be removed on all trail units, and the Independent handles should be in the RELEASE position if they are not removable.

15. Move the engine control switch to START.

16. Properly position the M.U. headlight selector switch.

17. Properly position the M.U. dynamic braking selector switch (if furnished).

18. Check that the throttle handle is in the IDLE position and that the Selector handle is in the OFF position.

19. Check that the dead-engine cock is in the LIVE (or closed) position.

## STARTING THE ENGINE

Perform the operations as in BEFORE BOARDING LOCOMOTIVE and AFTER BOARDING, and proceed as follows:

> *NOTE: If the engine has been stopped for a considerable period of time, the cylinders should be cleared of fuel or water accumulation before starting the engine.*

1. Apply the engine barring-over device and back off the compression relief plugs on the left side of each cylinder.



2. Rotate the engine at least two complete revolutions by use of the engine barring-over device.

3. Remove the barring-over device from the engine and tighten all compression relief plugs before cranking.

4. Check that the emergency stop switch is in the RUN position.

5. Close the battery switch located beside the engine control panel in the operator's cab.

6. Check that the ground-relay indicating light is <u>not</u> on. Cause of the ground fault must be removed before proceeding.

7. Close the following circuit breakers on the engine control panel:

a. Control Circuit

> *NOTE: When starting engines of several locomotives in a multiple-unit consist, start the engines one at a time. Close the control circuit breaker only on one unit. Push the fuel-pump reset button and allow the fuel pump to run a few seconds before starting the engine. When all engines are running, close the control circuit breaker on the lead unit only.*

b. Charging Circuit

c. Fuel Pump

d. Headlights

e. Running Lights

8. Push the engine start button on the engine control panel and hold it in until the engine starts.

*NOTE: If proper engine lube-oil pressure does not build up within approximately 40 seconds, the governor will shut off the fuel and prevent the engine from starting.*

*CAUTION: DO NOT DISCHARGE THE BATTERY EXCESSIVELY BY REPEATED ATTEMPTS TO START. IF THE FIRST TWO OR THREE TRIES ARE UNSUCCESSFUL, RECHECK THE STARTING PROCEDURE.*

## BEFORE MOVING THE LOCOMOTIVE

1. Turn the engine control switch to the RUN position.

2. Make an air-brake test and other checks in accordance with railroad regulations.

3. Check the main reservoir air pressure according to railroad rules.

4. Check the control air pressure. Normal pressure is 70 psi.

5. Make an Independent air-brake application. Release the hand brake and remove any blocking of the wheels.

6. Allow time for the engine cooling water to warm up before moving the locomotive in accordance with railroad rules.

## FASTER AIR PUMPING

To provide faster air pumping on the locomotive, when the reservoirs have been drained or after the locomotive has been coupled to a train, proceed as follows:

1. Leave the generator-field circuit breaker in the OFF position.



2. Close the control breaker on the engine control panel.

3. Leave the selector handle in the OFF position.

4. Move the throttle handle to 4TH or 5TH NOTCH as needed.

*NOTE: If the main reservoir air pressure is above 130 pounds and is not rising, increasing the engine speed will not raise the pressure.*

## MOVING A TRAIN

1. Close the generator-field circuit breaker on the master controller cover.

2. Move the selector handle to the FORWARD or REVERSE MOTORING position, depending on the direction of movement desired.

3. Place your foot on the safety-control foot pedal (if used) and release the brakes completely. Several minutes may be required to release the brakes, depending on the length of the train.

4. Advance the throttle handle.

5. The throttle handle has full notches and half notches (IDLE up to NOTCH 8), with each successive notch representing an increase in power, or locomotive tractive effort.

Starting a train depends on the type, length, weight, grade, condition of rail, and amount of slack in the train. This locomotive is designed to have easily controlled tractive effort build-up characteristics, with the tractive effort in each notch limited to definite values as the throttle is moved from the lowest to the highest notch. No harm will be done by moving the throttle beyond NOTCH 4 when starting a train. The engineman can easily control the amount of tractive effort required to start and accelerate a particular train. The speed can be controlled as desired by reducing or increasing the throttle position.

## STOPPING A TRAIN

Move the throttle handle to the IDLE position and apply the air brakes according to railroad regulations. If you are leaving the operator's position after the train has stopped, move the selector handle to the OFF position.

## REVERSING THE LOCOMOTIVE

1. Bring the locomotive to a full stop.

2. Move the selector handle to the opposite direction MOTORING position.

3. Release the brakes.

4. Advance the throttle.

## PASSING THROUGH WATER

Do not exceed two or three mph if there is water over the rails. Do not pass through water that is over 2.5 inches above the top of the rail.

## PASSING OVER RAILROAD CROSSINGS

Do not pass over railroad crossings at full power, or traction-motor flashover may result. Reduce power by moving the throttle handle to 5TH NOTCH or below, while all units are passing over the crossing.



## STOPPING THE ENGINES

1. Move the throttle handle to the IDLE position.

2. Open the generator-field circuit breaker on the master controller stand.

3. Move the engine control switch to the START position.

4. Press the STOP button on the engine control panel.

5. To shut down all engines when in multiple-unit operation, move the MU-ENG EMERGENCY SHUTDOWN SWITCH on the master controller to the STOP position. The emergency shutdown switch must be in the RUN position before attempting to start the engine.

## BEFORE LEAVING THE LOCOMOTIVE

1. Apply the hand brake and release the air brakes after uncoupling from the train.

2. Leave the throttle in the IDLE position and place the selector handle in the OFF position. Remove the selector handle after moving it to the OFF position.

3. Open all switches and circuit breakers.

4. Close the windows and doors.

5. Open the battery switch.

6. In freezing weather, precautions must be taken to see that the cooling water does not freeze.

## SAFETY CONTROL

Safety control (if installed) consists of a foot-pedal-operated air valve, whistle, and a cut-out cock. Except when the locomotive is stopped and locomotive brakes are applied, the engineman must keep the safety-control foot pedal depressed at all times. This prevents a safety-control brake application.

After a penalty brake application has occurred, normal locomotive operation is restored in the following manner:

1. Move the throttle handle to the IDLE position.

2. Move the automatic brake valve handle to the SUPPRESSION position.

3. Depress the safety-control foot pedal. (See Fig. 9-1.)

4. After the application pipe has built up to normal pressure, move the automatic brake valve handle to the RELEASE position.

*NOTE: Other forms of Safety Control may be provided. See railroad rules for specific procedures.*

## APPLYING DYNAMIC BRAKING

Dynamic braking is applied to the locomotive only. A dynamic brake interlock keeps the air brakes on the locomotive from being applied when automatic air braking and dynamic braking are being used. The M.U. braking selector switch (when installed) must be positioned according to railroad rules.

Applying dynamic braking is done in the following manner:

1. Move the throttle handle to the IDLE position.

2. Move the selector handle from MOTORING to BRAKING in the same direction the locomotive is moving.



3. Advance the throttle handle slowly to bunch train slack. (Braking is now controlled by the throttle handle.)

4. After the slack is bunched, advance the throttle handle until the desired braking effort is obtained. Observe and correct braking effort during the initial period of dynamic brake application.

*CAUTION: PROLONGED OPERATION OF DYNAMIC BRAKING IN THE 8TH NOTCH AT SPEEDS ABOVE 61 MILES PER HOUR CAN CAUSE INCREASED MAINTENANCE OF TRACTION MOTORS.*

The amount of braking effort obtainable varies with the position of the throttle for the various speeds. Maximum braking effort is obtained in the 8TH NOTCH at speeds of 22 to 30 mph, depending on locomotive gearing.

When a locomotive is equipped with variable-range dynamic braking, a series of peak braking efforts will occur down to 8 mph.

*NOTE: Wheel-slip warning may occur while in dynamic braking. This indicates that wheels are sliding. Sand is applied automatically to the wheels of the sliding unit. Reduce the throttle position until the warning stops.*

## USE OF AIR BRAKES DURING DYNAMIC BRAKING

When necessary, the automatic air brake may be used in conjunction with the dynamic brake. Automatic air brakes will apply on the train but not on the locomotive. If the Automatic air-brake handle is moved to the EMERGENCY position, the dynamic brake is removed and brakes on the locomotive as well as those on the train go into emergency application.

The independent air brake *must not* be used during dynamic braking, to avoid flat spots on the locomotive wheels caused by sliding.

## RELEASE OF DYNAMIC BRAKING

Release dynamic braking in the following manner:

1. Move the throttle handle to the IDLE position.

2. Move the selector handle from BRAKING to MOTORING or OFF as locomotive operation requires.

## OPERATING AS A LEADING UNIT

To operate the locomotive as a lead unit of a consist, proceed as follows:

1. Make the necessary preliminary preparations for operation.

2. Test the air brake in accordance with railroad rules.

3. Close the generator-field circuit breaker.

4. Move the selector handle to the desired direction.

5. When equipped with an M.U. braking selector switch (optional equipment), position the selector switch according to railroad rules.

6. Operate the locomotive in accordance with operating procedure.

## OPERATING AS A TRAILING UNIT

### AIR EQUIPMENT SET-UP

1. Make a Full Service application with the Automatic brake-valve handle.



2. Move the brake-valve pilot cut-out (double-heading cock) to the OUT position.

3. Move the Automatic brake-valve handle to the HANDLE OFF position and remove the handle.

4. Place the Independent handle in the RELEASE position.

5. Move the MU-2A valve to suit the brake equipment on the leading unit (either TRAIL-24 or TRAIL-26 or TRAIL-6 positions).

### ELECTRICAL SET-UP

1. Move the selector handle to OFF and remove the handle.

2. Open the generator-field circuit breaker on the master controller. Leave all breakers in the closed position on the engine control panel, *except the control circuit breaker* and engine run switch if used. The running-lights circuit breaker may be positioned as desired.

3. Place the M.U. headlight set-up switch in the proper position.

4. Place the M.U. braking selector switch (if installed) in the proper position.

## CHANGING OPERATING ENDS

To change operating control from the cab of one locomotive unit to the cab of another, proceed as follows:

### VACATING UNIT - AIR EQUIPMENT SET-UP

1. Make a Full Service brake pipe reduction.

2. Allow time for all air blowing sounds to stop; then, depress the handle of the brake-valve pilot cut-out cock and move it to the OUT position.

3. Place the Automatic brake-valve handle in the HANDLE-OFF position and remove the handle; then, place the Independent brake-valve handle in the RELEASE position.

4. Depress the handle on the MU-2A valve and move it to TRAIL-24, or TRAIL-6 or TRAIL-26 position, depending on the type of equipment used on the lead locomotive unit.

VACATING UNIT - ELECTRICAL SET-UP

1. Move the selector handle to the OFF position and remove the handle.

2. Open the generator-field circuit breaker on the master controller.

3. Leave all breakers in the closed position on the engine control panel, *except the control circuit breaker* and engine run switch if used. The running-lights circuit breaker may be positioned as desired.

4. Move the M.U. headlight set-up switch to the required position.

OPERATING UNIT - AIR EQUIPMENT SET-UP

1. Insert the Automatic brake-valve handle in the HANDLE-OFF position.

2. Move the Independent brake-valve handle to the FULL APPLICATION position.

3. Depress the handle of the MU-2A valve and move it to the LEAD or DEAD position.



4. Depress the handle of the brake-valve pilot cut-out cock and move it to the IN or FRT. or PASS. position, as designated by the service in which the locomotive is to be operated.

OPERATING UNIT - ELECTRICAL SET-UP

1. Insert the selector handle into the master controller.

2. Close the generator-field circuit breaker on the master controller.

3. Close all circuit breakers on the engine control panel.

4. Move the M.U. headlight set-up switch to the required position.

# CIRCUIT OPERATION

## GENERAL

The excitation system used with the General Electric a-c generator provides accurate power utilization throughout the range of locomotive operation. Using solid-state components, the system offers the advantages of:

1. Accurate control
2. Reliability with long life
3. Factory-set components that do not require adjustment during service.

Circuit components for the excitation system are mounted on bench-set, plug-in, pretested cards. This arrangement provides for ease of accessibility, fast replacement, and simple defect correction.

## ALTERNATOR-RECTIFIER LOCOMOTIVE

The General Electric locomotive is powered by the 16-cylinder diesel engine that drives a three-phase alternator. Three rectifier panels are connected to the alternator; each panel contains silicon diodes, fuses, and resistors. A capacitor and two resistors are connected in parallel with each diode.

On the four-motor locomotive (U33B), each rectifier panel contains 24 diodes, or a total of 72 diodes for the three panels. Each rectifier panel on the six-motor locomotive (U33C) contains 28 diodes, or a total of 84 diodes in the three panels. Three-phase alternating current from the traction alternator is rectified to direct current by the diodes, and the direct current then flows to the traction motors to move the locomotive.

The alternator rotor has 10 poles connected to slip rings. This provides the rotating field which induces alternating current in the stator windings. The stator windings in the frame are connected to the alternator output terminals. Excitation current to the field is provided by an exciter mounted on the alternator frame. During excitation, the level of alternator output is controlled by the speed and amount of excitation current in the field. The rotating speed of the field is the same as the governed speed of the diesel engine. Therefore, the level of excitation current is determined by the exciter output. This output is controlled by the excitation system.

## EXCITATION SYSTEM

To understand the locomotive excitation system, consider first three basic components.

1. Rectifier panel
2. Alternator
3. Exciter

If a voltmeter is connected across the rectifier terminals of a four-axle locomotive and the engine and alternator run at 8th notch (1050 rpm), the field current of the exciter can be adjusted to about 0.75 ampere. This will produce about 1320 volts no-load voltage on the alternator.

For the following explanation, assume that the d-c output terminals of the rectifier panel are connected to a variable loading resistor, to determine the system characteristics under load. A shunt and millivoltmeter calibrated to indicate amperes are connected in series with one of the output terminals. See Fig. 10-3.

With the top located for minimum resistance and the alternator rotating at full engine speed, the output characteristic resembles that shown in Fig. 10-1. Under this condition of operation, the alternator is producing excessive current and voltage. The load demand would exceed the capacity of the diesel engine.



Fig. 10-1 (E-14728)

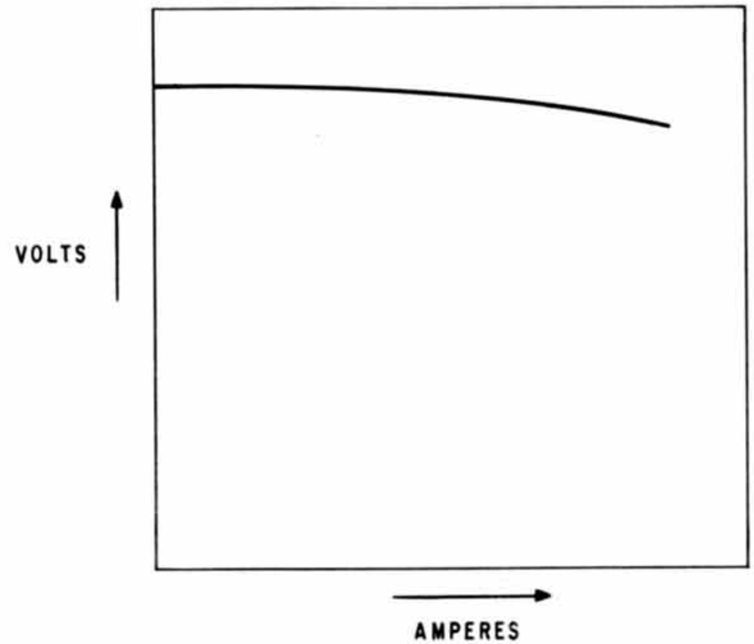



*Fig. 10-1. Constant-speed, constant-field characteristic of generator*

It is evident, therefore, that the locomotive must have an excitation control system that will limit the current and voltage characteristic to be within the horsepower capability of the diesel engine. This characteristic can be established by placing numbers in a formula and plotting the results on a graph.

From the relationship between mechanical power and electrical power,

$$\text{horsepower} = \frac{\text{volts x amperes}}{746}$$

Therefore, by simple algebraic transposition, the formula can also be expressed as

$$\text{volts} = \frac{\text{horsepower x 746}}{\text{amperes}}, \text{ or } V = \frac{746\ HP}{A}.$$

There are two known values that can be substituted in the formula; the horsepower input of the engine into the alternator (3300 hp at 1050 rpm), and the number 746 (watts per horsepower) which is an electrical constant. Disregarding efficiency, voltage is equal to the product of horsepower (3300) and the constant 746 divided by arbitrary values of current. By substituting ampere increments (about 200 amperes per step) into the formula, a voltage corresponding to each value of current can be obtained. The coordinates of volts and amperes are now plotted on a graph, and the results are as shown in Fig. 10-2. This curve is hyperbolic in shape and represents the following:

1. Any point on the curve represents 3300 horsepower at 1050 rpm (constant speed, constant horsepower).

2. The voltage and current are inversely proportional; i.e., when volts are high, amperes are low.

The horsepower characteristic (see Fig. 10-2) expressed in terms of volts and amperes represents an ideal arrangement for a locomotive. The horsepower is available for high-current, low-voltage train starting, and low-current, high-voltage conditions for maximum train speeds.

Figure 10-2 shows a hypothetical constant-speed, constant-field current excitation curve, as well as the constant-speed, constant-horsepower curve. It is evident from Fig. 10-2 that the curves match at only one point where they intercept. Elsewhere there is a large difference between the two curves. The alternator and engine outputs must match. This is accomplished by controlling the field current of the exciter which supplies power to the alternator field.



Fig. 10-2 (E-15061)

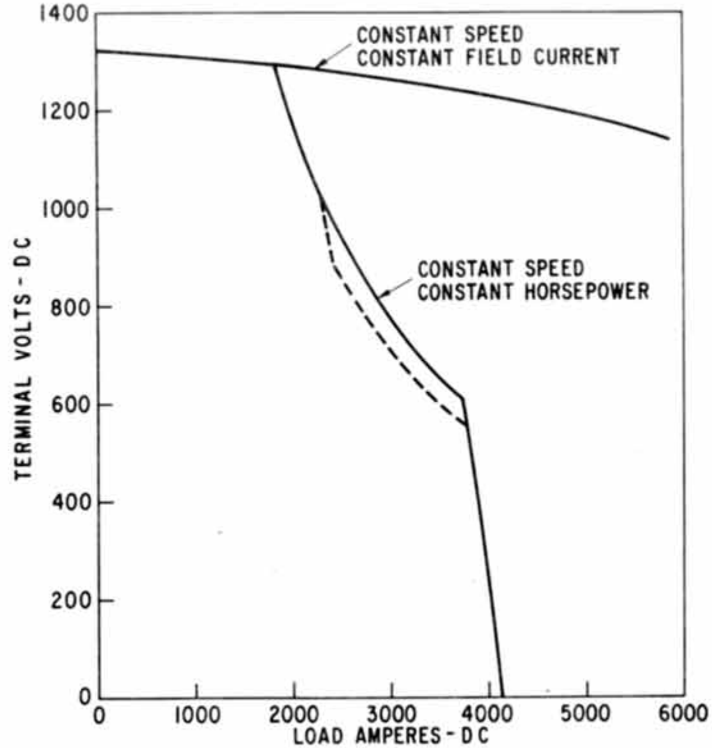



*Fig. 10-2. Horsepower characteristic*

Basic Control

The exciter field is connected in series with a transistor across the 75-volt system. By this arrangement, current passing through the field can now be controlled by adjusting the base-to-emitter current of the field transistor (FT1). This current flow through the exciter field can now be turned on and off rapidly by applying and removing the signal to the base-emitter circuit of transistor FT1. The average current resulting from this switching action sets the level of excitation. See Fig. 10-3.

CIRCUIT OPERATION

## ALTERNATOR, EXCITER, AND FIELD TRANSISTOR

The field transistor circuit is shown in Fig. 10-3. With excitation applied to the exciter, current from the battery PA wire (+75 volts) passes through resistors EFR2 and EFR4, through the exciter field (EF1 to EF2), field transistor FT1 (which is now ON) collector-to-emitter, and diode RD47, to the N(-) wire. Since the transistor is ON, or conducting, the exciter output is applied to the alternator control field during the time the transistor conducts; the negative end of the exciter field (EF2) is at nearly negative battery potential, and the positive end (EF1) is approximately 30 volts above battery negative. Field transistor FT1 goes on and off 800 times a second due to the switching of polarity from the oscillator. When transistor FT1 is turned off, no current passes through the transistor; however, current continues to flow through the field since current can "coast" up through diode RT4 when the field flux is collapsing on the field poles. This means the transistor does not have to actually stop and restart the current flow in this highly inductive circuit.

## OSCILLATOR

The basic timing for switching the excitation circuit on and off is a 400-cycle-per-second oscillator. This circuit (see Fig. 10-4) is a d-c to a-c square-wave generator that supplies a control signal for field transistor FT1. Transistors T1 and T2 will conduct alternately along with the primary windings of oscillator transformer OST which comprise the essential components of the oscillator.

A voltage divider (OVDR1 and OVDR2) across the PA wire (+) and the N wire (-) provides voltage to the input side of resistor R54. The Shockley diode RD3 conducts at a breakdown of 20 volts, and applies forward bias to transistor T2 by exciting the lower transformer winding with an instantaneous polarity to drive the base positive. Oscillator transistor T2, now conducting (collector-to-emitter), excites the lower transformer primary winding of oscillator transformer OST. All four series windings

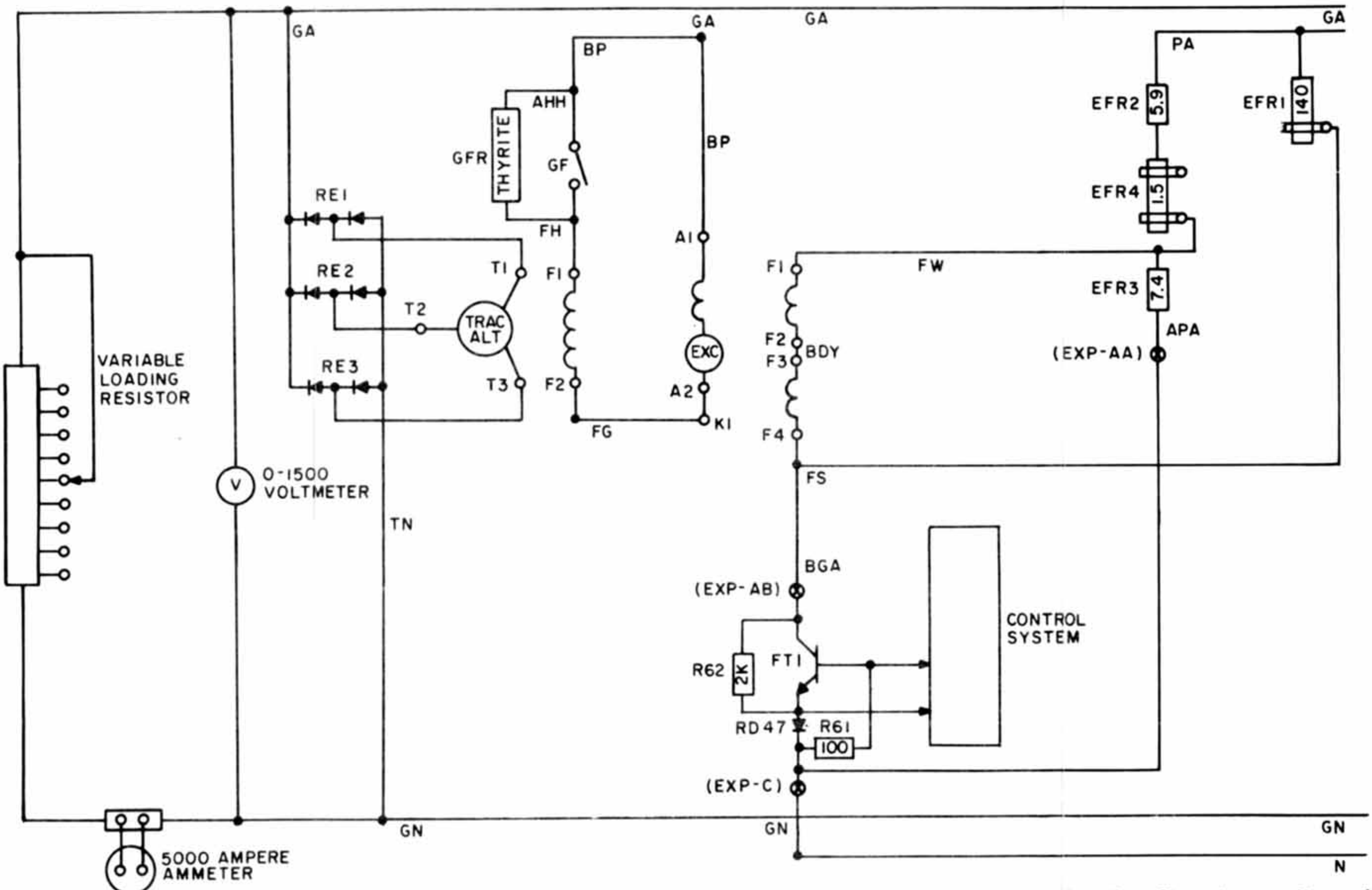



*Fig. 10-3. Traction alternator, exciter and field transistor (motoring)*

Fig. 10-4 (E-14731)

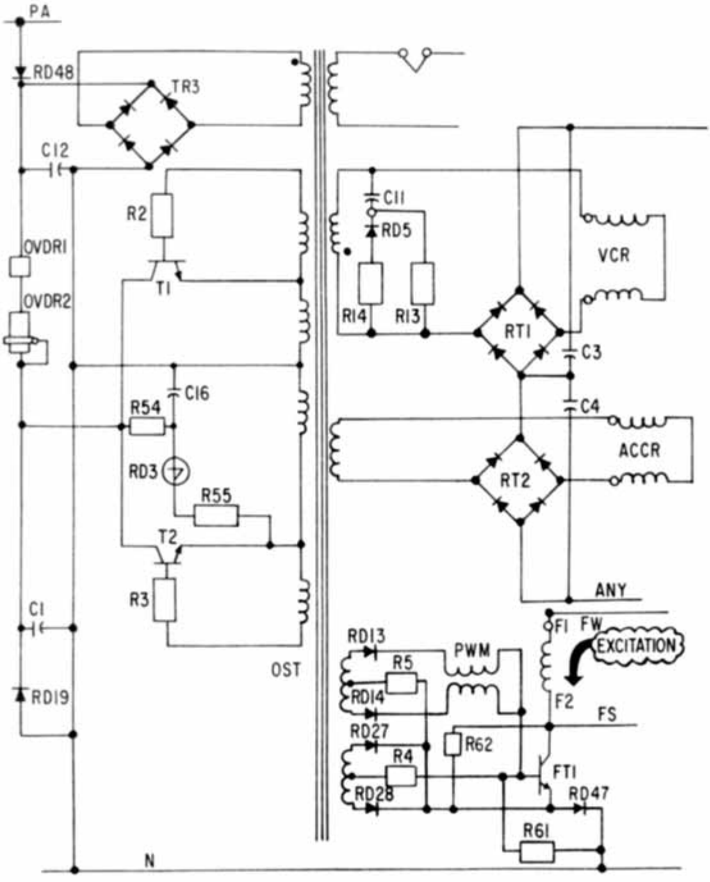



*Fig. 10-4. Oscillator transformer and pulse-width modulator (motoring)*

in the primary of the oscillator transformer are wound so that the voltages induced in them will add together. This is similar to a continuous winding with three taps. The current pulse created when transistor T2 conducts then passes upward through the two lower windings of the oscillator transformer primary and returns to the N wire (-)

During the time the pulse from transistor T2 is passing through the primary of the oscillator transformer, the winding connected to the base of transistor T1 is forward biased, so that transistor T1 conducts into the primary of the oscillator transformer in the reverse direction. This, in effect, turns off transistor T2 until it turns on again at the next half cycle.

Transistors T2 and T1, therefore, turn on and off alternately (oscillate), 400 times per second. This produces square-wave pulses in the primary of the oscillator transformer, as long as the PA wire is energized. On the first half cycle, and on each succeeding odd half cycle, transistor T2 conducts. Rectifier RD19 and capacitor C1 permit the voltage developed by the inductive effect of the oscillator transformer windings to be discharged without damage to transistors T1 or T2.

The oscillator transformer winding connected to the full-wave bridge (TR3) is a regulator winding to keep the voltage applied to the oscillator (PA to N wire) at a constant level. Although the PA wire is held within voltage limits by the battery-charging regulator, additional voltage regulation is needed to hold the voltages in the oscillator transformer winding at a constant level. Diode RD48 is a reverse-voltage diode. This diode prevents damage to the oscillator card if reverse polarity is accidentally applied to the PA wire when starting the locomotive from the battery of another locomotive.

## PULSE-WIDTH MODULATOR

The pulse-width modulator (PWM) is a small, self-saturating reactor with several d-c windings and one a-c winding. Connections for only the a-c winding are shown in Fig. 10-4. Both the a-c winding and d-c control windings are shown in Fig. 10-5. Control of polarity and the level of current flow through these windings determines the pulse width. The wider the pulse width, the greater the time duration that the field transistor is turned on during each half cycle of the oscillator, and, therefore, the higher the excitation level.



Fig. 10-5 (E-14732)

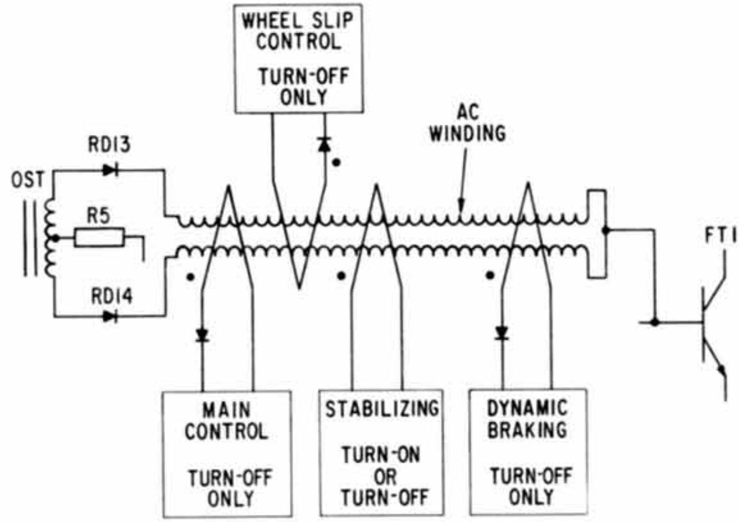



*Fig. 10-5. Pulse-width modulator (PWM) windings*

Diodes RD27 and RD28 (see Fig. 10-4) are connected as full-wave rectifiers to apply a reverse (negative) bias to field transistor FT1 to turn it off. The a-c windings of the pulse-width modulator, however, are connected to full-wave rectifier diodes RD13 and RD14 to apply a forward (positive) bias to transistor FT1 to turn it on. The oscillation of the transformer through "turn on" diodes RD13 and RD14 and "turn off" diodes RD27 and RD28 makes the field transistor turn on and off 800 times a second.

The length of the "on" time is controlled by the pulse-width modulator. Figure 10-6 shows the pulses in the a-c winding of the pulse-width modulator which turn on transistor FT1 and allow current to pass through the exciter field (EF1 and EF2). During maximum excitation, the "turn on" pulses are at maximum width, and current flows from EF1 to EF2 through the exciter field. During minimum excitation conditions, the transistor is "turned off" during the greater portion of the pulse (half cycle) and the

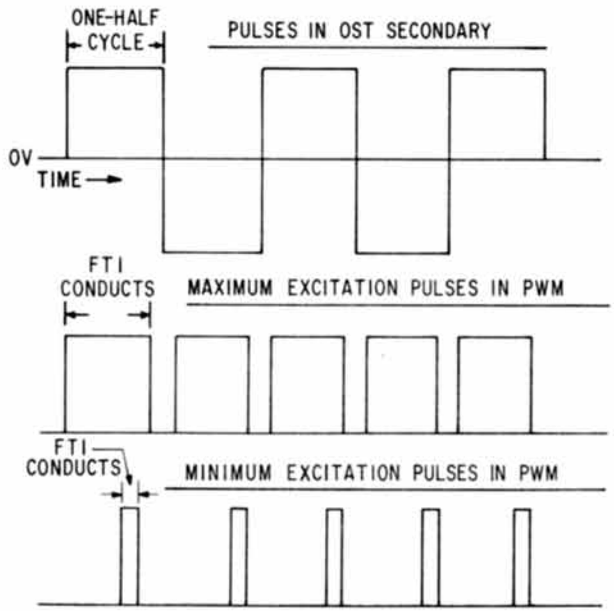



*Fig. 10-6. Pulse in oscillator transformer and a-c winding of pulse-width modulator (PWM)*

Fig. 10-6 (E-14733)

average field current in the exciter field is very low. The exciter-field excitation current, therefore, depends on the percentage of "on" to "off" time in transistor FT1, as controlled by the pulse-width modulator.

The direct current in the pulse-width modulator control windings receives signal inputs from various feedback sources in the control system. Current flow in one direction of each control winding increases the length of "turn on" time; the reverse direction of current flow decreases the "turn on" time. Since certain control windings are arranged for "turn on" effect and others are arranged for a "turn off" effect, the total or net excitation may be expressed as:



1. Percentage of "turn-on" time per half cycle in transistor FT1 for any period of time.

2. Average current in the exciter field (EF1 to EF2) during the same time period.

Resistor R61 and diode RD47 prevent "thermal runaway" in transistor FT1. The voltage drop across resistor R61 puts a reverse bias on the base of transistor FT1. This makes the base slightly negative, and clamps off the transistor to prevent possible conduction due to heating effects in the transistor.

## VOLTAGE AND CURRENT CONTROL

The current-measuring reactor (ACCR), shown in Fig. 10-7, is physically located in series with the negative d-c bus to the traction motors. It is designed in such a

Fig. 10-7 (E-14734)

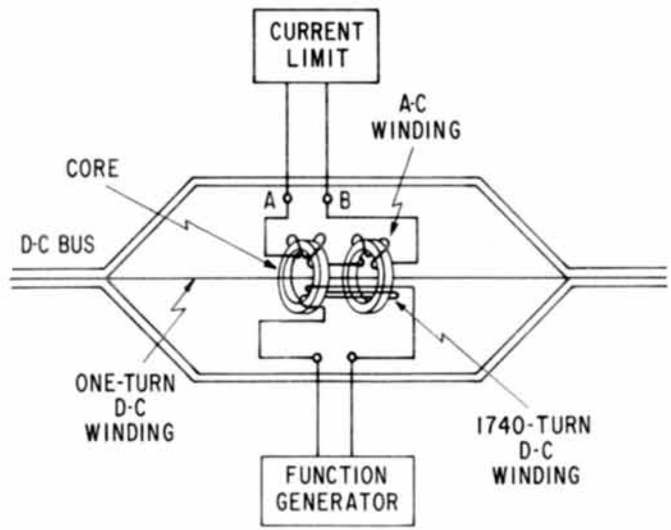



*Fig. 10-7. Construction of current-measuring reactor, ACCR*

way that only a small fraction of high motor current is actually effective in the device. A single turn of wire through the core represents the current from the power rectifier panel and the d-c bus. An additional d-c winding is connected to the function generator. The construction of the current-measuring reactor is also shown in Fig. 10-7.

ACCR is a current-measuring reactor. The alternating current passing through it and rectified by full-wave bridge RT2 is an accurate measure of the current in the d-c motor circuit. This output is modified by the function-generator winding (E and F) described in later paragraphs.

The main d-c voltage is measured by the voltage-control reactor (VCR), located on the voltage-reference card in the excitation panel. The alternating current through this reactor (see Fig. 10-8, Section D2) is rectified by a full-wave bridge (RT1), and its output is proportional to the d-c voltage on the traction motors.

Rectifier bridges RT1 and RT2 are connected in series with a "turn off" winding pulse-width modulator (PWM), a calibrating resistor (R36), a blocking diode (RD10), and the brake relay (BR1) contact to complete a loop circuit. The amount of current flow in this circuit is the result of the mixer circuit described in the next paragraph.

The "primary" mixer circuit is shown in Fig. 10-8, Section D2. From this illustration, it is shown that the current originating and flowing out of either source (ACCR or VCR) flows through the loop circuit. This resulting current flow through the pulse-width modulator is in a "turn off" direction. Normally, it would cause the excitation system to be turned fully off. However, another circuit has been added that establishes a reference current for each throttle notch. Assume that the load-potentiometer (LP) brush arm is in the extreme clockwise position on the governor (counterclockwise on the diagram), to provide maximum reference current. This current flows out of the brush arm of the load-control potentiometer, through rheostat MLR, resistors R51 and R7, braking switch contact BKT, rectifier bridges RT2 and RT1, braking switch contact BKT8A, and resistor LCR4, to the negative (N) wire.

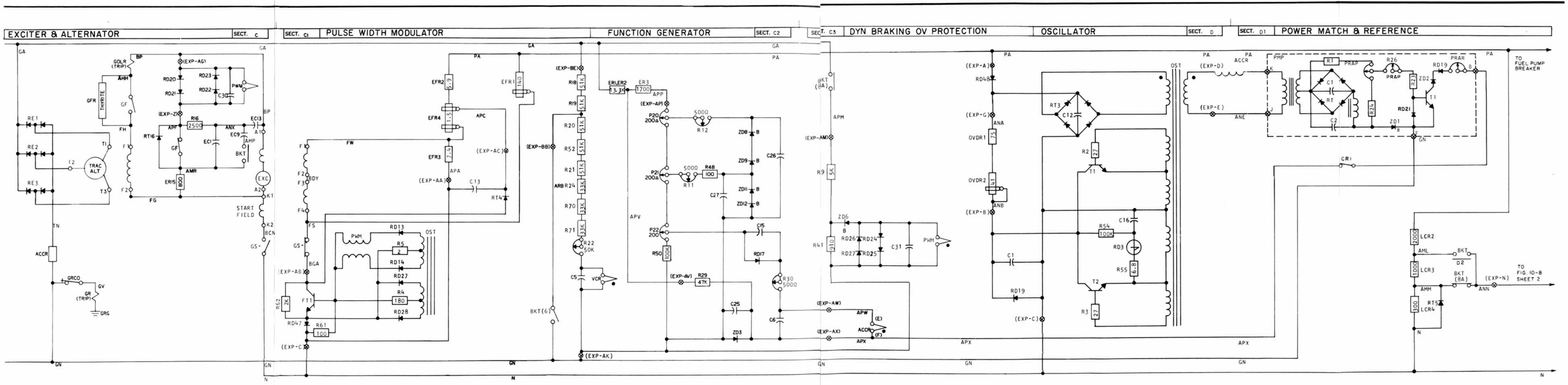



Fig. 10-8 (sheet 1) Excitation circuit

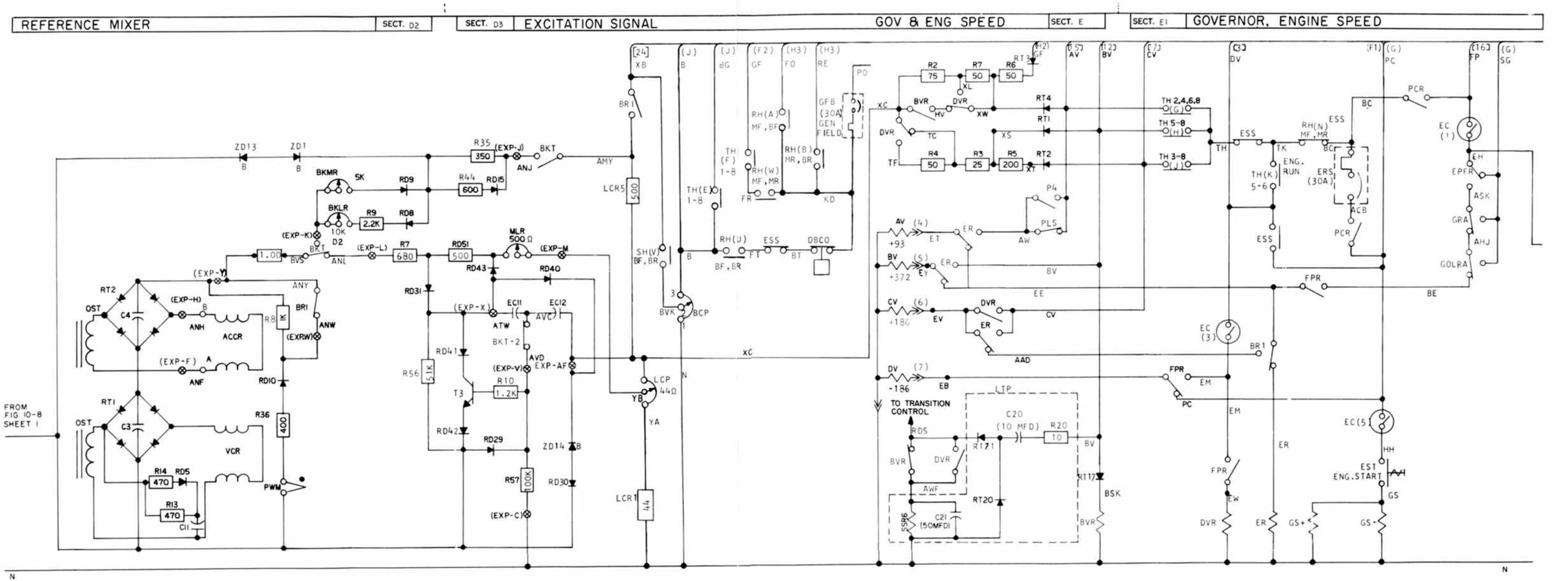



*Fig. 10-8 (sheet 2) Excitation circuit*

The engine speed and excitation signals for both lead and trailing units are accomplished by energizing the GF, AV, BV, CV and DV wires corresponding to throttle-notch positions. This energizes the engine-control governor speed solenoids to control engine speeds. See Fig. 10-8, Section E.

Current flows into the resistor combination (R1, R2, R3, R4, and R5) through the blocking diodes (RT1, RT2, RT3, and RT4). The various combinations of resistors, when energized, produce a variable voltage on the XC wire. As the throttle handle is moved to successively higher notches, the voltage on the XC wire increases and is proportional to the throttle notch position. Since the load potentiometer is connected to the XC wire, the reference current and excitation will correspond to the throttle-handle notch position.

The reference voltage between resistors LCR3 and LCR4 varies between 7 volts in the first-notch position to approximately 32 volts in notch 8. This reference voltage is increased by Zener diode ZD14 which breaks down at 43 volts. Current then flows from the upper side of the load potentiometer, through diodes ZD14 and RD30, through switch BKT, through resistor LCR4, to the N wire. This added current flow through resistor LCR4 increases the voltage drop to 32 volts. Current in this circuit flowing from the brush arm of the load-control potentiometer, through rheostat MLR, resistors R51 and R7, rectifier bridges RT2 and RT1, switch BKT, and resistor LCR4, is determined by the voltage difference between the brush arm of the load-control potentiometer and the voltage between resistors LCR3 and LCR4. This is called the reference current. It is limited by rheostat MLR to establish the maximum reference current.

The current-measuring reactor passes approximately 8 milliamperes of current in its a-c winding for every thousand amperes in the alternator-rectifier load circuit. This current is imposed on the reference circuit along with the reference current. If the output current from the current-measuring reactor is less than the reference current, no limiting occurs; thus, the pulse-width modulator does not yet try to reduce excitation. When the current-measuring reactor output current exceeds the reference current, the excess flows through resistors RT2 and RT1, the pulse-width modulator winding (out of the dot), resistor R36, diode RD-10, brake relay BR1, the ANY wire, and then to the negative side of rectifier bridge RT2. This current flow through the pulse-width modulator winding reduces the pulse width in the a-c winding of the modulator, and tends to shut off excitation. Two milliamperes of excess current through the pulse-width modulator winding will turn off the excitation completely.

Similarly, an increase of voltage across the alternator-rectifier output terminals produces a similar output current from the voltage-control reactor as shown in Fig. 10-8, Section D2. This current from the voltage-control reactor acts in a similar manner to the current produced by the current-measuring reactor. When the current from rectifier RT1 exceeds the reference current, the excess current also flows through the pulse-width modulator winding and tends to shut off excitation. At this point in the analysis, the description of the mixer is concerned with only the reference current, voltage limit, and current limit. There is both a voltage limit and current limit for each throttle position.

## RATE CIRCUIT (See Fig. 10-8, Section D3)

An increase in excitation caused by increased throttle-notch position or a change in position of the load-control potentiometer will cause a temporary change of the reference circuit. When the throttle handle is advanced, the voltage on the XC wire is proportional to the number of notches. The increase in voltage on the XC wire charges capacitor EC12 which provides bias to the base of transistor T3 and resistor R10, and "turns on" the transistor. When transistor T3 conducts, it drains off some of the reference current from the junction between resistors R51 and R7 (through diodes RD31, RD41, and RD42) to the junction of resistors LCR3 and LCR4. The current then passes through resistor LCR4 to the N wire. This increases the voltage drop across resistor R51.



As capacitor EC12 reaches maximum charge, the reference current drain through transistor T3 is turned off. A similar action occurs when the load-control potentiometer increases as actuated by the engine governor. This increase in voltage on the arm of the load-control potentiometer produces a similar increase in voltage on the junction of resistors R51 and R7, as controlled by motoring-load rheostat MLR. In this case, capacitor EC11 charges, turns on transistor T3, drains off reference current, and, thus, slows down the rate of reference current increase.

Diode ZD14 is a 43-volt Zener diode connected directly to the XC wire and the top of the load-control potentiometer. When the diode conducts, current passes through diodes ZD14 and RD30, to the junction of diode RD42 and resistor R56, then through BKT-1 interlocks to the junction of resistors LCR3 and LCR4, and then on through to the negative wire (N). Diode ZD14 limits the junction of resistors LCR3 and LCR4 to a maximum of 32 volts, if the voltage on the XC wire is 75 volts maximum. By stabilizing the voltage on the resistor (LCR3-LCR4) junction, the locomotive produces full horsepower independent of actual voltage on the XC wire, as long as it is above approximately 60 volts.

Reverse currents in the rate circuit are prevented by blocking diode RD30. Otherwise, when the throttle is in the IDLE position, current would flow from the resistor (LCR3-LCR4) junction, back to the load-control potentiometer, and then to the N wire.

## FUNCTION-GENERATOR CIRCUITS

The excitation system as described so far has established two limits on the alternator output:

1. The current limit is set by current-measuring reactor ACCR.

2. The voltage limit is set by voltage-control reactor VCR.

These two limits are not satisfactory for establishing a power limit and preventing the alternator from overloading the engine. Therefore, another circuit must be added. This is provided for by the function-generator circuit.

The constant-horsepower curve on Fig. 10-9 shows d-c output from the rectifier panels. When excitation is applied to the exciter field, the current is limited to the value established by the current-measuring reactor. The volt-ampere coordinates represented by the sloping lines

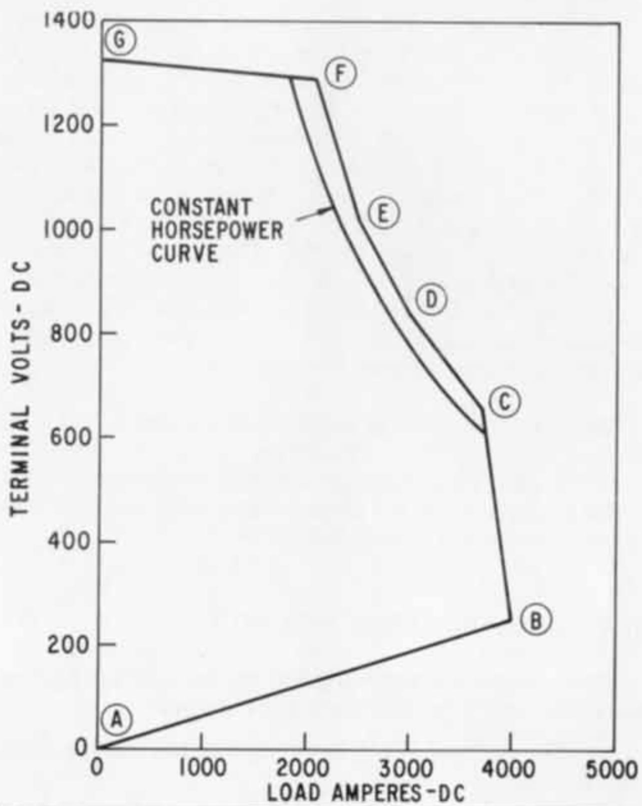



*Fig. 10-9. Load characteristics*

Fig. 10-9 (E-15064)



CD, DE, and EF are established by the function-generator circuits. These are shown on Figs. 10-8, Section C2. A voltage-divider network, consisting of resistors and potentiometers, is applied across the GA and GN wires. This measures the terminal voltage of the rectifier panels. Current flows from the GA wire, through ER1, ER2, ER3, P20, and P21, out of the brush arm of P22, through diode RD17 and rheostat R30, and then through the current-measuring reactor gate winding (E to F), breaking down Zener diode RD3; then, it passes to the GN wire.

When current flows (E to F out of the dot) through the current-measuring reactor, it causes the reactor to "think" that excess current is flowing and it then reduces excitation to provide slope CD. The current-measuring reactor winding has many turns of wire wound on the same core as the current-limit winding AB (Fig. 10-7), and has the same effect as increased load current.

The current flow through the EF winding of the current-measuring reactor aids the AB gate winding to saturate the core of the current-measuring reactor. Saturation of the current-measuring reactor core causes the inductive reactance to go to zero in the control winding, allowing it to pass more alternating current. The increased current flow in the current-measuring reactor control winding reduces the pulse-width signal and the excitation.

At this point in the analysis, the volt-ampere characteristic will be located on slope CD. Consider again system conditions with the power output connected to a variable loading resistor set for minimum circuit resistance. When the throttle is notched out, the volt-ampere coordinates fall on the IR line AB. At point B, the circuit resistance is increased, and then the volt-ampere coordinates will fall on line BC. This line BC is the current-limit line established by the current-measuring reactor and the current flowing through the control winding in series with the d-c bus.

The function generator provides enough "turn off" current in the EF winding of the current-measuring reactor to cause the load point to fall on line CD. When point

D is reached, the voltage across the GA and GN wires has been increased, and current will flow out of the brush arm of potentiometer P21 (see Fig. 10-8, Section C2), through rheostat R11 and resistor R48, Zener diodes ZD11 and ZD12, to the junction of diode ZD3, and then to the N wire. Although there is an increase in voltage across the GA to GN wire, the current flow will be increased in the current-measuring reactor gate winding by a lesser amount. This amount is established by the circuit consisting of Zener diodes ZD11 and ZD12. These diodes, by their breakdown voltage, determine the amount of current that goes through the current-measuring reactor gate winding. This action reduces the "turn off" effect of the signal winding, and, thereby, sets a new slope angle by drawing line DE.

If the load circuit resistance is raised still further, the voltage across the GA to GN wires is increased. Here, the shunting action of another set of Zener diodes takes place. Current flows out of the brush arm of potentiometer P20, through rheostat R12, resistor R69 and Zener diodes ZD8, ZD9, ZD11, and ZD12, to the junction of Zener diode ZD3 and the N wire.

The breakdown of diodes ZD8 and ZD9 recalibrates the "turn off" circuit of the current-measuring reactor gate winding by creating another shunting circuit for current flow around the gate winding. This shunting circuit establishes slope EF.

When the circuit resistance is increased still further, the volt-ampere characteristic will follow the slope EF. At point F, the voltage (GA to GN) is high enough to force current through the resistors (R18, R19, etc.) and the voltage-control reactor gate winding. Current through this gate winding produces an additional "turn off" effect on the excitation system. This effect establishes the voltage limit line FG.

The excitation panel layout is shown in block diagram form on Fig. 10-10. Factory adjustments are made to these circuits as follows:



Fig. 10-10 (E-14739)

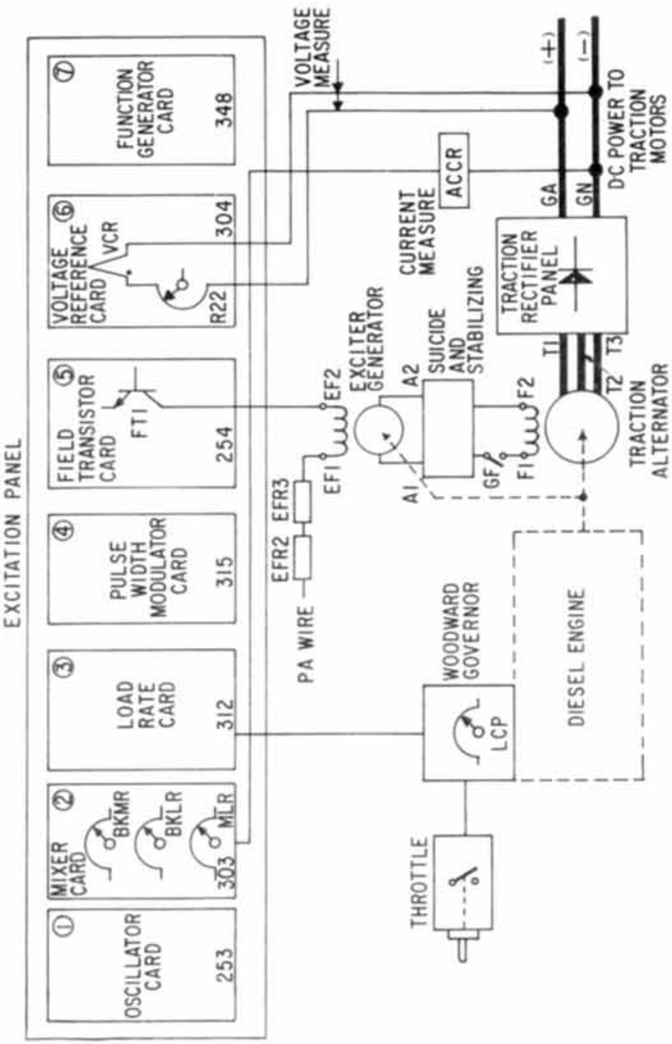



*Fig. 10-10. Locomotive excitation system, simplified block diagram*

1. Slope CD, potentiometer P22 on function-generator card 348

2. Slope DE, potentiometer P21 on function-generator card 348

3. Slope EF, potentiometer P20 on function-generator card 348

4. Voltage limit line FG, rheostat R22 on voltage reference card 304

The function-generator and voltage-reference cards are part of the excitation panel. These controls normally do not require adjustment.

## LOAD-CONTROL POTENTIOMETER

The sloping lines established by the function generator do not provide the desired horsepower curve. However, the action of the load-control potentiometer on the engine-control governor acts to hold the volt-ampere coordinates on the horsepower curve.

> *NOTE: The three sloping lines are closer to the horsepower curve than shown on Fig. 10-9. For clarity, however, they are shown above the horsepower curve. In actual locomotive operation, the two curves almost coincide.*

It is the action of the load-control potentiometer that prevents the horsepower demand from exceeding the engine capability. In normal operation, the position of the load-control potentiometer brush arm will vary between 4:00 and 5:00 o'clock positions.



## STABILIZING AND SUICIDE CIRCUITS
(See Fig. 10-8, Section C)

From the system description, it is noted that the excitation control system is constantly being modulated by signals from various feedback sources. These feedbacks could cause hunting and instability. The system is stabilized by a pulse-width modulator gate winding that is transiently energized to oppose the correction signal. Current flows through this pulse-width modulator gate winding (EC1) (and EC9 during braking) to provide this stabilizing effect. Diodes RD20, RD21, RD22, and RD23 prevent over-saturating the pulse-width modulator stabilizing winding, by limiting the voltage drop across it to 1.4 volts.

## DYNAMIC BRAKING

### General

During dynamic braking, the excitation system controls the alternator excitation in a similar manner to that of motoring. The traction alternator-rectifier combination provides d-c output for only the traction-motor fields which are connected in series across the rectifier panel output. The motion of the locomotive wheels rotates the motor armatures, which are connected to resistor grids. During braking, the motors are connected as separately-excited shunt generators. Their outputs are dissipated in the resistor grids as shown in Fig. 10-11. The engine speed is increased to 1050 rpm (8th notch). This drives the fan at full speed and provides cooling air to the resistor grids. The amount of braking is controlled by the throttle notch position.

To understand the dynamic braking system, consider first the characteristics of the locomotive by examining the braking curve in Fig. 10-12. In this illustration, braking effort in thousands of pounds is plotted against speed in miles per hour. The field-current limit curve AB represents the braking developed from 0 to 24 miles per hour with maximum motor field current of 1165 amperes. At

24 mph, this field-limit line AB intercepts the grid-current limit curve BC. Curve BC represents the maximum permissible grid current limit of 740 amperes. It is obvious from this curve that at speeds above 24 mph the motor-field current must be decreased in order to keep the grid current from exceeding 740 amperes. The motor field current must be held inversely proportional to armature speed for a steady-state grid (armature) current of 740 amperes. For example, the grid (armature) current of 740 amperes at 24 mph can be obtained with 1165 amperes of field current; therefore, at 48 mph (twice the speed) the same grid current of 740 amperes can be held with only one-half the field current, or 583 amperes.

The control system must be designed with an automatic feedback so that a constant grid current can be held at any throttle (braking) notch position. This relieves the engineer of the responsibility for having to constantly adjust the throttle-handle position in order to keep the braking within the limits he observes on the load-indicator braking scale.

## Braking Circuits

The excitation circuits used during dynamic braking are shown in Fig. 10-8. Dynamic braking is established by first moving the throttle handle to IDLE and then moving the selector handle to the BRAKING (B) position. The engine-run relay (ER) drops out and the braking relay (BR1) picks up. This energizes the A, B and C solenoids of the engine-control governor from the dynamic-brake setup wire B. Also, this establishes the engine speed at 1050 rpm. The brake-start wire BG is energized at this time and while energizing relay BR1 it also energizes the braking-switch magnet valve. This positions braking switch BKT for dynamic braking. The traction-motor armatures are connected across to resistor grids, and the motor fields are connected in series across the rectifier output.

By relay action, the tap on the load-control resistors (LCR2, LCR3, and LCR4) is changed from the resistor

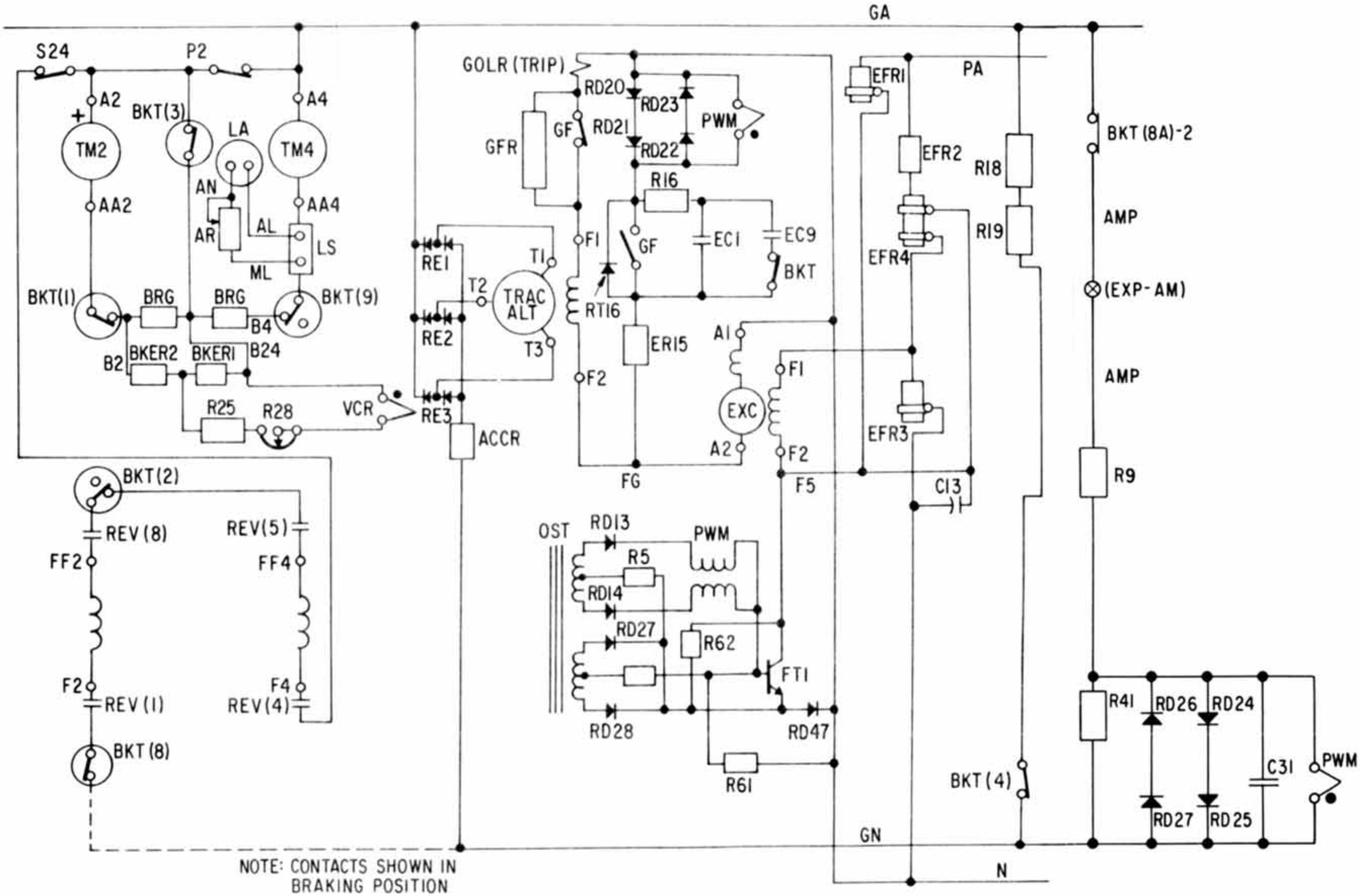



*Fig. 10-11. Motor and generator excitation circuits under dynamic braking operation*

Fig. 10-12 (E-14742)

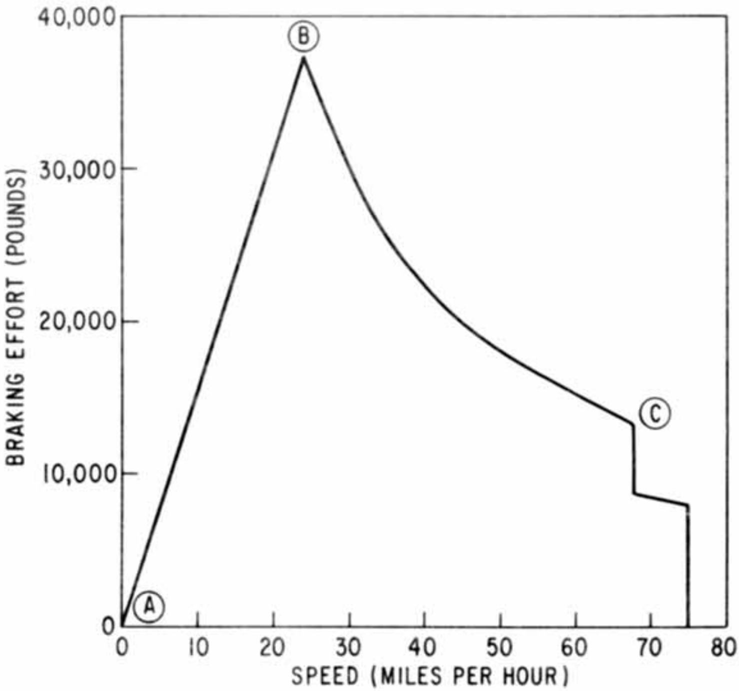



*Fig. 10-12. Dynamic braking curve*

(LCR3-LCR4) junction used in motoring to the resistor (LCR2-LCR3) junction used in dynamic braking. The voltage at the resistor (LCR2-LCR3) junction is approximately 30 volts. Braking-switch interlock BKT, through the picked-up contacts of braking relay BR1, connects the XB wire to the junction of resistor R35 and diode RD15. The reference voltage and current is now established by the throttle position. At the half-notch position, the voltage at resistor (LCR2-LCR3) junction is greater than the voltage of the XB wire, or the voltage on the brush arm of the braking control potentiometer. This difference in potential causes current to flow from resistor (LCR2-LCR3) junction through BKTD2, PWM, R36, RD10, R8, BKT-2, BKMR, RD9, R44, RD15, BKT, BR1, the XB wire, and back to the load pot LCP and then to the N wire.

The minimum braking level is established by setting BKMR. Since current flows through the pulse-width modulator winding, excitation is reduced. This has the maximum effect in narrowing the pulse-width modulator pulse width and shuts off the system to produce a minimum of excitation and, therefore, reduced alternator output. This minimum excitation permits entering braking with minimum retarding effect by the traction motors. With this control, the engineman can bunch his train slack at a desired rate. When the throttle handle is increased, the XB wire voltage increases. This effectively lowers the pulse-width modulator (turn-off gate winding) current, widens the pulse width and increases the amount of excitation.

When the excitation increases due to advancing the throttle handle, the voltage on the XB wire increases to approximately 75 volts at eighth notch. Since the voltage on the XB wire is now higher than the 30 volts on the resistor (LCR2-LCR3) junction, the current reverses in the circuit. The current now flows from the XB wire, through BKT, R35, RD8, R9, BKLR, BKT-2, RT2, RT1, BKT-1, LCR3, and LCR4, to the N wire. This flow indicates the current has now reversed from that described for minimum braking. This reversal of current flow takes place around notch 1. With the throttle handle in notch 8, maximum braking is adjusted with braking-limit rheostat BKLR.

*NOTE: Rheostats BKLR, BKMR, and MLR are located on the mixer card (303) in the excitation panel.*

Current limiting to the grids is accomplished by the current-detection circuit shown in Fig. 10-11. Only motors No. 2 and 4 are shown, since this circuit is actuated at the braking grids for motor No. 2. The voltage drop across the grid of motor No. 2 is applied to divider resistors BKER1 and BKER2. A small current proportional

BKT-2, BKMR, RD9, R44, RD15, BKT, BR1, the XB wire, and back to the load pot LCP and then to the N wire.

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to grid (armature) current flows from the midpoint of the two braking grids through VCR, R28 and to the junction of BKER1 and BKER2 resistors. This current, controlled by resistor R28, recalibrates the voltage-measuring reactor. As the armature current increases, the control current in the voltage-measuring reactor winding increases. This causes the current in the voltage-measuring reactor signal (a-c) winding to increase. As in motoring, when this current exceeds the reference current already flowing in the voltage-measuring reactor and the current-measuring reactor, the excess current flows through the pulse-width modulator and reduces the excitation so that grid (armature) currents are held within limits. These limits are increased with each increased throttle handle position, giving control of braking effort. Braking overvoltage (open-field) protection is accomplished by a pulse-width modulator winding connected to the GA wire across resistor R41. The voltage drop across the pulse-width modulator is limited to 1.4 volts by diodes RD24, RD25, RD26, and RD27.

## Excitation Summary

The primary component in the excitation system is the pulse-width modulator which determines the length of time that field transistor FT1 is turned on during each oscillator pulse. As shown in Fig. 10-5, the pulse-width modulator has one a-c winding excited by the oscillator transformer secondary, and four gate, or d-c, windings. Rectified pulses from the a-c winding of the pulse-width modulator control the "on" and "off" time for the field transistor. The "on" time, or pulse width, is established by the combined results of the currents in the gate windings.

1. Current in a pulse-width modulator gate winding that FLOWS FROM THE DOT THROUGH THE WINDING produces an excitation "turn-on" effect in the a-c winding. This increases the length of time that transistor FT1 conducts during each pulse to allow more current to pass through the exciter field.

2. Current in a pulse-width modulator control winding that FLOWS THROUGH THE WINDING TOWARD THE DOT produces an excitation "turn-off" effect in the a-c winding. The conduction time of transistor FT1 is reduced during each pulse, thus reducing the average current flow in the exciter field.

3. Net excitation, or the excitation at any point in time, is the combined effect of all the "turn-on" and "turn-off" currents in the control windings of the pulse-width modulator.

## WHEEL-SLIP CONTROL

The wheel-slip control protects against motor damage due to overspeeding caused by loss of adhesion during motoring. It also protects against wheel slides resulting in flat spots during dynamic braking or a locked axle by operating the wheel-slip warning in the cab.

There are three systems of detection:

1. Differential detection

This compares the difference between the rotating speed of one axle against the others. If the designed permissible limits of difference are exceeded, a correction signal is actuated.

The output of each alternator is fed into the wheel-slip detection panel (WSP). Here, the frequency signal is converted to a voltage signal. This is accomplished by saturating transformers ET1 through ET4, each of which is loaded through a resistor and a potentiometer. The potentiometers are factory adjusted to obtain equal voltage at each brush arm for equal axle speeds.

Each potentiometer output is connected to a rectifier network and a transistor circuit. The only time that current flows through the rectifier and transistor is when



there is sufficient difference in axle-alternator speeds. When sufficient speed differential exists, the transistor conducts current through its collector circuit to energize a sensitive relay (SSR) and energize the winding of the pulse-width modulator reactor (PWM). The differential in axle speeds necessary to actuate the detection circuit varies over the speed range of the locomotive.

The sensitivity must be decreased at higher speeds because of possible variations in wheel diameter. This is accomplished by voltage across another secondary winding of transformer ET2. Voltage across this winding increases with locomotive speed, and decreases the sensitivity of detection as speed increases.

When relay SSR operates, it energizes the wheel-slip relay. Also, the winding of pulse-width modulator PWM energized at this time will reduce excitation. When wheel-slip relay WSR closes, it "drains off" current from the reference circuit through the MSR rheostat. This reduces excitation by lowering the reference current.

2. Acceleration Rate Detection

The differential detection system will detect a difference in axle speeds so that a slipping or sliding axle condition can be corrected. However, if all of the wheels break adhesion at the same time and slip at the same speed, this condition would not be detected by the differential detection system. A synchronous slip with all wheels slipping at the same time and the same speed is accompanied by a sudden rise in acceleration rate. This sudden rise in acceleration provides the means of detection since it changes the charge level on capacitor C2. During steady-state conditions, capacitor C2 is charged to a level corresponding to the saturable-transformer secondary voltages. A sudden rise in acceleration provides an increase in the secondary voltage of the transformers and an increase in the charge level of capacitor C2. The capacitor receives its charging current through the base-to-emitter circuit of transistor ST. This turns on the transistor and provides a wheel-slip detection.

3. High-Speed Synchronous Slip Detection

At high locomotive speeds, all of the wheels can slowly lose adhesion and accelerate to a speed high enough to damage the traction motors. This slowly accelerating synchronous slip can not be detected by the differential or acceleration-rate detection system. Therefore, another system is used to detect this overspeeding condition. A connection is made from the brush arm of the potentiometer of the number 2 transformer to a Zener diode-transistor combination. When overspeeding takes place, current flows out of potentiometer P2 and through a calibrating Zener diode, into the base and out the emitter of transistor SST, and back into the center tap of transformer ET2. Transistor SST now conducts current from potentiometer P1, through resistor R6 and back to the center tap of transformer ET1. This loads transformer ET1 so that its voltage decreases enough to unbalance the detection bridge. It has the same effect as a slower rotating, or locked, number one axle. The unbalance in the detection bridge causes a wheel slip detection.

## WHEEL-SLIP CORRECTION

When wheel-slip relay WSR picks up, it energizes the automatic-sanding magnet valve (ASMV). This action turns air into a 435 cubic-inch reservoir, and delivers sand to the rails. Since the reservoir builds up to 60-psi pressure in about four seconds, a pressure switch closes and turns on the wheel-slip indicating light. Also, at this time, another set of contacts on the wheel-slip relay closes and connects a current shunt across the reference circuit. This shunt causes a sudden decrease in reference current so that it will be at a value less than that of ACCR current. As a result of this, current now flows through the pulse-width modulator gate winding to reduce excitation. When current flows through sensitive relay SSR, it also energizes another gate winding of the pulse-width modulator. This directly reduces excitation by turning off the pulse-width modulator.



## POWER MATCHING

As shown on the broken line of the load characteristic curve on Fig. 10-13, the horsepower is reduced at 2300 amperes and 1025 volts. This power matching is accomplished by the power matching Type 17FL24 panel and is effective in series-parallel motor connections. The load gate winding of ACCR reduces the reactance in the ACCR control winding in series with the power matching panel (PMP) (see Fig. 10-8, Section D1). This increases the current flow on the secondary of PMP transformer and puts a forward bias on transistor T1. The circuit is calibrated by Zener diodes ZD1 and ZD2, rheostats R26 and RRAR, also potentiometer PRAP. When transistor T1 conducts it forms another path for current through the turn-off winding of ACCR (E to F) by way of the APX wire. This added turn-off signal reduces excitation and horsepower falls as shown on the broken line characteristic curve of Fig. 10-13.

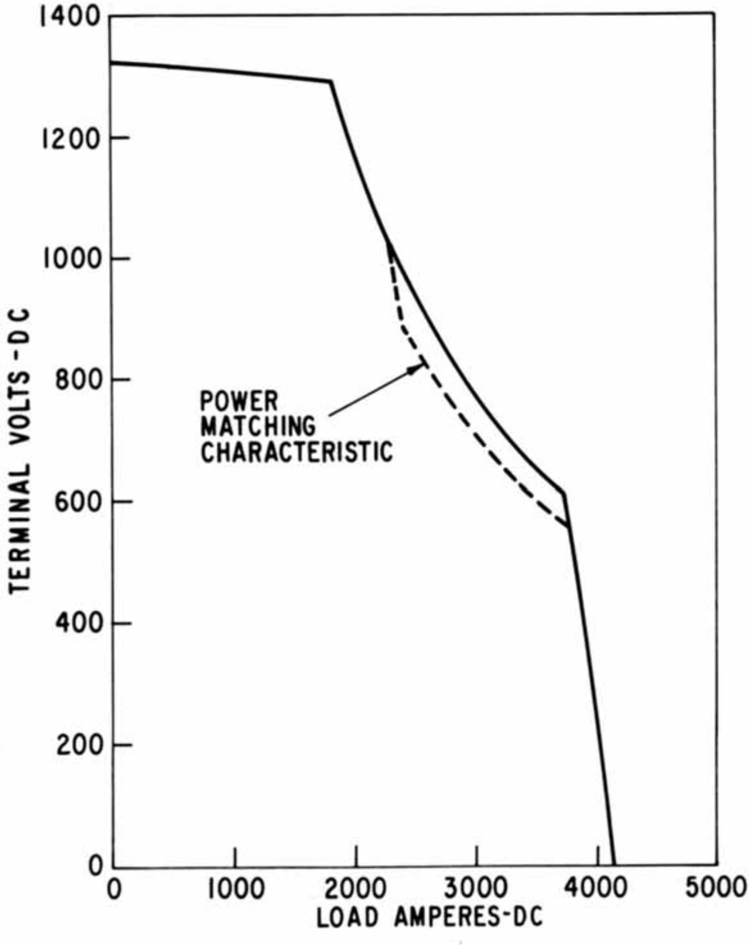


Fig. 10-13 (E-15065)

*Fig. 10-13. Power matching*