GEJ-3849A

EDUCATIONAL MANUAL

MODEL U30
DIESEL-ELECTRIC LOCOMOTIVE

GENERAL ELECTRIC

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DIESEL-ELECTRIC LOCOMOTIVE

TRANSPORTATION SYSTEMS DIVISION

GENERAL ELECTRIC

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LOCOMOTIVE DATA

MAJOR EQUIPMENT

	U30B	U30C
Air-brake System	26L	26L
Air Compressor (Gardner-Denver)	WBO-9500 Series	WBO-9500 Series
Air Compressor (Wabco)	3 CWDL	3 CWDL
Traction Motors	GE-752	GE-752
Main Alternator	GTA9	GTA9
Auxiliary Generator	GY-27	GY-27
Exciter	GY-27	GY-27
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
Starting Motor (2 per locomotive) (Leece-Neville)	Navy Type D	Navy Type D

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	300 gal	300 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	48 cu ft	48 cu ft
Main Air Reservoirs	56,000 cu in.	56,000 cu in.
Oil-bath Air Filters	10 gal	10 gal

LOCOMOTIVE DATA

BRAKE SYSTEM ADJUSTMENTS

	U30B	U30C
Brake-cylinder Piston Travel (Minimum)	2-1/2 in.	3/4 in.
Brake-cylinder Piston Travel (Maximum)	6 in.	4 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
(Dual Contact)		
(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
Regulating Valve	Variable	Variable
Independent Brake Valve (Full Service)	Variable	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

Diesel Engine (Idle)	400 ± 15 rpm	400 ± 15 rpm
Diesel Engine (Full Speed)	1025 ± 4 rpm	1025 ± 4 rpm
Overspeed-shutdown Trips	1130 ± 10 rpm	1130 ± 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

LOCOMOTIVE DATA

OPERATING SETTINGS

	U30B	U30C
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)	170-190 F	170-190 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

DIESEL-ENGINE SYSTEMS PRESSURE VALVES

Fuel-oil Supply Line (Relief Valve)	75 psi	75 psi
Fuel Header to Metering Pumps (Idle)	35 psi	35 psi
Lubricating-oil Pump Pressure-relief Valve (Begins to Open)	135 psi	135 psi

LOCOMOTIVE DATA

WEIGHTS
(Approximate for Lifting Purposes Only)

	U30B	U30C
Complete Locomotive (Fully Serviced) (Basic with 1700-gallon Fuel Tank) . . .	254,500 lb	-
Complete Locomotive (Fully Serviced) (Modified with 3250-gallon Fuel Tank) . . .	270,000 lb	-
Complete Locomotive (Fully Serviced) (Basic with 3000-gallon Fuel Tank) . . .	-	360,000 lb
Complete Locomotive (Fully Serviced) (Basic with 4000-gallon Fuel Tank) . . .	-	370,000 lb
One Truck (Complete	43,000 lb	60,000 lb
One Truck Frame	6,050 lb	10,200 lb
One Truck Bolster	1,475 lb	5,200 lb
One Spring Plank	390 lb	-
One Motor, Wheel, and Axle Assembly.	11,600 lb	11,600 lb
Traction Motor (Less Gear Case).	7,000 lb	7,000 lb
Air Compressor (Dry) (Gardner-Denver, if used). .	1,590 lb	1,590 lb
Air Compressor (Dry) (Wabco, if used)	1,575 lb	1,575 lb
One Battery Tray	300 lb	300 lb
Engine Hood Assembly (Not Including Radiator Hood) . .	4,150 lb	4,150 lb
Fan Gear Unit	860 lb	860 lb
Radiator Fan	340 lb	340 lb
Compressor Drive-shaft and Hubs	280 lb	280 lb
Each Radiator Section	310 lb	310 lb
Equipment Blower	1,106 lb	1,106 lb
Lube Oil Cooler (Dry)	850 lb	850 lb
Lube Oil Cooler (Wet)	1,010 lb	1,010 lb
Engine and Alternator (Complete)	60,410 lb	60,410 lb

LOCOMOTIVE DATA

	U30B	U30C
Lube-oil Filter (Including New Element) (Dry)	660 lb	660 lb
Lube-oil Filter (Including New Element) (Wet)	1,060 lb	1,060 lb
Main Alternator with Auxiliaries	16,695 lb	16,695 lb
Auxiliary Generator and Exciter	690 lb	690 lb
Engine (Less Alternator)(Dry)	43,510 lb	43,510 lb
Engine Component Parts		
Main Frame (Bare)	11,800 lb	11,800 lb
Crankshaft	3,950 lb	3,950 lb
Turbocharger	1,425 lb	1,425 lb
Intercooler (Dry)	660 lb	660 lb
Cylinder (Complete)	760 lb	760 lb
Piston and Master Rod Assembly	207 lb	207 lb
Piston and Articulating Rod Assembly	94 lb	94 lb
Oil Pump	350 lb	350 lb
Water Pump (with Gear)	280 lb	280 lb
Control Governor	112 lb	112 lb
Governor Drive Assembly	159 lb	159 lb
Oil Pan	1,050 lb	1,050 lb
Free-end Cover	1,350 lb	1,350 lb
End Cover (Alternator End)	80 lb	80 lb
Exhaust Manifold	630 lb	630 lb

LOCOMOTIVE DESCRIPTION

GENERAL

The General Electric, Model U30, 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 in a minimum of time. It is equipped with cast-iron pistons and the 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 cooling system is pressurized, and a spring-loaded relief cap on the fill opening discharges to a vent line. 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.

ENGINE STARTING

Two 36-volt starting motors, connected in series, are mounted on the engine. An inertial-type pinion engagement rotates the ring gear on the alternator rotor during the starting period. An arrangement is provided to protect against excessive torque demands.

ELECTRIC TRANSMISSION

TRACTION ALTERNATOR

The GTA9 traction alternator is a 12-pole, rotating-field, three-phase, "Y"-connected, separately excited, a-c machine.

The traction alternator converts mechanical energy into a-c electric power. The alternating current is rectified to power the locomotive d-c traction motors.

Principal parts of the alternator are the stator, rotor, framehead, and bearing.

The alternator is a single-bearing machine which is overhung-mounted on the diesel engine. The drive end of the rotor is bolted to the crankshaft. The crankshaft supports one end of the rotor and the other end is supported by a roller bearing. A gear unit, exciter, and auxiliary generator are mounted on the collector-ring end of the alternator.

The operating principle of the alternator is as follows: The d-c output of the GY-27 exciter energizes the alternator field windings on the rotor, to set up a rotating magnetic field. This rotating field causes a-c to be induced in the alternator stator windings. The a-c from the stator windings is then rectified (full wave) by panel-mounted rectifiers, and the resulting d-c drives the d-c traction motors on the locomotive. A schematic diagram of the alternator is shown in Fig. 2-1, and the arrangement of the accessories is shown in Fig. 2-2.

LOCOMOTIVE DESCRIPTION

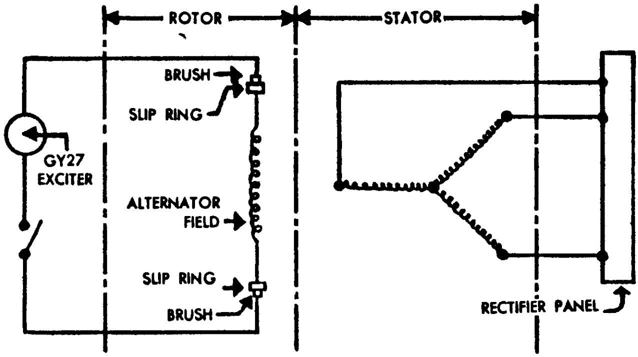

Fig. 2-1 (E-14670)

Fig. 2-1. Schematic diagram, alternator

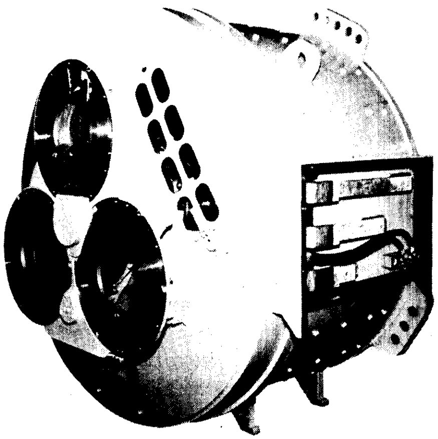

Fig. 2-2 (E-12761)

Fig. 2-2 Accessories mounting arrangement

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 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-27 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 flash-over), 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, reverse, and selector levers.
Engine Start push button. Engine Stop push button.
Brake valves.
Sander valve. Bell ringer valve. Air horn valve.
Window wiper.
Circuit breakers and switches.
Emergency Engine Stop 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.

LOCOMOTIVE DESCRIPTION

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:

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.

LOCOMOTIVE DESCRIPTION

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 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.

LOCOMOTIVE DESCRIPTION

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.

LOCOMOTIVE DESCRIPTION

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 insulated and 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.

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* Registered trade-mark

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.

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 on the air plennum which separates the engine cab from the radiator cab. Access is through doors in the radiator cab located opposite the air filter. The air filter consists of an inertial-type air cleaner.

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.

LOCOMOTIVE DESCRIPTION

UNDERFRAME

The underframe is fabricated of low-alloy steel sections and plate. The centerplate bolster of these trucks 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 plate, 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 cast 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.

DIESEL ENGINE
DESCRIPTION & SPECIFICATIONS

COMPONENT LOCATION TERMS

The following terms will be used throughout this manual, in locating various components on the engine. (See Figs. 3-1 and 3-2.) 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.

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

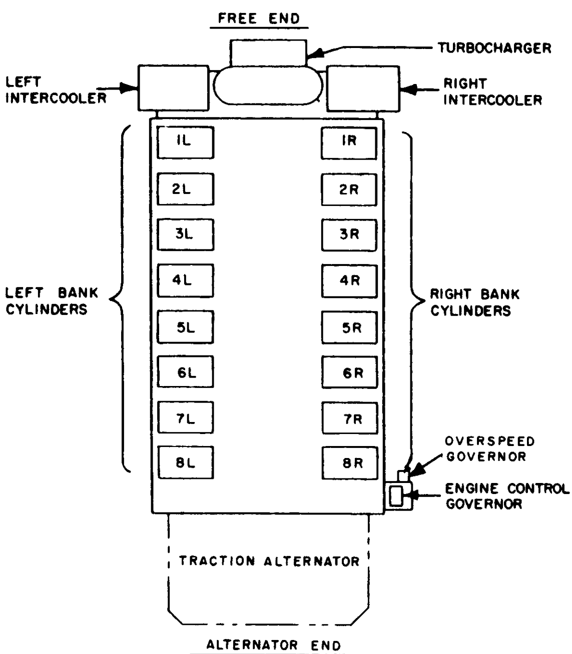

Fig. 3-1 (E-10028B)

Fig. 3-1. Schematic overhead view of engine

DIESEL ENGINE
DESCRIPTION & SPECIFICATIONS

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
Idle Speed	400 rpm
Firing Order	1R - 1L - 3R - 3L - 7R - 7L - 4R - 4L 8R - 8L - 6R - 6L - 2R - 2L - 5R - 5L
Turbocharger	Single
Engine Dimensions	
Height (Over-all Including Stack)	9 ft 1 in.
Length (Over-all Including Alternator)	21 ft 8 7/16 in.
Width (Over-all)	5 ft 8 1/2 in.
Weight (Including Alternator)	60,410 lb

LUBRICATING OIL SYSTEM

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 there are 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 flow. (See Fig. 4-1.)

1. Engine crankcase
2. Pump
3. Relief valve
4. Filter
5. Cooler
6. 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. Two oil-fill openings, one on each side of the crankcase, are sealed by expandable plugs. The dipstick (left side of the engine) is used to measure the crankcase oil level.

LUBRICATING OIL SYSTEM

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.

OIL FLOW INSIDE THE ENGINE

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 two orifices and back to the cylinder.

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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.

LUBRICATING OIL SYSTEM

The oil then flows upward through the valve push-rods to supply lubrication to the working valve 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 SYSTEM

LUBRICATING OIL

Heavy-duty lubricating oil must be used. This oil should be a neutral mineral-oil compound, with suitable additives to provide a non-corrosive stable lubricant which is resistant to oxidation and the formation of acid and sludge. When the oil is changed, the engine should require no further cleaning. The additives should also control foaming.

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.

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 discharges excess fuel back to the tank. Fuel discharged by the booster pump flows to a large, single-element, primary 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 OIL SYSTEM

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, then crosses over by the turbocharger and supplies the injection pumps on the right bank.

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. Two vent pipes vent the tank to atmosphere.

The electrically operated, emergency fuel cut-off system is arranged with three emergency trip switches, one located near each tank fill opening and one in the operator's cab. 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.

COOLING WATER SYSTEM

DESCRIPTION

COMPONENTS

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

The cooling system consists of the following principal components:

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 panels
8. Cab heaters
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. Two fill openings, equipped with spring-loaded caps, are located near the top of the water-storage tank. The openings are situated to allow water to be added to the tank from either side of the locomotive. (See Fig. 6-6.)

COOLING WATER SYSTEM

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 flexible couplings.

The engine intercoolers, which remove heat from combustion air, are constructed with a fabricated-steel case enclosing a fin and a tube-type 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.

COOLING WATER SYSTEM

Water is supplied to the cab heater by a pipe connected to the outlet-water header on top of the engine. Water 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 is 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 flexible 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. 6-6.)

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.

COOLING WATER SYSTEM

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 must be kept clean and within proper limits of alkalinity, hardness, and inhibitor concentration.

FILLING THE SYSTEM
(See Fig. 6-1)

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.*

COOLING WATER SYSTEM

Fig. 6-1 (E-11809)

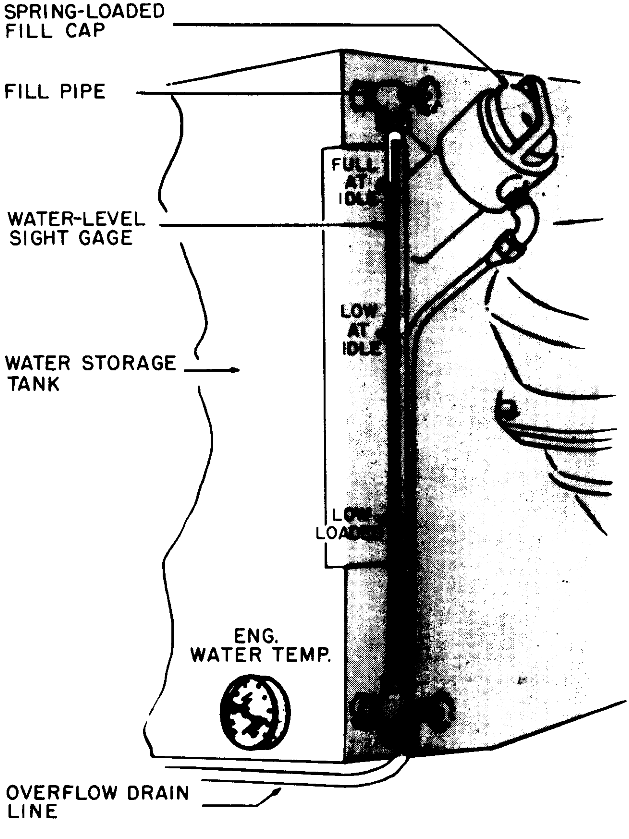


Fig. 6-1. Water-level sight gage

COOLING WATER SYSTEM

CAUTION: *DO NOT OPERATE THE LOCOMOTIVE IF THE WATER SUPPLY DROPS BELOW THE LEVEL MARKED "LOW AT IDLE" OR "LOW LOADED" ON THE SIGHT GAGE. THE ENGINE MAY OVERHEAT AND BECOME DAMAGED IF OPERATED WITH THE WATER BELOW THE INDICATED LEVELS. ADD TREATED WATER TO THE PROPER LEVEL WITH THE ENGINE IDLING.*

DRAINING THE SYSTEM (See Fig. 6-6)

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 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.*

FLOW-CONTROL VALVE

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 opening in the water-storage tank, and is connected to the engine by a single pipe, and to the radiator sections by two pipes. Three removable covers permit access to the control valves 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 tap is provided in the rectangular cover, to permit installation of a temperature test gage.

VALVES WITHIN THE CASE

Thermostat Valves

The thermostats function as two-way valves. When the water temperature is below their operating point, as in Fig. 6-2 (A), they pass the water directly through their cylindrical skirts 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 inter-

COOLING WATER SYSTEM

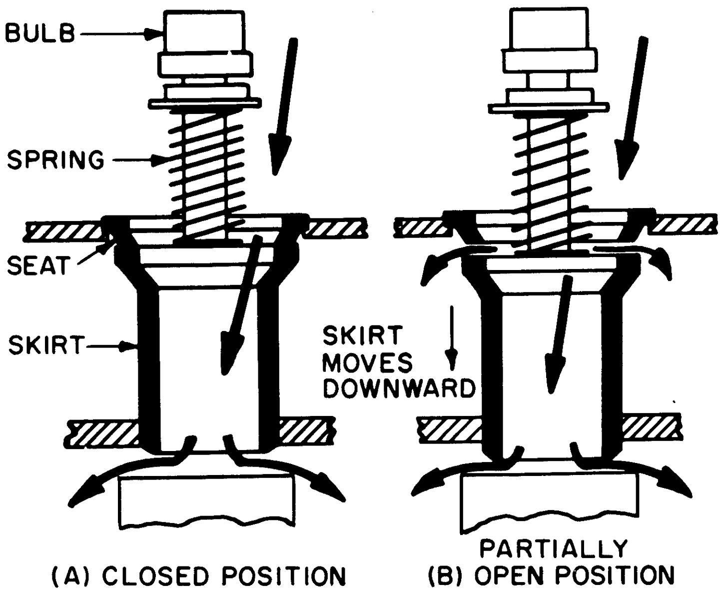


Fig. 6-2 (E-9989)

Fig. 6-2. Operation of thermostats

changeable. 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.

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 accomplished this purpose.

COMBINED OPERATION

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

COOLING WATER SYSTEM

1. When minimum engine cooling is required (Fig. 6-3):

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

2. When partial engine cooling is required (Fig. 6-4):

   As the engine discharge water temperature rises, the thermostats begin to operate. Downward movement of the skirts partially restricts water flow to the tank. At the same time, openings at the top of the lower 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 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 cooling demands are now satisfied, and water temperature remains approximately constant, no changes in valve position take place. Small variations in cooling requirements are satisfied by slight opening or closing of the thermostats to modulate the flow.

COOLING WATER SYSTEM

If 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 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.

3. When full engine cooling is required (Fig. 6-5):

   If, with valve V_1 open, 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 the pressure 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 radiator sections, resulting in maximum cooling by the system. As before, small variations in cooling requirements are satisfied by slight opening or closing of the thermostats to modulate the flow.

4. When engine cooling requirements decrease:

   When 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.

COOLING WATER SYSTEM

When valve V_2 closes, the flow of water to 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.

COOLING WATER SYSTEM

CAUTION: *DO NOT SET THE SWITCH ON THE LOCOMOTIVE BY COVERING THE RADIATOR INLET SCREENS. 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 205 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. If necessary, reset the switch to obtain the proper opening and closing values.

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 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 instructions.)

COOLING WATER SYSTEM

RADIATORS
(See Fig. 6-6)

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 side.

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 flexible fittings, to permit easy removal.

Cooled water flows from the radiator sections through their respective drain header pipes to the water storage tank.

AIR SYSTEMS

DESCRIPTION

LOCOMOTIVE AIR SYSTEM (See Fig. 7-4)

Air enters the locomotive through a screened inlet. The incoming air passes through the equipment blower and into the platform. Part of the air moves to the front of the locomotive, passing through an air cleaner. This cleaned air is supplied to the control compartment, to the operator's cab through the cab heater, and to the front traction motors. The remaining air moves toward the rear of the locomotive, and is cleaned by another air cleaner. The cleaner at the rear of the locomotive supplies ventilating air to the rear traction motors and extended-range dynamic-braking compartment when used. Another air cleaner, located in the platform directly below the alternator, supplies cleaned air to the alternator, the auxiliary generator, the exciter, and to the engine cab for pressurization. As shown in Fig. 7-1, the equipment air cleaner consists of 14 panels, with 54 individual tubes in each panel. Each tube is a miniature cyclonic dirt separator, see Fig. 7-2. Incoming air enters the tubes through vanes, swirling the air. Dirt particles, being heavy, go to the outside and eventually leave the far end of the outer tube. The cleaned air from the central portion is collected and separately directed from the cleaner. The bleed air carries the dirt from the cleaner and discharges directly under the locomotive in each case.

As shown in Fig. 7-1, a small opening at the bottom of each panel permits the separated dirt and bleed air to escape.

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 0.00004 of an inch.)

The ventilating air passes through the main air duct of the locomotive, formed by enclosing the space between the sills, top and bottom, with metal plates welded air-tight.

AIR SYSTEMS

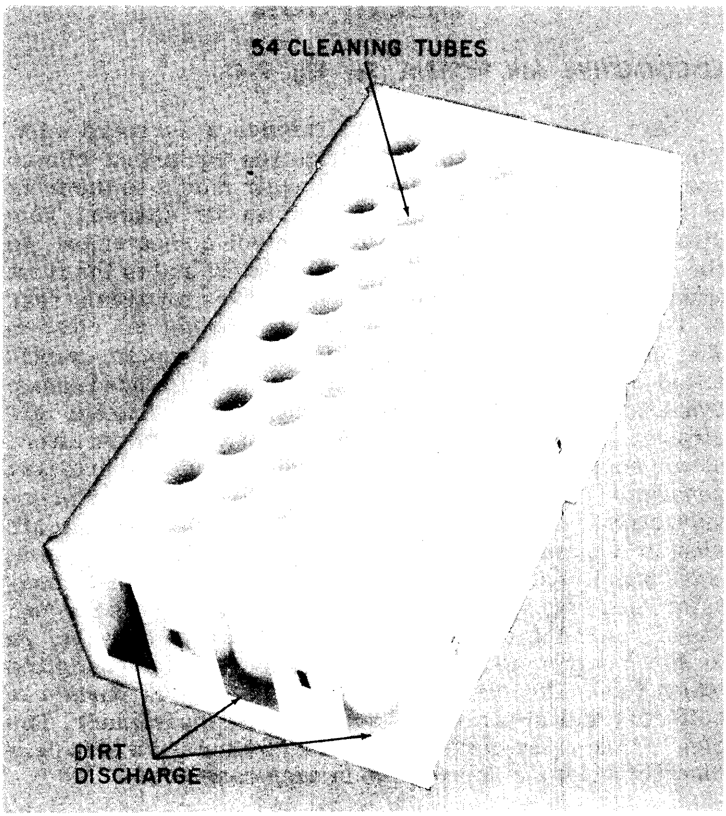


Fig. 7-1 (E-14921)

Fig. 7-1. Equipment air cleaner

AIR SYSTEMS

Fig. 7-2 (E-13565)

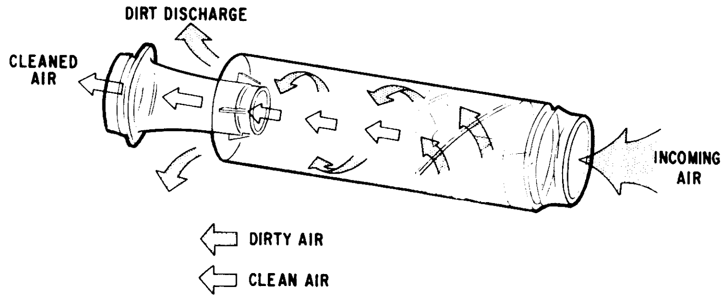


Fig. 7-2. Equipment and engine air cleaner tube

ENGINE AIR SYSTEM

Air enters the side of the radiator cab through screened inlets. Part of the air goes to the engine air-cleaning system. The engine air cleaner consists of six air-cleaner assemblies mounted to the engine air plenum. Each of these assemblies consists of a centrifugal air cleaner fastened to an oil-bath filter. (Shown in Fig. 7-4.)

The centrifugal air cleaner (Fig. 7-1) is the same unit as previously referred to in "Locomotive Air System." Here it is supported by the oil-bath filter, and provides preliminary cleaning of all engine air. The evacuation of dirt from the air cleaner is accomplished through an aspirator in the exhaust stack of the turbo-charger. At the lower engine speeds, supplemental air is provided from the patform air duct. A bleed-air damper will prevent the reverse flow of bleed-air during adverse operating conditions.

When the diesel engine is running at low speed, all air entering the oil-bath filter assembly from the centrifugal cleaner 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

AIR SYSTEMS

this oil, draining back to the reservoir at the bottom, that washes away dirt particles trapped by the wet filter screen. The quantity of dirt collected here is comparatively small due to the previous cleaning of the air by the preliminary centrifugal-type air cleaner.

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

The turbocharger, driven by engine exhaust, compresses the air for delivery through intercoolers (where part of the heat of compression is removed) and butterfly valves, to the sectional air-intake manifolds on each side of the engine.

The diesel-engine exhaust system consists of seven interchangeable main pipe sections, and a transition section connecting them to the turbocharger. There are left-hand and right-hand elbows connecting each cylinder to the main exhaust header. All components in contact with the exhaust gas are of austenitic stainless steel, and are assembled with split, vee-grooved, clamping rings. The large end of the transition section is connected directly to the turbine inlet casing, and the rear of the manifold is closed off with a separately supported end-closure which takes the rear thrust loading. The left-hand and the right-hand elbows are connected to the exhaust ports of the individual cylinders by gasketed flange fittings, and to the pipe sections (with an adjustable joint) by vee-grooved clamping rings. This joint is designed with a metal-to-metal seal, arranged so that sealing pressure increases with temperature. The main joints are designed with conventional spiral-wound metal-asbestos gaskets and, again, the pressure sealing increases with rising temperature. The increased sealing pressure is obtained by the use of metals with different thermal expansion rates. Any manifold section may be replaced without the removal of the adjacent sections and without the removal of the water discharge header. See Fig. 7-3.

Fig. 7-3 (E-13438)

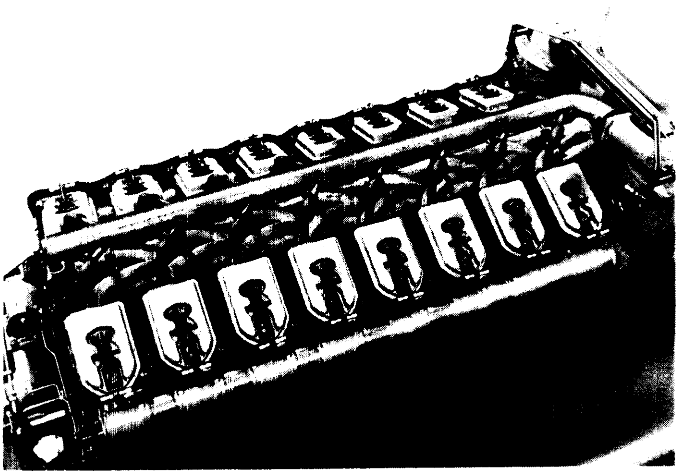


Fig. 7-3. Exhaust manifold arrangement (single pipe)

OVERSPEED SYSTEM

OVERSPEED AND FUEL CONTROL DEVICE

GENERAL APPLICATION

The overspeed and fuel control device 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 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 and is cast with one open 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).

OVERSPEED SYSTEM

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

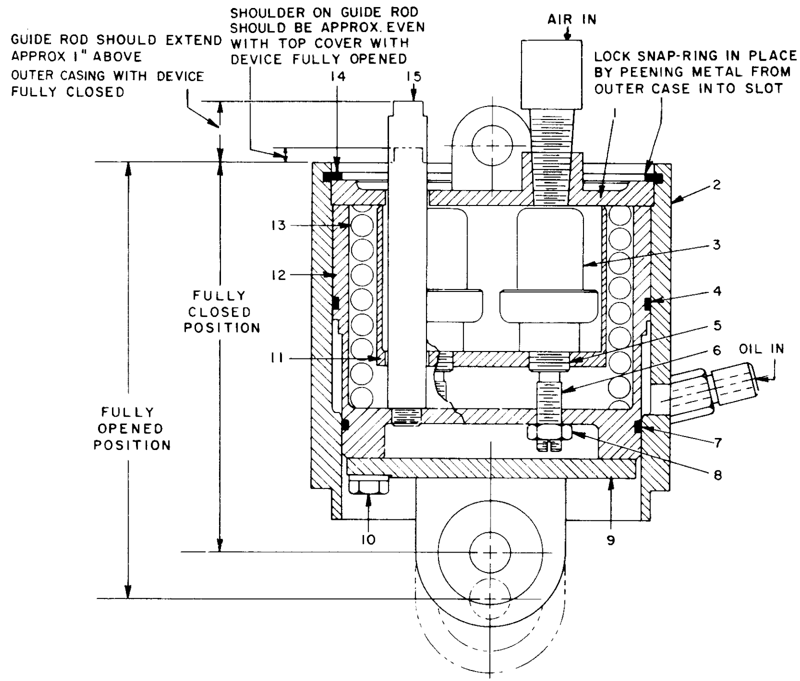


Fig. 8-1. Cutaway view of overspeed and fuel control device

Fig. 8-1 (E-14949)

OVERSPEED SYSTEM

Fig. 8-2 (E-14950)

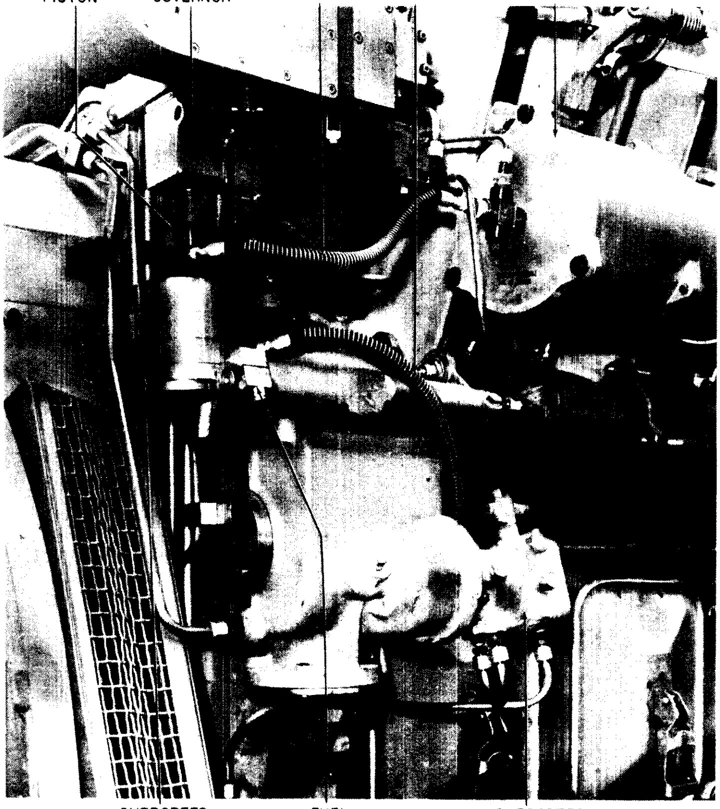


Fig. 8-2. View of overspeed and fuel control device mounted on engine

OVERSPEED SYSTEM

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 SYSTEM

INSPECTION

At prescribed intervals, perform the following inspection of the overspeed and fuel control device:

1. Check to ensure that the air inlet and oil line inlet connections are tight and leak free.

2. Check to ensure that the inner casing moves freely from its fully closed to fully open position.

3. With the engine running (device in fully closed position), check that the guide rod extends above the outer casing top cover approximately 1 1/4 inches.

4. Stop the engine and observe fuel linkage movement to ensure that it is sufficient to shut off fuel to injection pumps.

5. If conditions 2, 3, and 4 above are not met, check the output oil pressure at the overspeed governor. This pressure should be 200 psi. Also, inspect for failed "O" ring seals.

OVERSPEED GOVERNOR

DESCRIPTION
(See Fig. 8-3)

The overspeed governor contains the following components:

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

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.

OVERSPEED SYSTEM

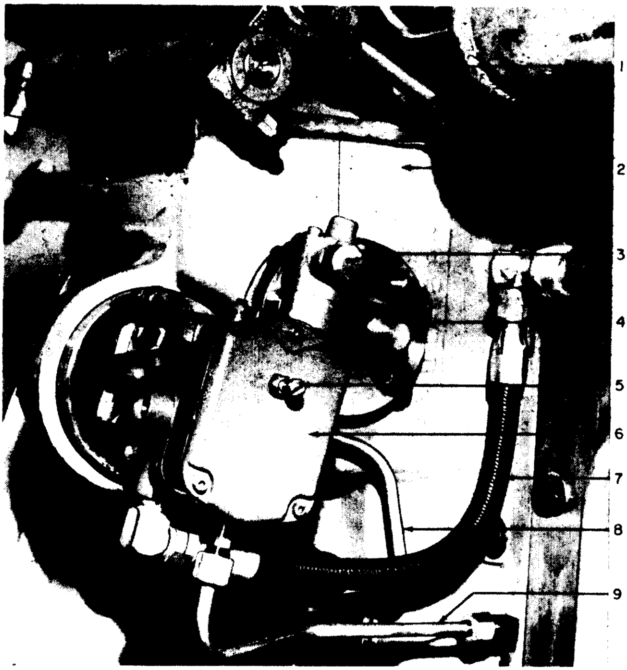


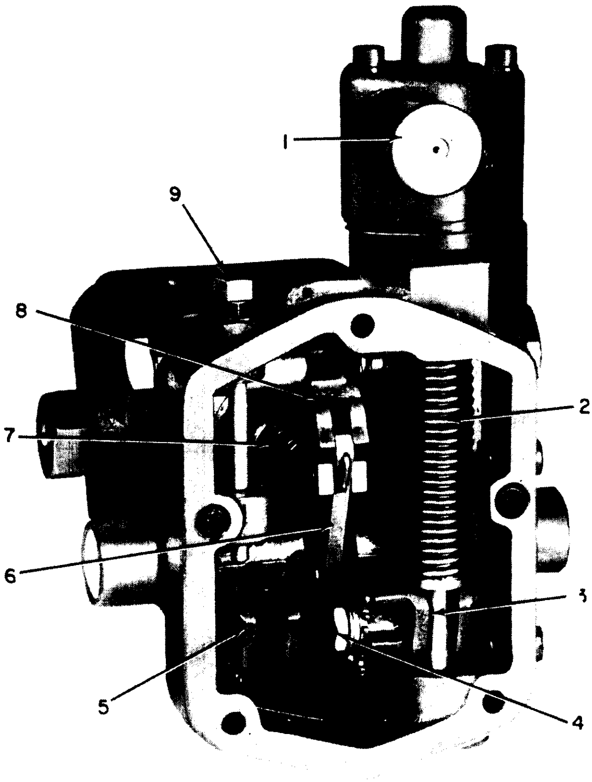
Fig. 8-3 (E-13455A)

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

OVERSPEED SYSTEM

Fig. 8-4 (E-9725B)



1 Reset button
2 Reset spring
3 Overspeed lockout rod
4 Speed droop adjustment (set at 50 percent 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

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. 3 and Fig. 4 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 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 section on 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.

OVERSPEED SYSTEM

NOTE: *Before resetting, attempt to find cause of tripping and take 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.

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
(See Figs. 9-1 and 9-2)

The master controller is a set-up switch, used by the operator to control the locomotive. It has a throttle handle, a selector handle, and a reverse 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.)

THROTTLE HANDLE

The throttle handle has an IDLE position and eight major and eight intermediate positions or notches. Major notches are registered by a number. Intermediate notches are registered by a dot or 1/2 mark. This handle controls tractive effort when motoring, and controls braking effort when dynamic braking is being used.

OPERATING INFORMATION

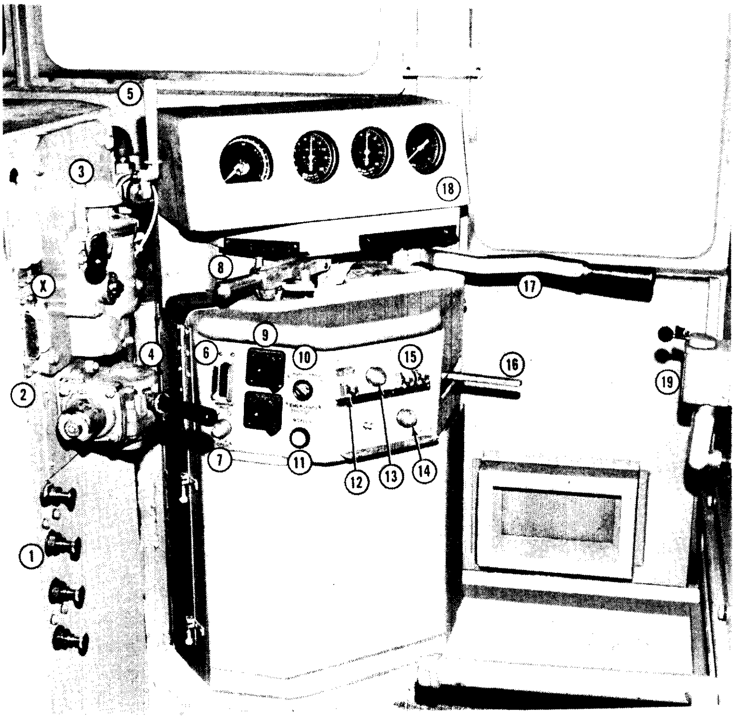


Fig. 9-1 (E-13526)

1 Bell ringer and window wipers	10 Emergency shutdown switch
2 Air regulating valve (back of brake stand)	11 Call button
3 Automatic brake valve	12 Power limit switch
4 Independent brake valve	13 Brake warning light
5 Horn valve	14 Wheel slip light
6 Generator-field circuit breaker	15 Light switches
7 "PCS OPEN" light	16 Reverse handle
8 Selector handle	17 Throttle handle
9 Headlight switches	18 Instrument panel
	19 Sander control
	X Optional circuit breakers

Fig. 9-1. Engineman's position

OPERATING INFORMATION

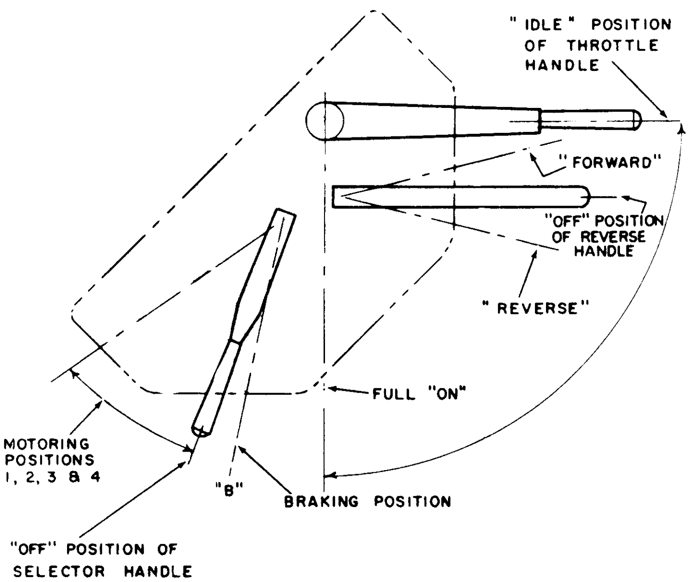


Fig. 9-2. Master controller handle position

Fig. 9-2 (E-10102A)

REVERSE HANDLE

The reverse handle has three positions, FORWARD, OFF, and REVERSE. It is used to control the direction of locomotive movement.

SELECTOR HANDLE

The selector handle has positions 4, 3, 2, 1, OFF and B. The numbered positions are used when motoring. Position B is used when in dynamic braking.

In ordinary operation, since all U30 locomotives are equipped with automatic transition, the selector handle may be placed in Position 1 during motoring and left there.

OPERATING INFORMATION

Positions 2, 3, and 4 are used to provide transition for any locomotive units which are in multiple operation and are not equipped with automatic transition. Handle movement is governed by transition speed of other locomotive units in the consist.

INTERLOCKING BETWEEN HANDLES

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

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

2. The reverse handle cannot be moved unless the selector handle is in the OFF position or position 1, and throttle handle is in the IDLE position.

3. The throttle handle cannot be advanced from the IDLE position unless the selector handle is in position 1, 2, 3, 4, or B.

4. The throttle handle can be moved with the reverse handle in any position.

5. The selector handle cannot be moved into the B position (braking) unless the throttle handle is in the IDLE position, and the reverse handle is in the FORWARD or REVERSE position.

DEVICES ON MASTER CONTROLLER HOUSING

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 the STOP position, the diesel engines on all units in multiple-unit locomotive consist will shut down.

OPERATING INFORMATION

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

After an emergency shut-down, 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 operated 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 the NOTCH 7 position, 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

a. Front headlight switch

b. Rear headlight switch

c. Step lights switch

d. Gage lights and dimmer control switch

OPERATING INFORMATION

Call Button

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

Wheel-slip Light

This light indicates when a pair of wheels is slipping.

"PCS OPEN" Light

This 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.

ENGINE CONTROL PANEL (See Fig. 9-3)

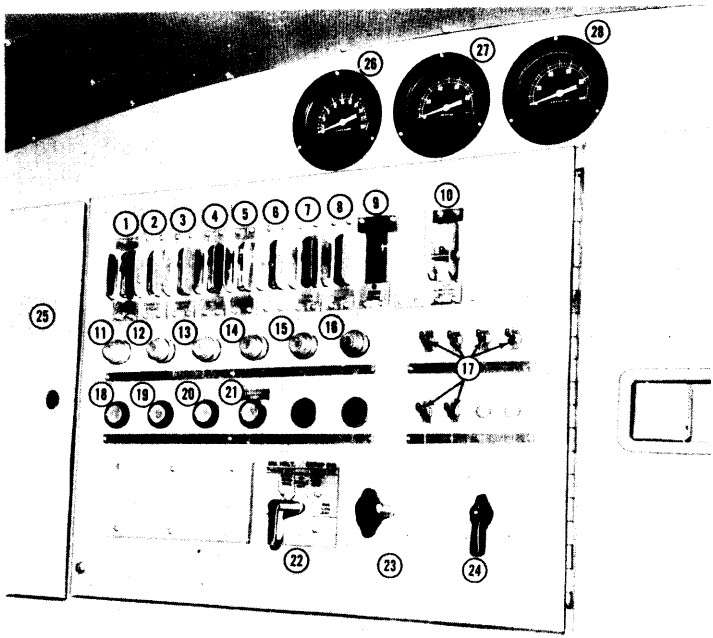
The engine control (EC) panel is located on the rear wall of the operator's cab. Mounted on this panel are various other switches, circuit breakers, and operating devices used during locomotive operation.

ENGINE CONTROL SWITCH

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.

OPERATING INFORMATION

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
23 Engine control switch
24 Motor cut-out switch 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

OPERATING INFORMATION

When the engine is running and the engine control switch 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 must be moved to the RUN position.

ENGINE START AND STOP BUTTONS

To start the diesel engine, depress the ENGINE START button firmly and hold 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 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 location of the locomotive unit in the consist, and whether the front of the locomotive unit is leading or trailing. These switch positions are as follows:

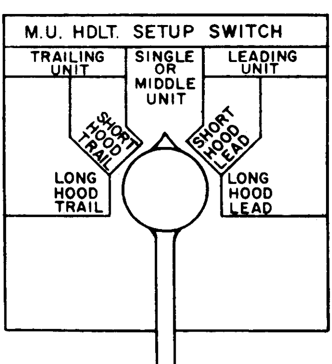


Fig. 9-4 (E-11960)

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

OPERATING INFORMATION

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.

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, 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.

OPERATING INFORMATION

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 Circuit Breaker – Isolates the battery-charging generator from the control system.

2. Running Lights Circuit Breaker (all lights except the headlights)

3. Headlights Circuit Breaker

4. Control Circuit Breaker

5. Fuel Pump Circuit Breaker

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 Switch

2. Rear Classification Lights Switch

3. Front Classification Lights Switch

4. Front Number Lights Switch

5. Rear Number Lights Switch

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

OPERATING INFORMATION

7. Slip-suppression Cut Out or Wheel-slip Cut Out - 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 in the ceiling over the helper's position.

5. Hand Brake - Located on the outside of the cab nose.

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 power removal.

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, and after any emergency fuel cut-off button has been depressed.

9. Cab Heater – Cab heat is regulated by turning the water 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, and the hand-operated lever for proper air flow.

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.

OPERATING PROCEDURE

The following information related to locomotive operation consists of condensed details. For a more specific procedure, refer to the Locomotive Operating Manual.

OPERATING INFORMATION

STARTING THE ENGINE

Before starting the engine, complete the necessary inspection and preparations required by railroad regulations. Then, proceed as follows, with the engine control switch in the START position.

1. Close the battery switch.

2. Close the following circuit breakers on the engine control panel.

   a. Control Circuit
   b. Charging Circuit
   c. Battery Negative
   d. Fuel Pump and Depress Reset Button
   e. Headlights
   f. Running Lights

3. After fuel pressure builds up, depress the engine start button on the engine control panel, and hold the button in until the engine starts (approximately 25 seconds).

NOTE: *If proper engine lube-oil pressure does not build up within approximately 40 seconds, the governor will shut off 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 PRELIMINARY PREPARATIONS FOR STARTING.*

4. After the engine starts, turn the engine control switch to the RUN position.

5. Before moving the locomotive, allow time for the cooling-water system to warm up in accordance with railroad regulations.

OPERATING INFORMATION

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 reverse handle to the desired direction.

5. Move the selector handle to Position 1. If any trailing units require manual transition, the selector handle for the trailing unit must then be moved to Positions 2, 3, and 4 at locomotive speeds required for transition on these units.

6. When equipped with a M. U. Braking Selector Switch (optional equipment), position the selector switch according to railroad rules.

7. Operate the locomotive in accordance with the 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 the TRAIL-24, or TRAIL-26, or TRAIL-6 positions).

Electrical Set-up

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

2. Place the selector handle in the OFF position. (Leaving the handle in Position 1 on the trailing unit prevents loading when in multiple with some type locomotives.)

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

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

5. 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 the 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; 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 reverser handle to the OFF position and remove the handle.

2. Place the selector handle in the OFF position.

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

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

5. 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 and move it to the RELEASE 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 INFORMATION

Operating Unit (Electrical Set-up)

1. Insert the reverser handle into the reverser of the master controller.

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

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

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

M.U. Braking Selector Switch (When Equipped)

This switch is mounted on the engine control panel. It has two positions: G. E. BRAKING and LOOP BRAKING, and should be set to correspond to the type of dynamic braking on each unit in the locomotive consist. If all units in the locomotive consist have G. E. excitation and dynamic-brake equipment, the M. U. braking selector switch must be set in the G. E. BRAKING position. If a U30 locomotive is leading in a mixed locomotive consist with one, two, or three locomotive units having dynamic-brake equipment requiring loop-braking circuit control, the selector switch must be set in LOOP BRAKING position on the lead unit only.

The selector switch should be set before leaving the terminal. Positioning must not be changed, even if the engine is isolated enroute. If locomotive units in the consist are changed enroute, then the position of this switch may have to be changed.

APPLYING DYNAMIC BRAKING

Dynamic braking applies 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 simultaneously.

OPERATING INFORMATION

NOTE: *On some locomotives, this switch may have several positions for "Loop Braking". Position the switch as required by railroad rules.*

Applying dynamic braking is accomplished in the following manner:

1. Move the throttle handle to the IDLE position.

2. Move the selector handle from position 1 to OFF to B.

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 the braking effort during the initial period of dynamic brake application.

CAUTION: *PROLONGED OPERATION OF DYNAMIC BRAKING IN 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 and with the speed. 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 warning stops.*

OPERATING INFORMATION

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 handle is moved to the EMERGENCY position, the dynamic brake is removed and air brakes on the locomotive and on the train go into emergency application.

CAUTION: *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 position B to OFF to 1.

OTHER OPERATING DETAILS

Wheel Slip (When Equipped with Wheel-slip Braking Feature)

When a slip occurs, a light independent air-brake application is made automatically. This may be observed by a fast flicker of the needle on the brake-cylinder air gage. Most slips will be corrected by this automatic action.

If bad rail conditions cause the slip to exceed three seconds, sand is automatically applied to the rail. The wheel-slip light will come on at about the same time the sanding starts. When wheel slips cannot be controlled by braking and sanding, the excitation is reduced automatically.

OPERATING INFORMATION

If the engineman desires to correct an anticipated wheel slip, a lightly controlled brake application may be made with the Slip-Suppression Brake push button.

If, in the engineman's judgment, the wheel slip is not corrected by the automatic control, it may be necessary to reduce the throttle position or manually apply sand, or both, until the wheel slip is fully controlled.

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 (U30B), each rectifier panel contains 24 diodes, or a total of 72 diodes for the three panels. Each rectifier panel on the six-motor locomotive (U30C) 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.

CIRCUIT OPERATION

The alternator rotor has 12 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 (1025 rpm), the field current of the exciter can be adjusted to about 0.4 ampere. This will produce about 1305 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 load box, to determine the system characteristics under load. A shunt and millivoltmeter calibrated to indicate amperes is connected in series with one of the output terminals. Assume that the dummy load is a water box of high capacity. The water box consists of a large steel tank of salt water and a steel blade that can be raised and lowered.

CIRCUIT OPERATION

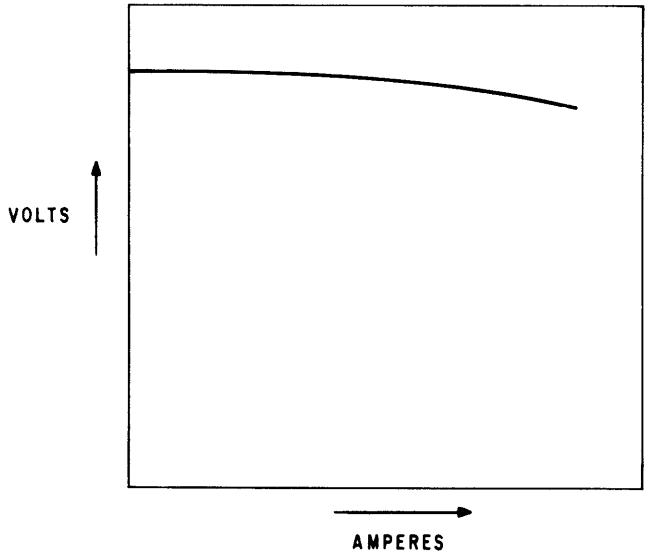


Fig. 10-1. Constant-speed, constant-field characteristic of generator

This blade is connected to the positive side of the d-c output, and the tank is connected to the negative side. When the blade is lowered into the box, the resistance is decreased; when the blade is raised, the resistance increases.

With the blade lowered into the box (least resistance) and the alternator rotating at full engine speed, the output characteristic resembles that shown in Fig. 10-1. This curve is similar to the output from a flat, compounded generator. Under this condition of operation, the alternator is producing excessive current and voltage. The load demand would exceed the capacity of the diesel engine.

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

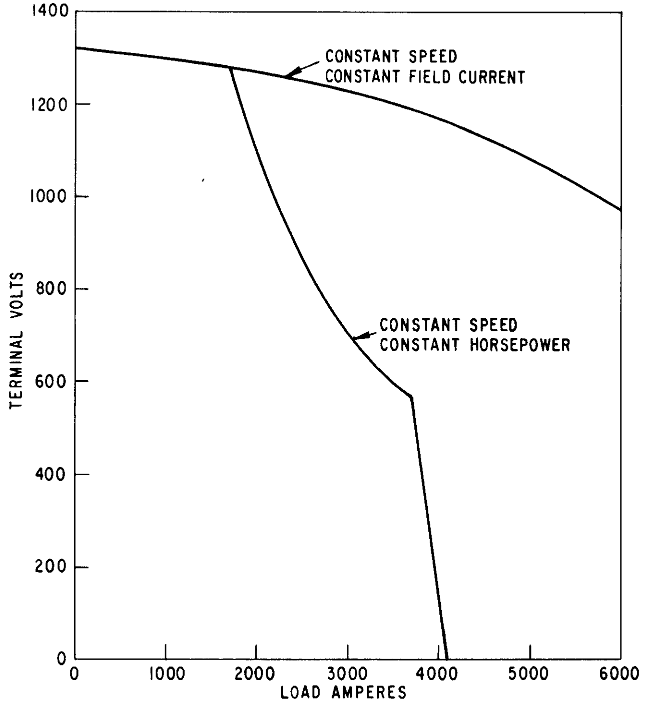


Fig. 10-2 (E-14729)

Fig. 10-2. Horsepower characteristic

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

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

CIRCUIT OPERATION

There are two known values that can be substituted in the formula; the horsepower input of the engine into the alternator (3000 hp at 1025 rpm), and the number 746 (watts per horsepower) which is an electrical constant. Disregarding efficiency, voltage is equal to the product of horsepower (3000) 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 3000 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 the constant-speed, constant-excitation curve, as well as the constant-speed, constant-horsepower curve. It is evident from Fig. 10-2, that 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.

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.

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 600 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 300-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 the field transistor (FT1). Transistors (T1 and T2) will conduct alternately along with the pri-

Fig. 10-3 (E-14730)

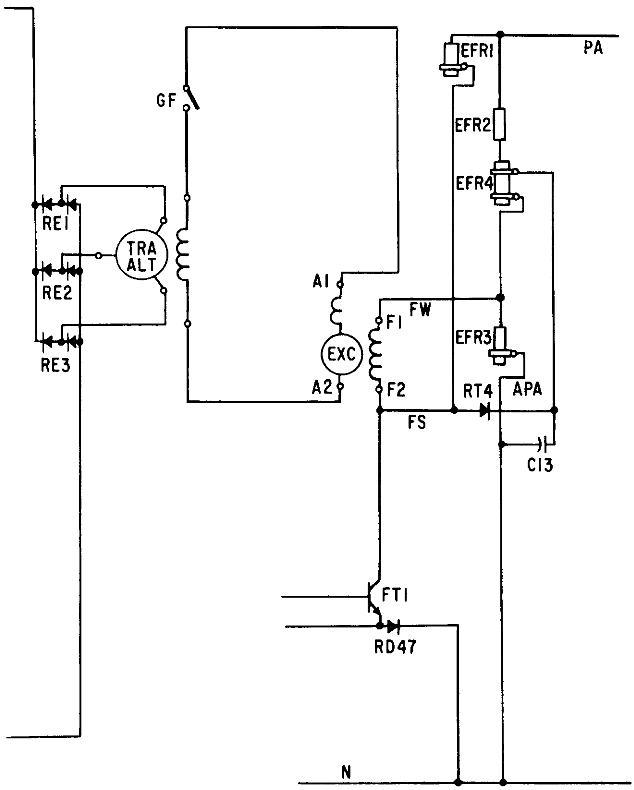


Fig. 10-3. Traction alternator, exciter and field transistor (motoring)

mary windings of the 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

CIRCUIT OPERATION

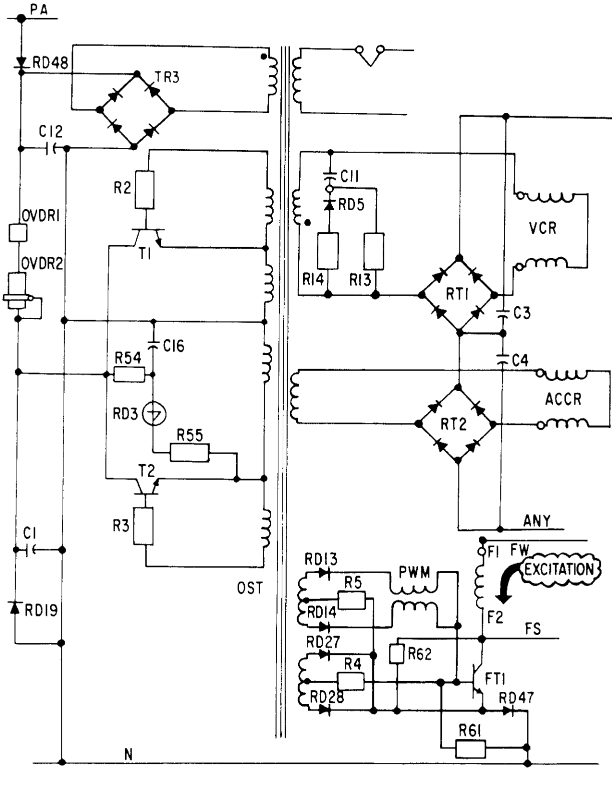


Fig. 10-4 (E-14731)

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

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 the oscillator transformer (OST). All four series windings 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), 300-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.

Diodes (RD27 and RD28) (see Fig. 10-4) are connected as full-wave rectifiers to apply a reverse (negative) bias to the 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 600 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 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

CIRCUIT OPERATION

Fig. 10-5 (E-14732)

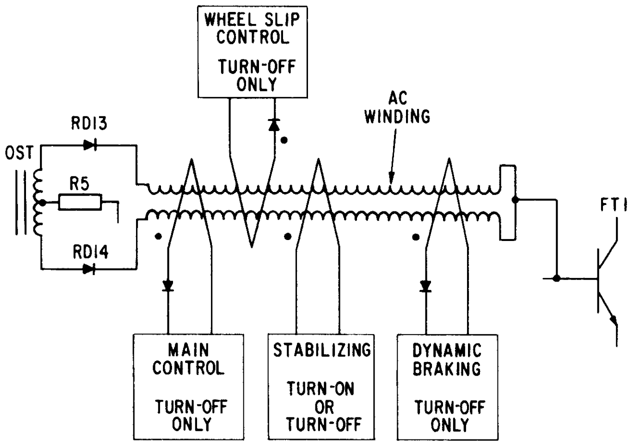


Fig. 10-5. Pulse-width modulator (PWM) windings

Fig. 10-6 (E-14733)

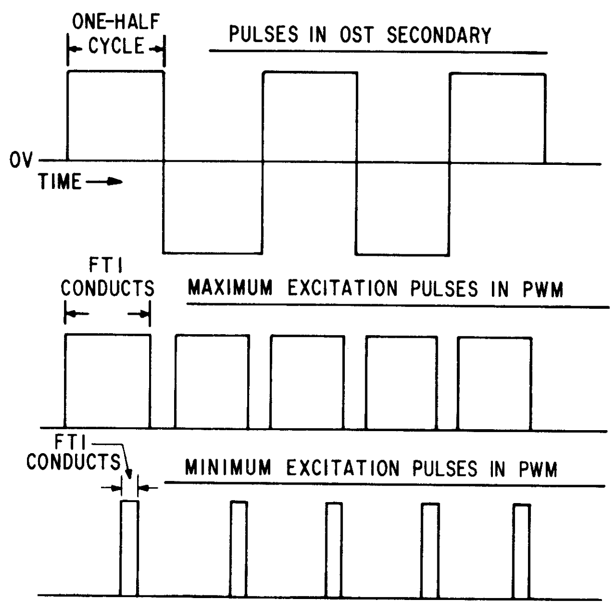


Fig. 10-6. Pulse in oscillator transformer and a-c winding of pulse-width modulator (PWM)

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 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.

CIRCUIT OPERATION

Fig. 10-7 (E-14734)

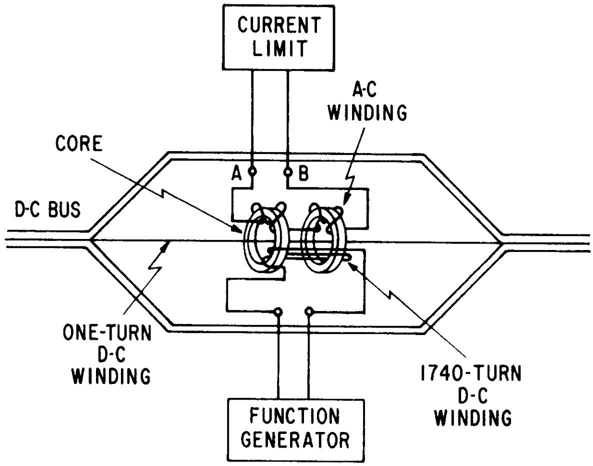


Fig. 10-7. Construction of current-measuring reactor, ACCR

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) 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. 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 modu-

CIRCUIT OPERATION

lator 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), switch (BKT-2), rectifier bridges (RT2 and RT1), switch (BKT-1) and resistor (LCR4), to the negative (N) wire. The throttle-handle position can now establish a given reference current for each notch. Voltage on the XB wire will be proportional to the throttle-notch positions, and varies from about 25 volts at the first half-throttle notch to 75 volts in notch 8. The voltage on the PA wire is 75 volts when the fuel-pump breaker is closed.

The reference voltage between resistors (LCR3 and LCR4) varies between 7 volts in the first half-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), down 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), the brake relay (BR1) contact, 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. 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

An increase in excitation caused by increased throttle-notch position (see Fig. 10-8) 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

CIRCUIT OPERATION

XB wire is proportional to the number of notches. The increase in voltage on the XB wire charges capacitor (EC12) which provides bias to the base of transistor (T3) through switch (BKT-2) and 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 and BKT-1) to the junction of resistors (LCR3 and LCR4). The current then passes through resistor (LCR4) to the N wire.

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 XB 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 XB wire is 75-volts maximum. When the locomotive is trailing behind others, the voltage on the XB wire may be reduced to slightly lower voltage due to voltage drop in trainline wires and jumpers. By stabilizing the voltage on the resistor (LCR3-LCR4) junction, the locomotive produces full horsepower independent of actual voltage on the XB wire, as long as it is above approximately 60 volts.

Reverse currents in the rate circuit are prevented by the blocking diode (RD30). Otherwise, when the throttle is in the IDLE position, current would flow from the resistor (LCR3-LCR4) junction, back to the XB wire and 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 the 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 CD, DE, and EF are established by the function-generator circuits. These are shown on Figs. 10-10 and 10-11. A voltage-divider network (see Fig. 10-10), 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

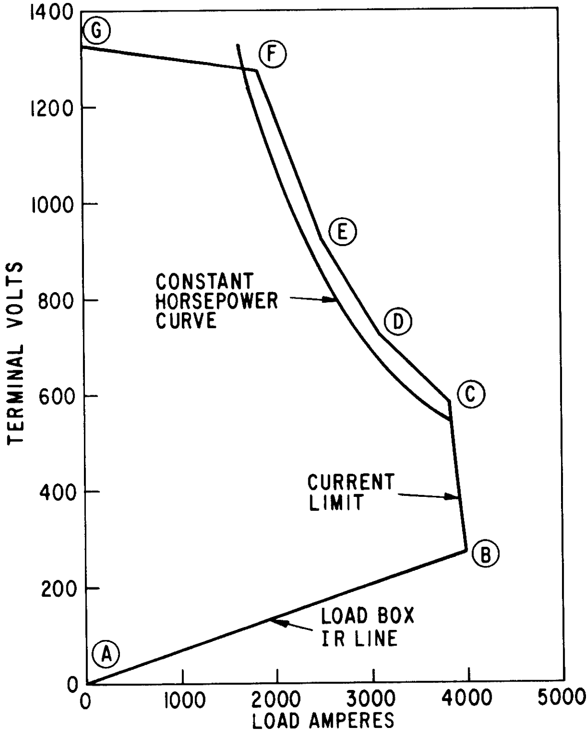


Fig. 10-9. Load characteristics

Fig. 10-9 (E-14736)

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.

CIRCUIT OPERATION

Fig. 10-10 (E-147737)

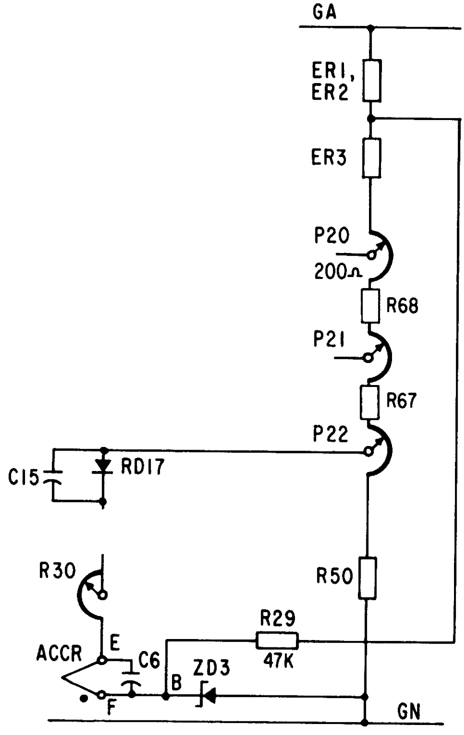


Fig. 10-10. Function-generator circuit for establishing slope CD on the horsepower curve

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. Con-

CIRCUIT OPERATION

sider again system conditions with the power output connected to a water box, with the blade of the box all of the way down for minimum circuit resistance. When the throttle is notched out, the volt-ampere coordinates fall on the IR line AB. At point B, the water-box blade is raised some, and then the volt-ampere coordinates will fall on line BC. This line BC is the current-limit line established by 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. 10-11, 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 the Zener diodes (ZD11 and ZD12). These diodes, by their breakdown voltage (5 volts each), 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 water-box blade 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.

CIRCUIT OPERATION

Fig. 10- 11 (E-14738)

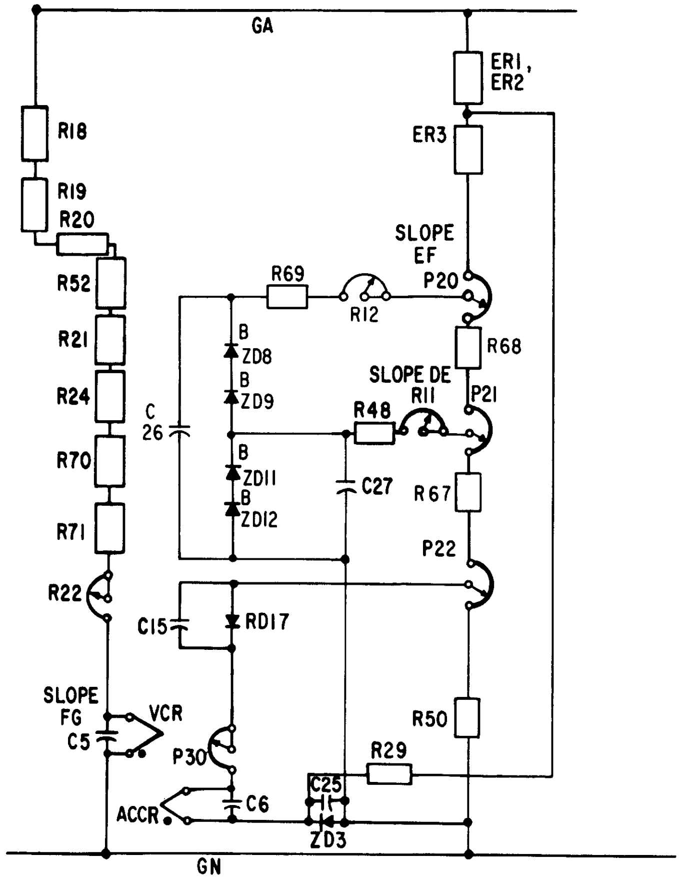


Fig. 10-11. Function-generator circuits for slopes CD, DE, and EF on the horsepower curve

CIRCUIT OPERATION

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 water-box blade is raised 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 Figure 10-12. Factory adjustments are made to these circuits as follows:

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.

CIRCUIT OPERATION

Fig. 10-12 (E-14739)

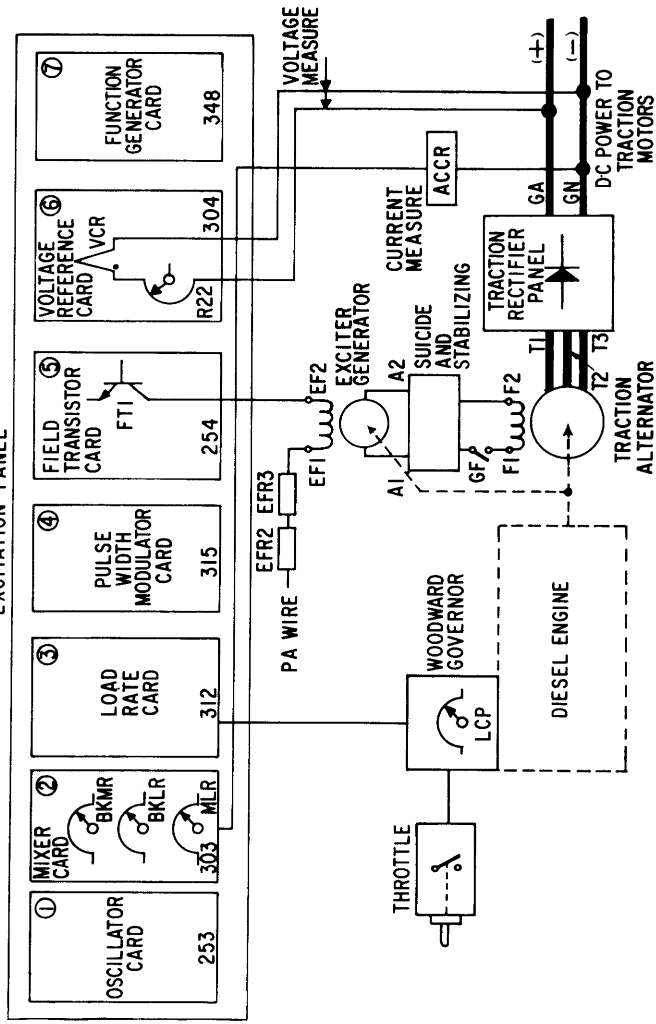


Fig. 10-12. Locomotive excitation system, simplified block diagram

CIRCUIT OPERATION

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. 10-13)

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. Dur-

CIRCUIT OPERATION

Fig. 10-13 (E-14740)

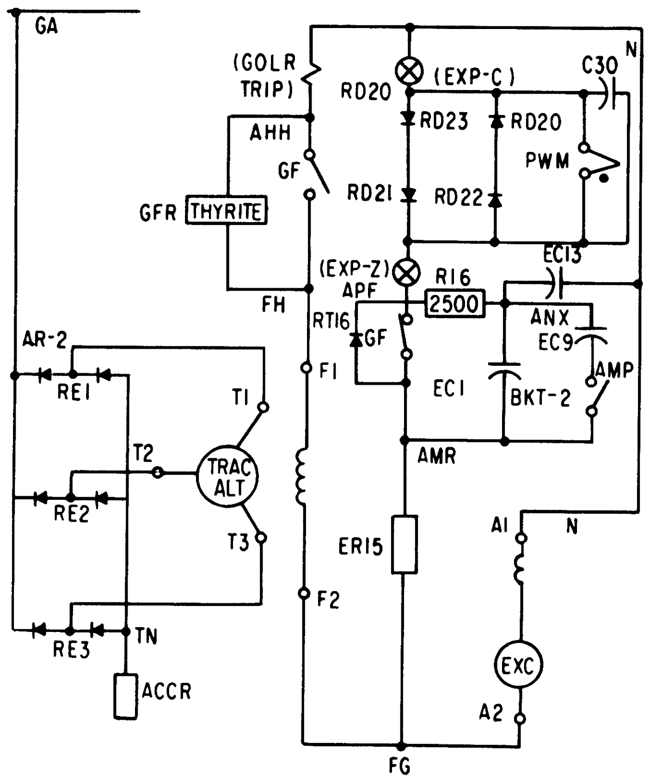


Fig. 10-13. Stabilizing and suicide circuits

ing braking, the motors are connected as separately-excited shunt generators. Their outputs are dissipated in the resistor grids as shown in Fig. 10-14. The engine speed is increased to 1025 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

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examining the braking curve in Fig. 10-15. 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-miles per hour, 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 1025 rpm. The brake-start wire BG is energized at this time

Fig. 10-15 (E-14742)

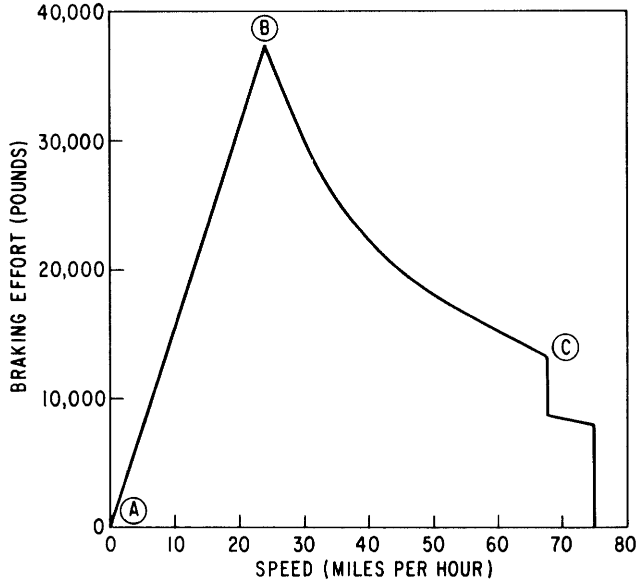

Fig. 10-15. Dynamic braking curve

and while energizing the relay (BR1) it also energizes the braking-switch magnet valve. This positions the 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 (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 notch position. At the half notch position, the voltage at resistor (LCR2-LCR3) junction is greater than the voltage of the XB wire. This difference in potential causes current to flow from resistor (LCR2-LCR3) junction through BKT1, PWM, R36, RD10, R8, BKT-2, BKMR, RD9, R44, RD15, BR1, the XB wire, MR, LP and LCR1, 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 notches are increased, the XB wire voltage increases. This effectively lowers the pulse-width modulator current, widens the pulse width and increases the amount of excitation.

When the excitation increases due to advanced throttle notches, 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 BR1, 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.*

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Current limiting to the grids is accomplished by the current-detection circuit shown in Fig. 10-14. 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 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

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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.

MULTIPLE-UNIT CONTROL

So far, the explanation has only been concerned with a single General Electric locomotive. During multiple-unit operation however, the lead unit must control several more locomotives in the consist.

The engine speed is controlled on both the leading and trailing units by energizing the AV, BV, CV and DV wires from the throttle-handle contacts. These are connected to the respective governor solenoids and provide the proper control of engine speeds. Excitation control is accomplished by varying the voltage on the XB wire between 26 and 75 volts on notch eight, during motoring. During dynamic braking, this will vary from 13 volts to 75 volts.

When the throttle handle is moved from IDLE to the first half-notch, the SN wire is energized through the controller contact (E). This causes the multiple-unit relay (MR) to pick up. On trailing units, a similar event occurs; the MR relays are also picked up. By this arrangement, if a General Electric locomotive is leading the consist, all General Electric locomotives in that consist will receive their excitation signal from the XB wire.

If other than a General Electric locomotive is leading the consist, the XB wire is not energized during motoring. However, excitation will be received on the trailing General Electric units from the XC wire. As the leading (other than General Electric) locomotive notches out on the throttle, no signal will be put out on the XB wire. The engine speed signals will be trainlined on the GF, AV, BV, CV and DV wires. Current flows into the resistor combination (Rl, R2, R3, R4, and R5) through the blocking diodes (RT1, RT2, 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 just as it did on the XB wire. The voltage on the XC wire 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.

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. Figure 10-16 shows the wheel-slip detection circuit.

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 de-

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signed 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 the pulse-width modulator (PWM) energized at this time will reduce excitation. When the 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.

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2. Acceleration Rate Detection

The differential detection system (Fig. 10-16) 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 the 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 the 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.

Fig. 3-2 (E-13461)

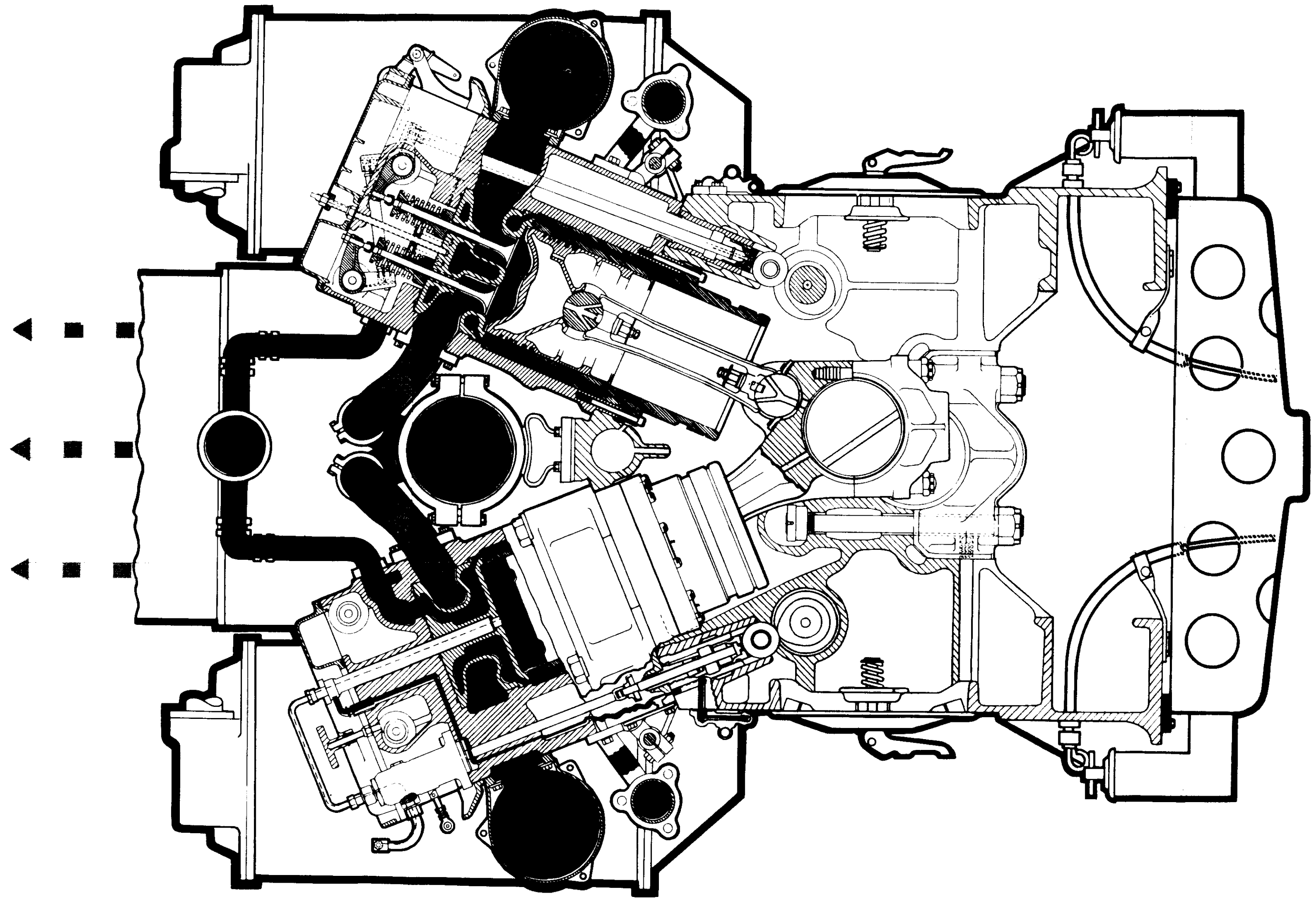


Fig. 3-2. Cross-section view of engine

Fig. 4-1 (E-9902F)

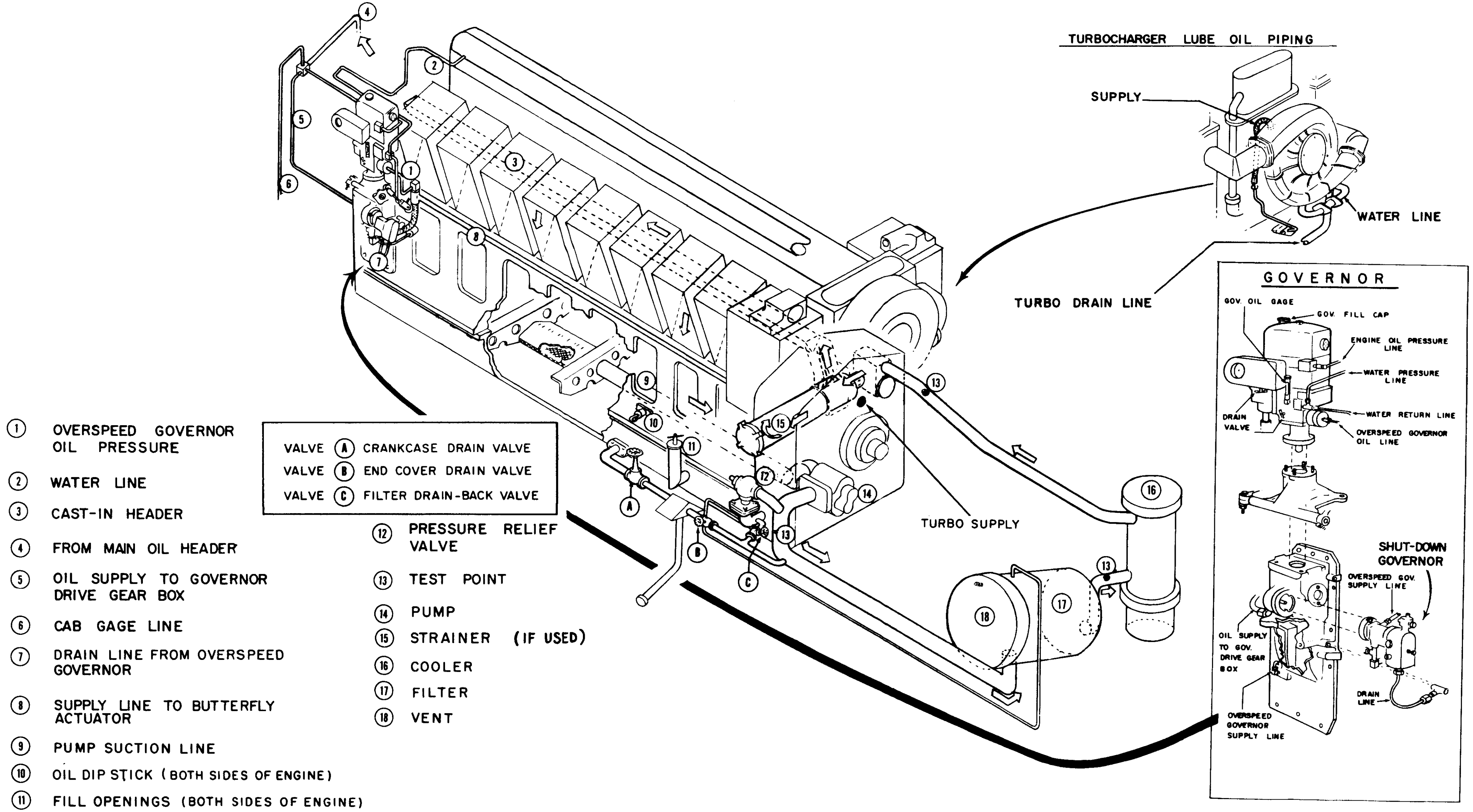


Fig. 4-1. Lubricating-oil system

Fig. 5-1 (E-13536A)

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
18. SECONDARY FUEL FILTER (IF USED)

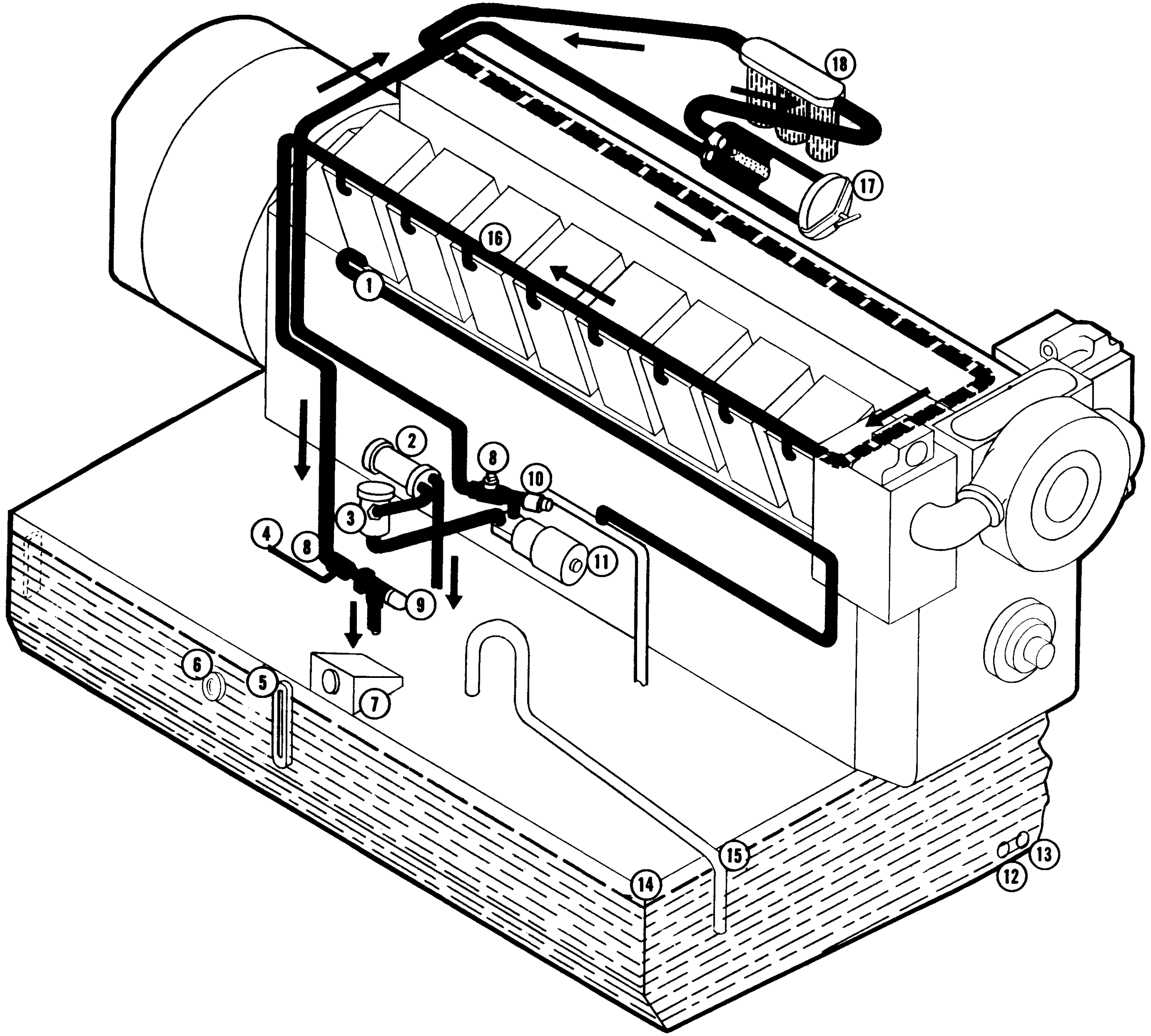
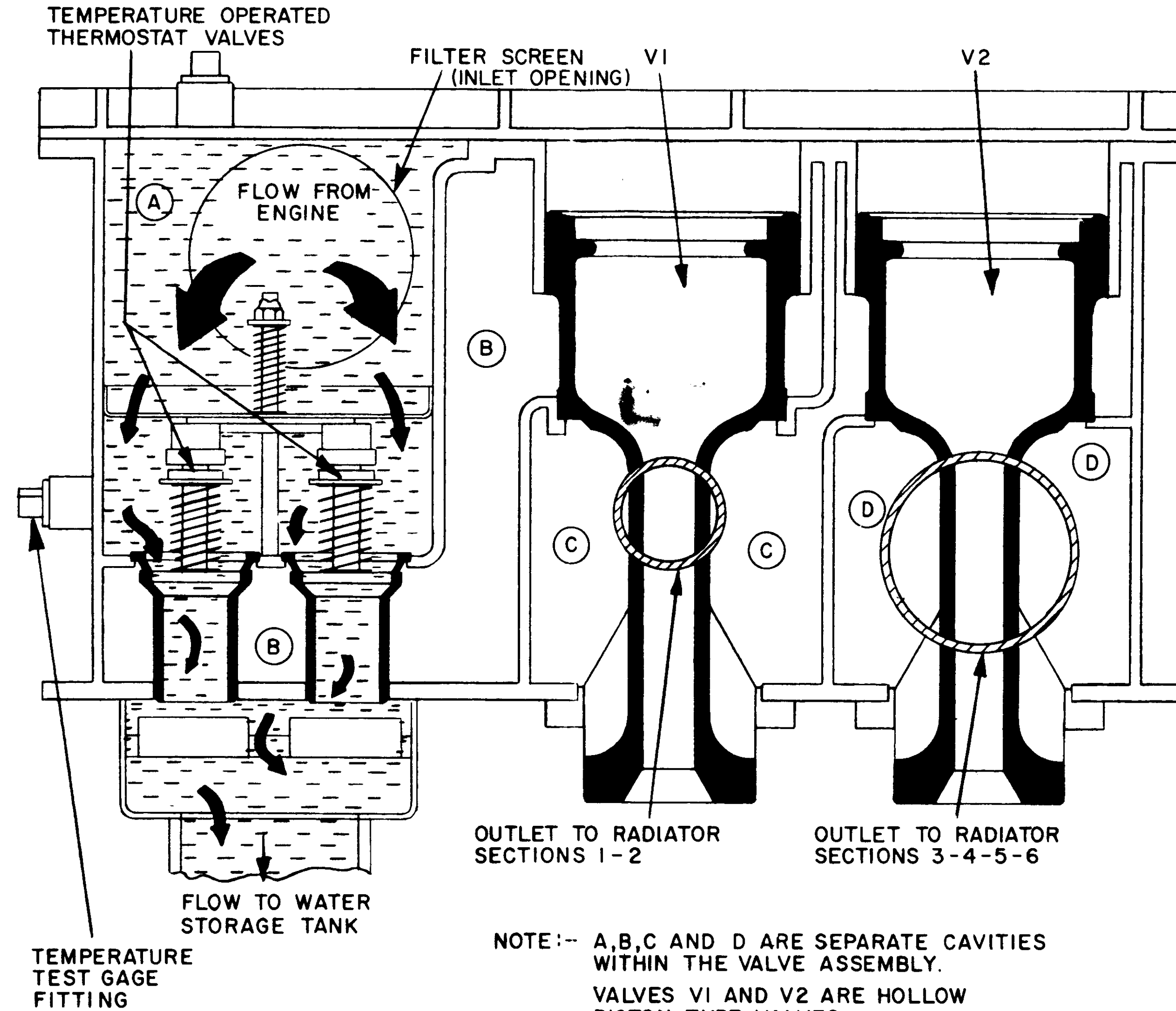


Fig. 5-1. Engine fuel-oil system

Fig. 6-3 (E-9946A)



NOTE:– A,B,C AND D ARE SEPARATE CAVITIES WITHIN THE VALVE ASSEMBLY.

VALVES V1 AND V2 ARE HOLLOW PISTON TYPE VALVES.

Fig. 6-3. Flow-control valve operation (Condition: minimum engine cooling required)

Fig. 6-4 (E-9947A)

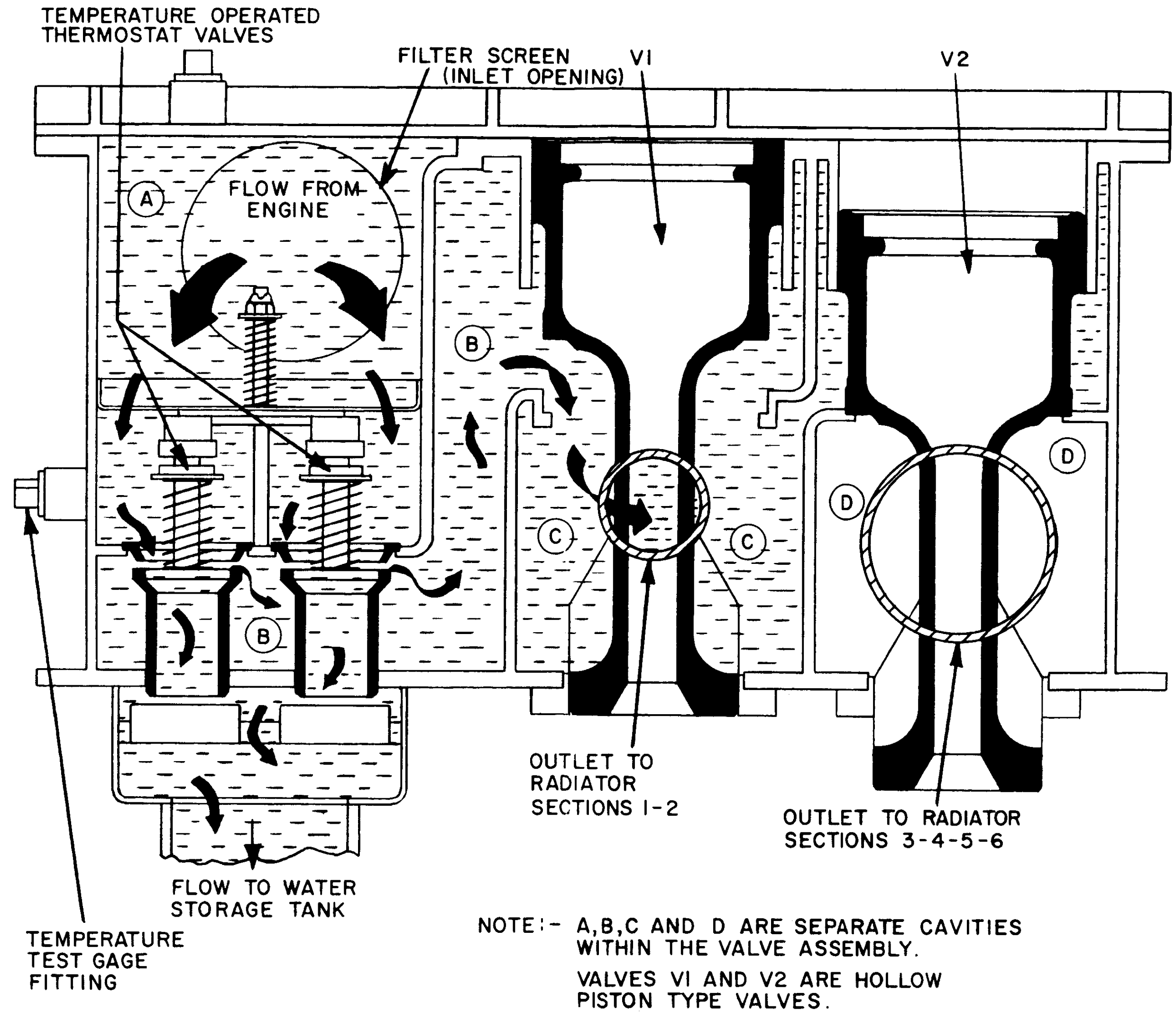


Fig. 6-4. Flow-control valve operation (Condition: partial engine cooling required)

Fig. 6-5 (E-9948A)

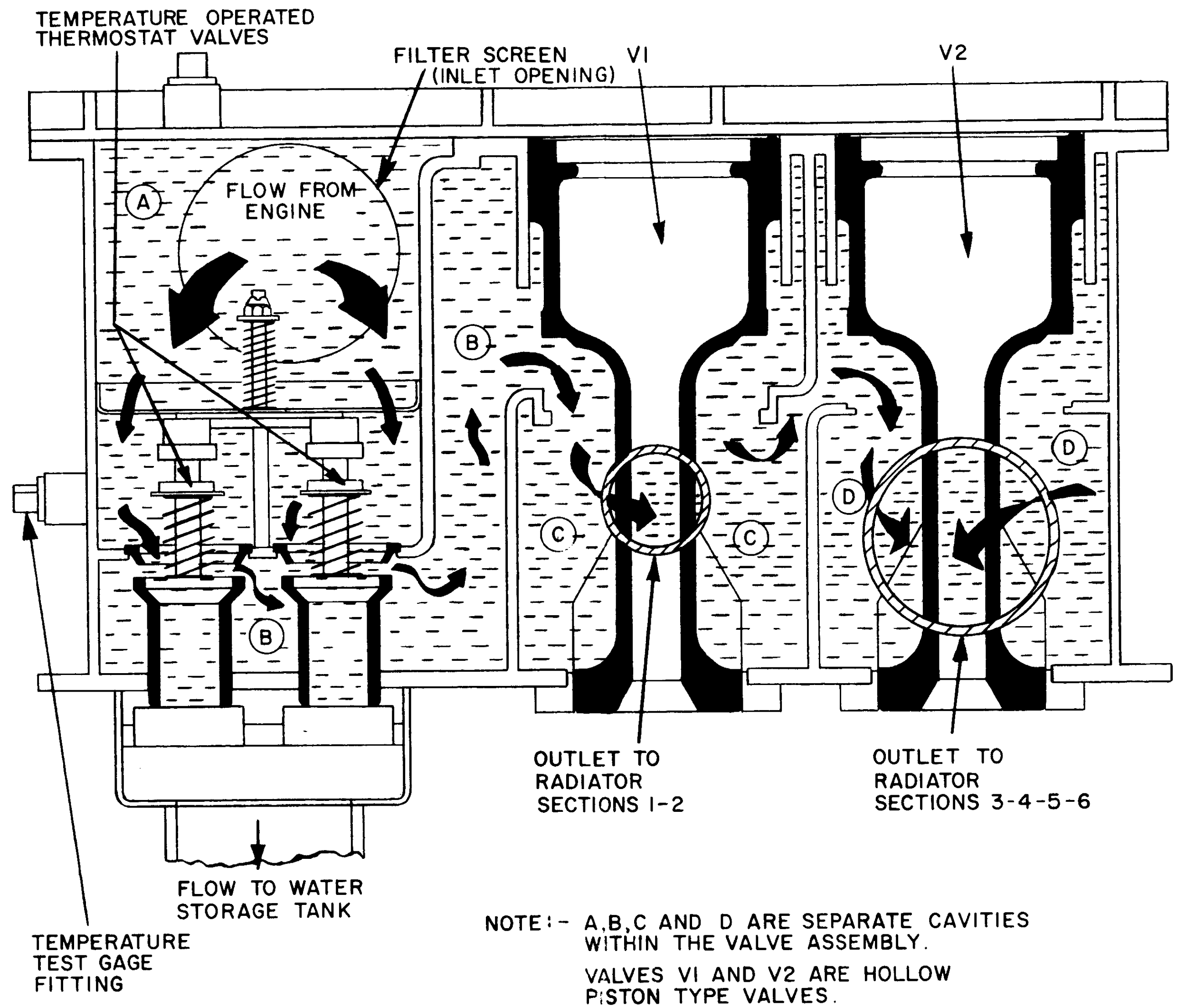


Fig. 6-5. Flow-control valve operation (Condition: full engine cooling required)

Fig. 6-6 (E-13525B)

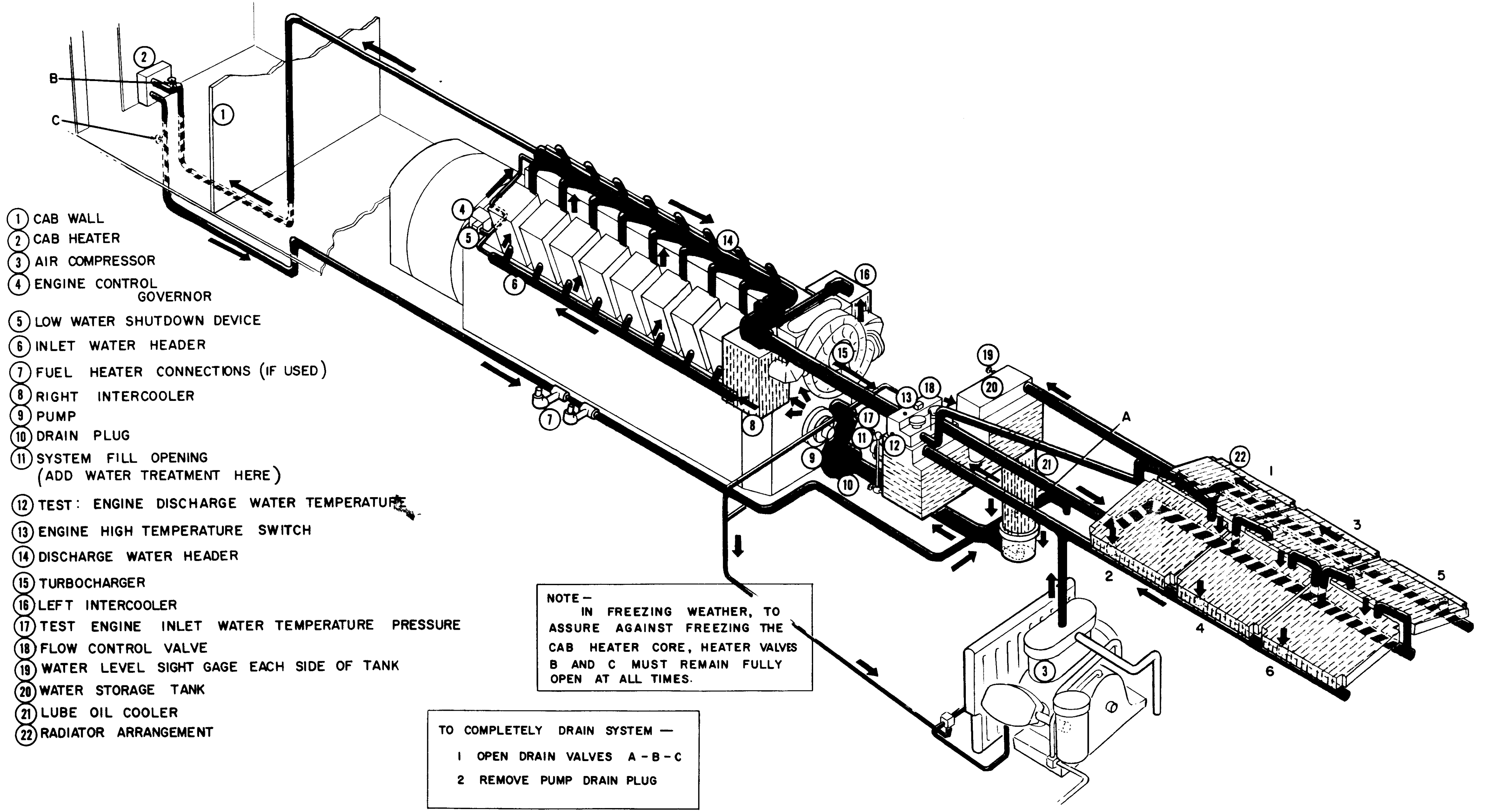


Fig. 6-6. Locomotive cooling-water system

Fig. 7-4 (E-13535)

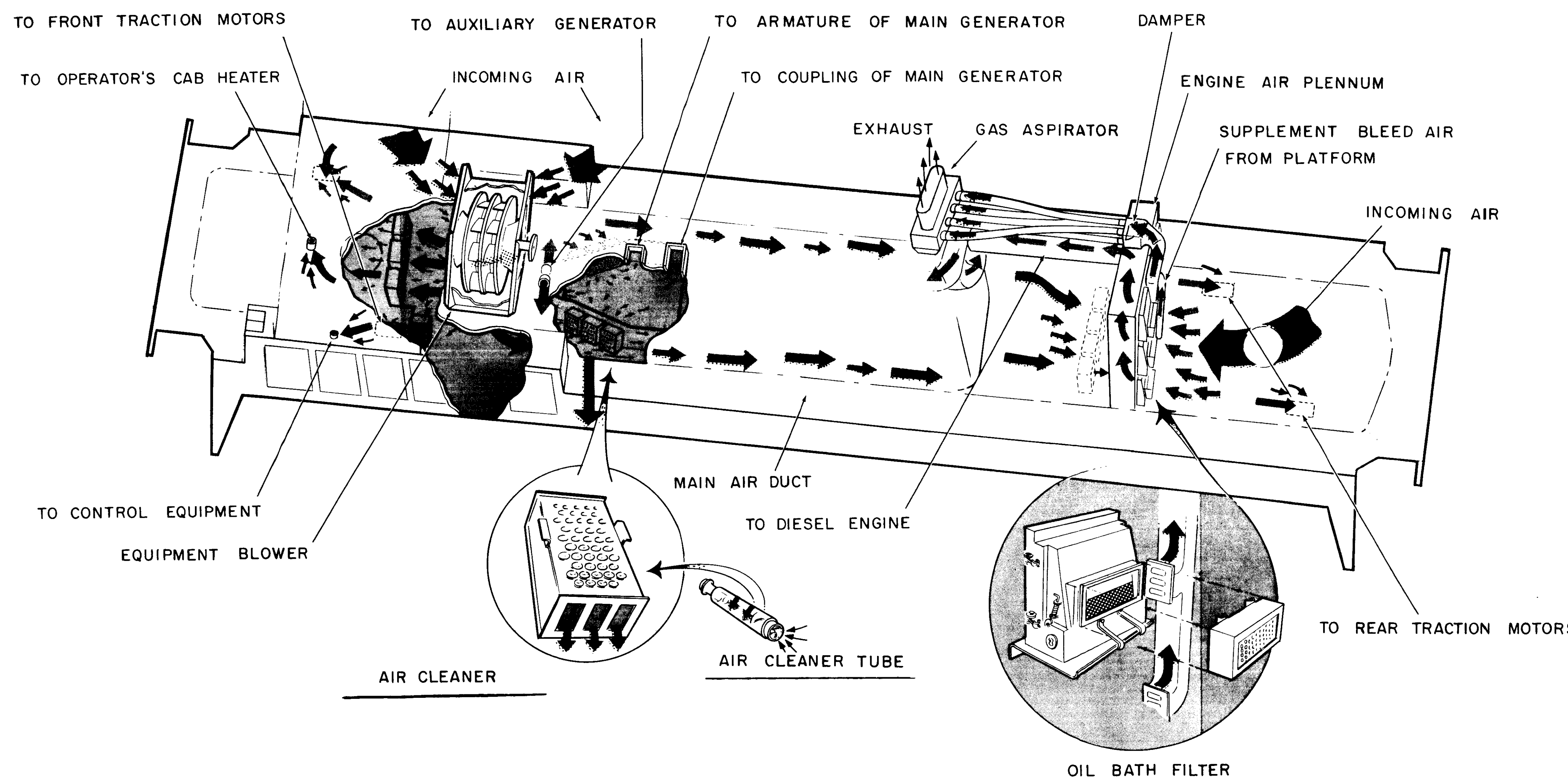


Fig. 7-4. Locomotive air system

Fig. 8-5 (E-9707A)

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 percent 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)

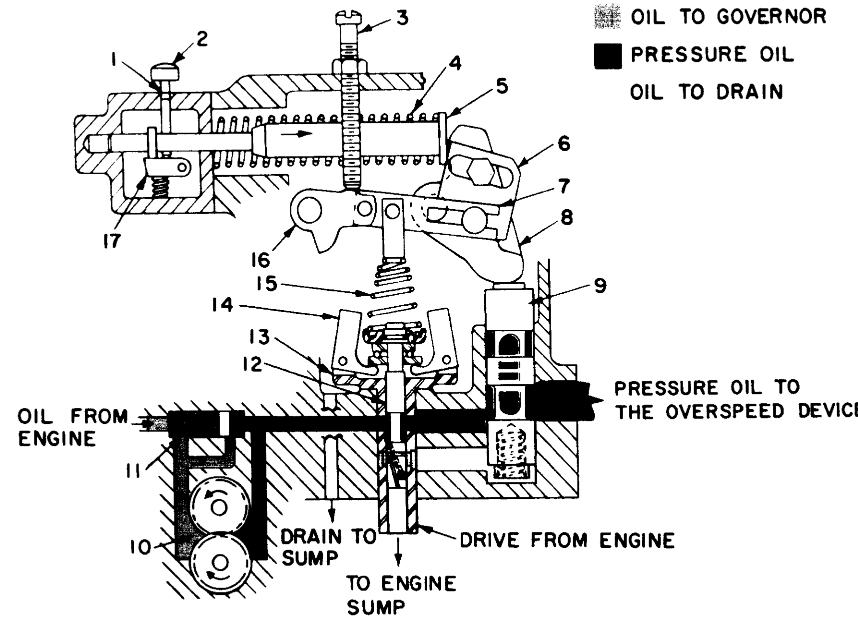
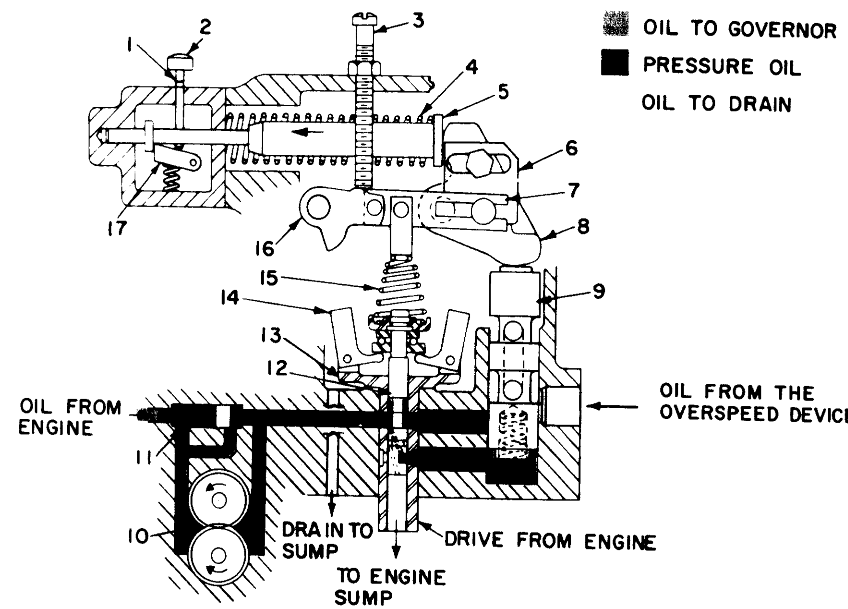


Fig. 8-5. Operating condition—engine running at normal speeds

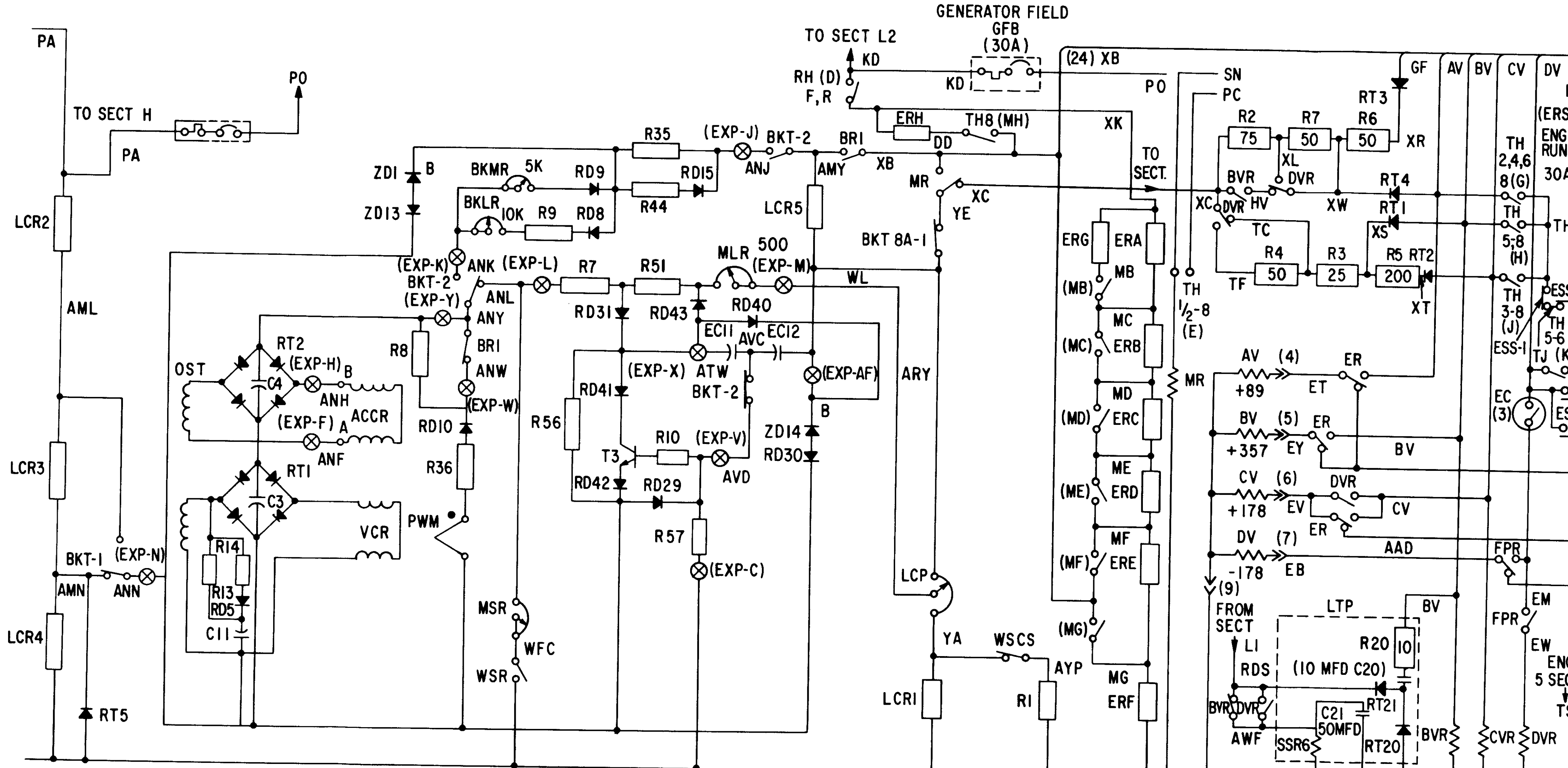
Fig. 8-6 (E-9708A)



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 percent 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

Fig. 10-8 (E-14735)



NOTE: CONTACTS SHOWN IN NORMAL POSITIONS.

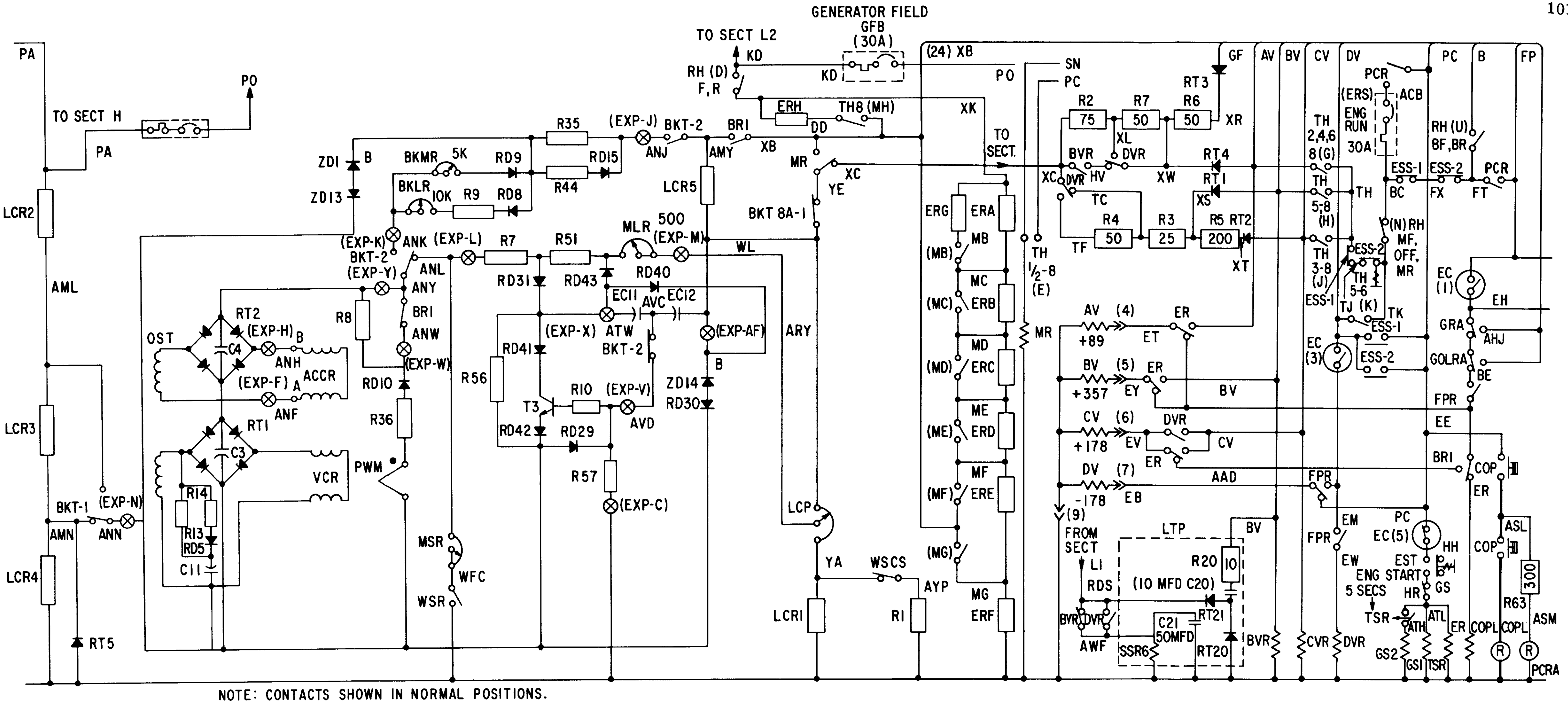


Fig. 10-8. Mixer reference and notching circuits

Fig. 10-14 (E-14741)

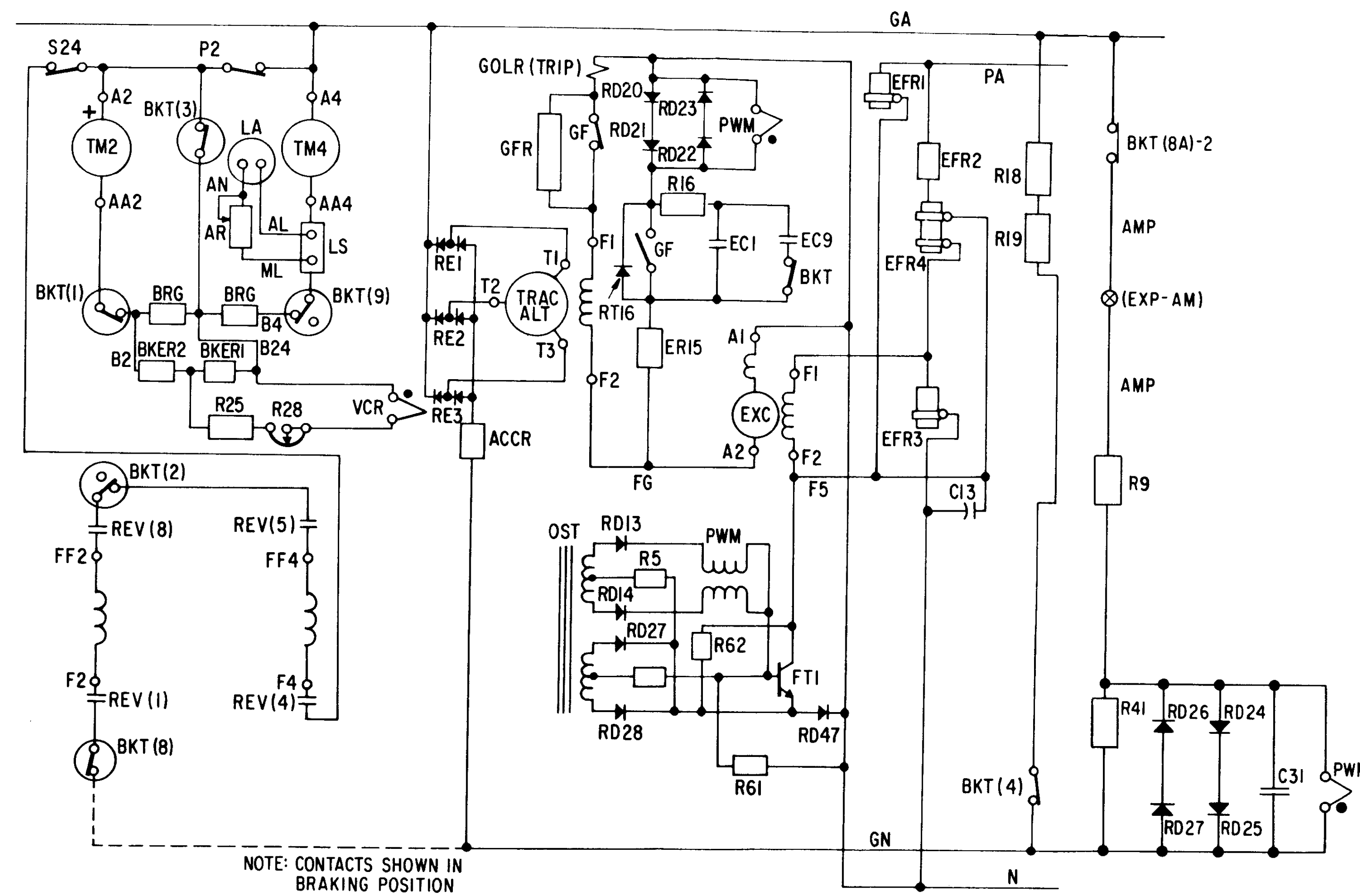


Fig. 10-14. Motor and generator excitation circuits under dynamic braking operation

Fig. 10-16 (E-14743)

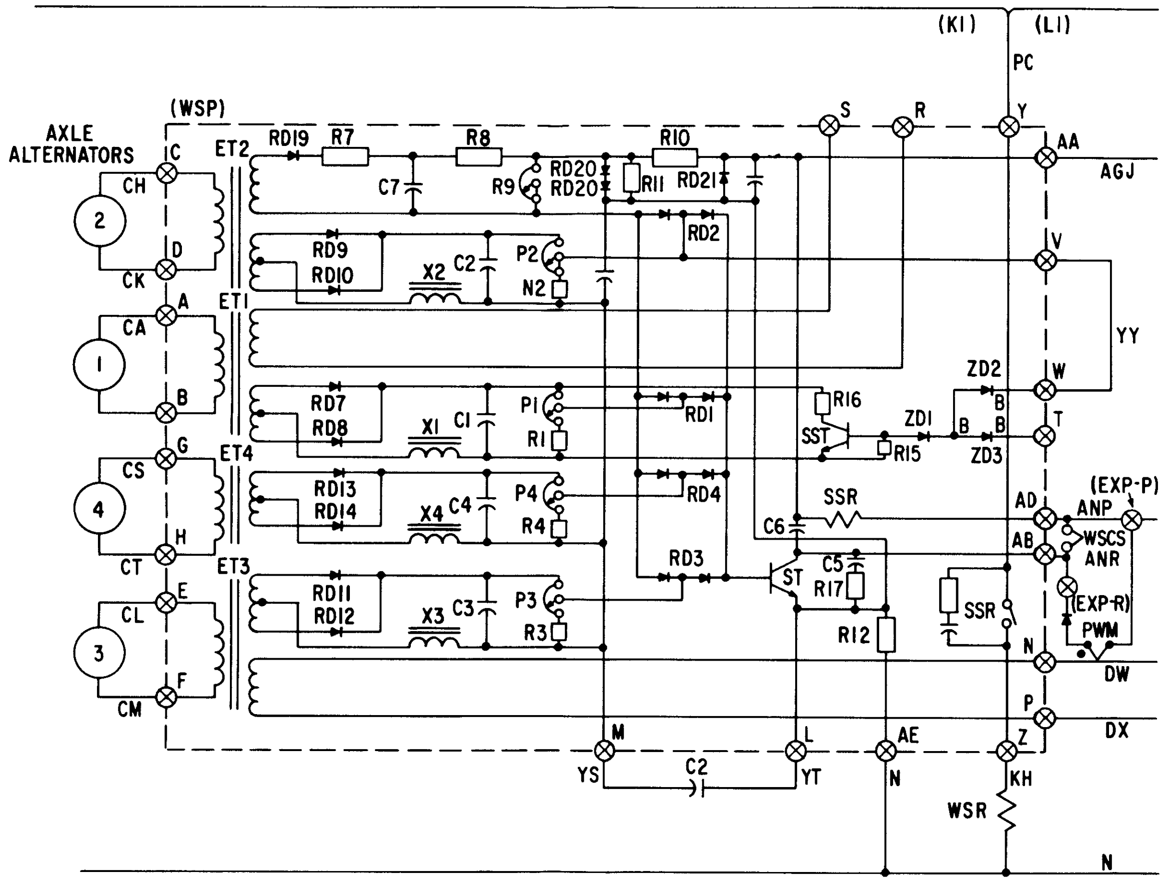


Fig. 10-16. Wheel-slip detection circuits