

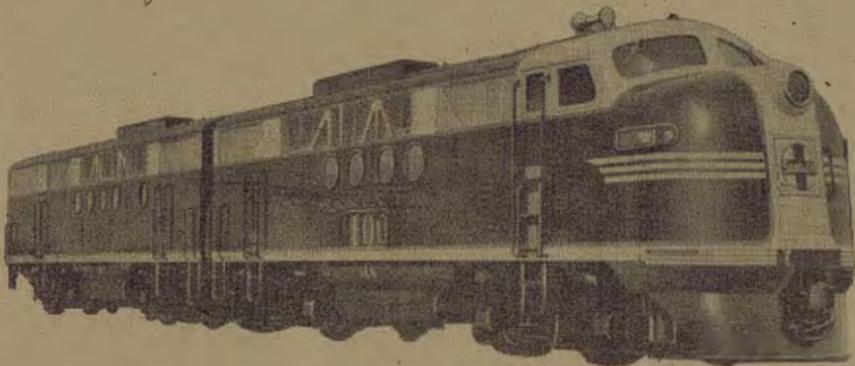
# Operation of

GM Electro-Motive Division

## FT

2700 HP Diesel Freight

# Locomotives



- 1947 -

by

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ENGINEERING DEPARTMENT, ELECTRO-MOTIVE DIVISION,  
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# OPERATION OF DIESEL FREIGHT LOCOMOTIVES

Serial 5718

Edition 1

## INSTRUCTIONS FOR OPERATION

### ARRANGEMENT OF OPERATING EQUIPMENT

93948

1. **Unit Arrangement.**—A Diesel freight locomotive as manufactured by the Electro-Motive Division of General Motors Corporation consists of two, three, or four power units connected by permanent links or by automatic couplers. Each unit is powered by a 16-cylinder 1,350-horsepower (hp) Diesel V-bank engine driven by the combustion of a highly refined fuel oil. All required equipment is self-contained in the unit. The power of the Diesel engine is converted into direct current for turning the traction motors of the locomotive trucks, thus avoiding mechanical transmission of power from engine to truck with its many complications.

The leading unit is provided with a cab and the necessary control equipment for operating the various sections of the locomotive. The standard Diesel locomotive, Fig. 1, has a control section, known as an A unit, and a booster section, known as a B unit. The two sections are permanently connected together by links to provide 2,700 hp. When a standard 5,400-hp locomotive is required, two such combinations are connected together back to back by automatic couplers provided at the rear of each combination. The standard 5,400-hp freight locomotive, therefore, consists of an A, or control, section at each end separated by two B sections, allowing the locomotive to be operated from either end without turning. The three-unit locomotive of 4,050 hp consists of a B unit with an A unit, or control section, permanently connected at each end. This also allows operation in either direction.

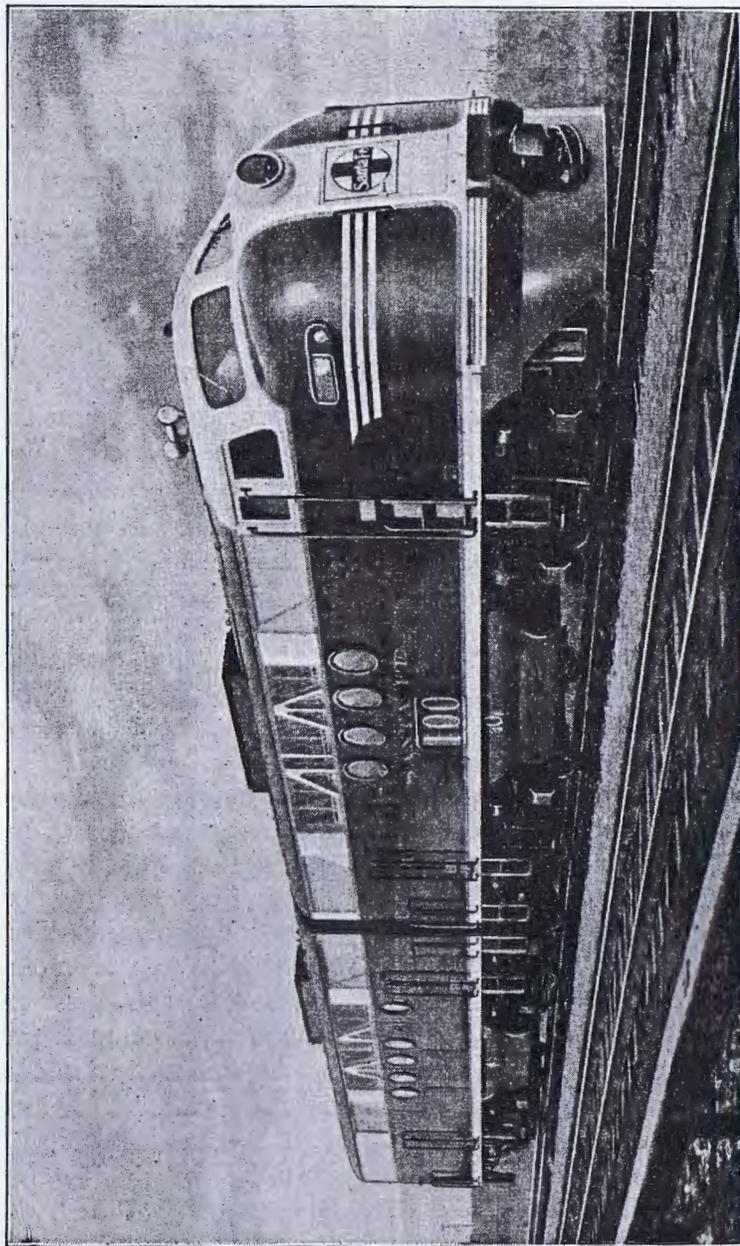


FIG. 1. 2,700-HP FREIGHT LOCOMOTIVE

Inasmuch as each combination is similar, the locomotive will be considered as consisting of a standard A and B section for a 2,700-hp or two such combinations for a 5,400-hp locomotive.

2. The length of the 2,700-hp freight locomotive is about 96 feet (ft) 6 inches (in.). The maximum width and height is about 10 ft 7 in. and 15 ft, respectively, and its weight is about 450,000 pounds (lb). The locomotive is designed to operate on curves having a minimum radius of 274 ft. The tractive effort at 10 miles per hour (mph) is about 112,000 lb, depending on the traction-motor-pinion and gear ratio.

The engineer's control cab is located in the front end of the A section to allow full vision of road conditions. The headlight and locomotive number lights are built into the side and the front end of the cab, as shown. Two warning horns are located on the roof of the cab and dynamic braking grids are located on the roof of the engine room. The exterior of each unit is streamlined to reduce wind resistance to a minimum.

3. **Plan and Side Elevations.**—A floor plan and a side elevation of the locomotive are shown in the two lower views of Fig. 2. The arrangement of the Diesel engine, the main generator, and the auxiliaries are shown in the plan view. The leading ends of the 2,700-hp locomotive are known as the No. 1 ends of the units, but it will be noted that the front, or the accessory end, of the Diesel engine of the A unit is turned to the rear of the engine room. The head end of the engine in the B unit, however, corresponds with the head end of the unit. This arrangement locates the accessories of each pair of engines adjacent to each other.

The walls of the engine room are spaced to allow for a passage way on each side of the Diesel engine and its equipment. The rear end of the A unit and both ends of the B unit are provided with end doors to allow entrance to any unit of the locomotive by an attendant while the locomotive is in motion.

The freight-locomotive equipment generally corresponds with that of the switching locomotive previously described. The freight locomotive, however, has a steam generator, in some

cases, and a manual transition, and is usually equipped for dynamic braking. A description of the steam generator and its operation is given in another section.

**4. Engine Controls.**—The controls for each Diesel engine are arranged in an engine control and instrument panel as shown in Fig. 3. The panel is mounted on the engine-room wall near the accessory end of the engine.

The gage mounted on the left-hand side of the engine-control and instrument panel indicates the piston-cooling-oil pressure, whereas the gage on the right-hand side indicates the lubricating-oil pressure. Alarm lights located between the two gages, when not lighted, indicate satisfactory engine temperatures, steam-generator operation, and a satisfactory pressure of engine lubricating oil. If one of the alarm lights becomes lighted, it indicates an unsatisfactory performance, which should be corrected at once.

The lower part of the panel contains the engine start switch, the engine stop switch, a fuel-pump switch, a fuel pump contactor and fuse, a master magnet valve, and an isolation switch. The engine start switch energizes the starting contactor coils to close the contactors that connect the battery to the main generator. The engine stop switch energizes a magnet coil of the electro-pneumatic governor control, which causes the governor to shut off admission of fuel oil to the cylinders. A fuel-pump contactor in each engine-control cabinet is operated by a push-button switch in the cab of the locomotive. After the fuel-pump contactors are closed by the cab switch, the fuel pumps may be started or stopped individually by the fuel-pump switch in the engine-control cabinet. The master magnet valve controls the air supply to the electro-pneumatic governor control.

**5.** A distribution panel or cabinet on one of the battery boxes contains switches and fuses to control the battery circuits throughout the locomotive. An ammeter and a voltmeter are also furnished in the panel to indicate the battery charge or discharge. A fuse-test light is furnished to locate burned-out fuses and breaks in the circuits. The magnetic

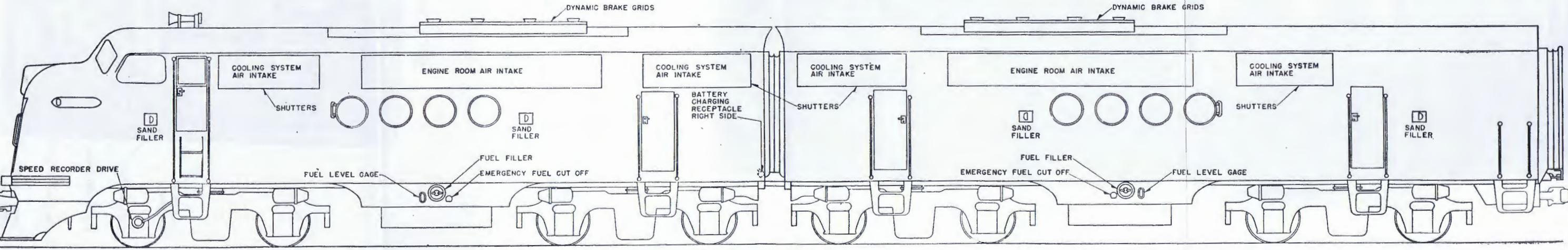
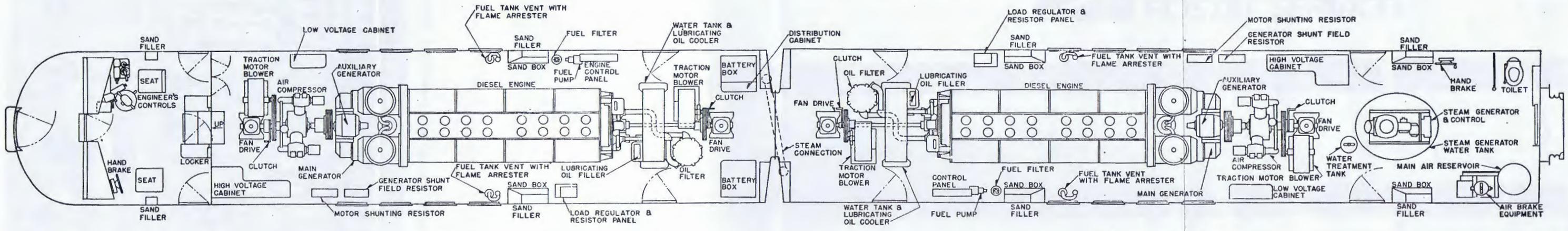
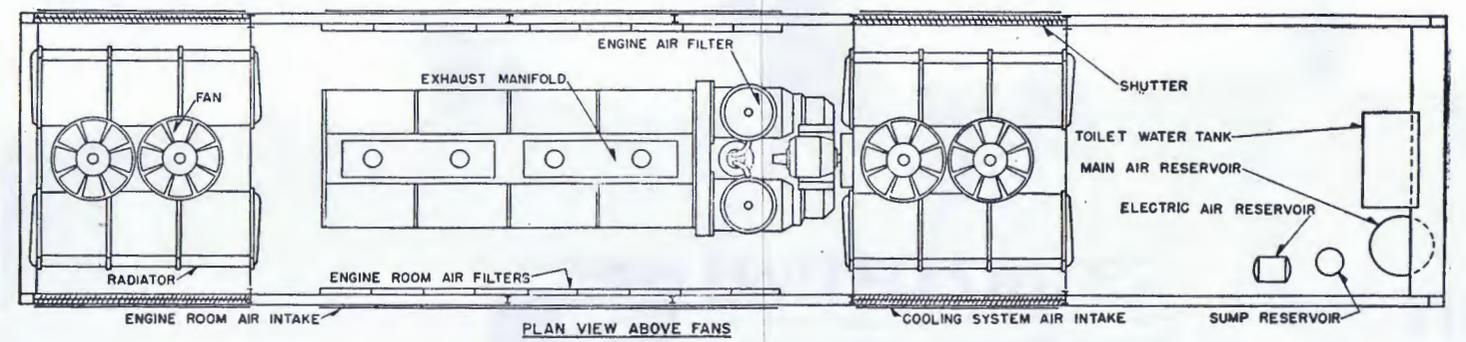
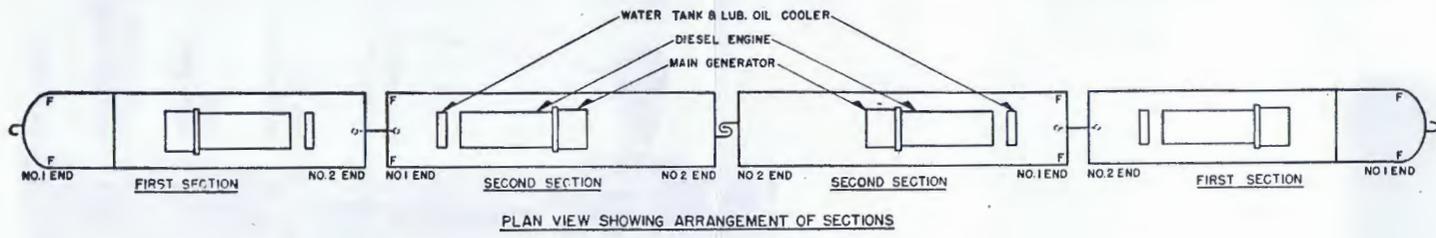


FIG. 2. GENERAL ARRANGEMENT OF FREIGHT LOCOMOTIVE

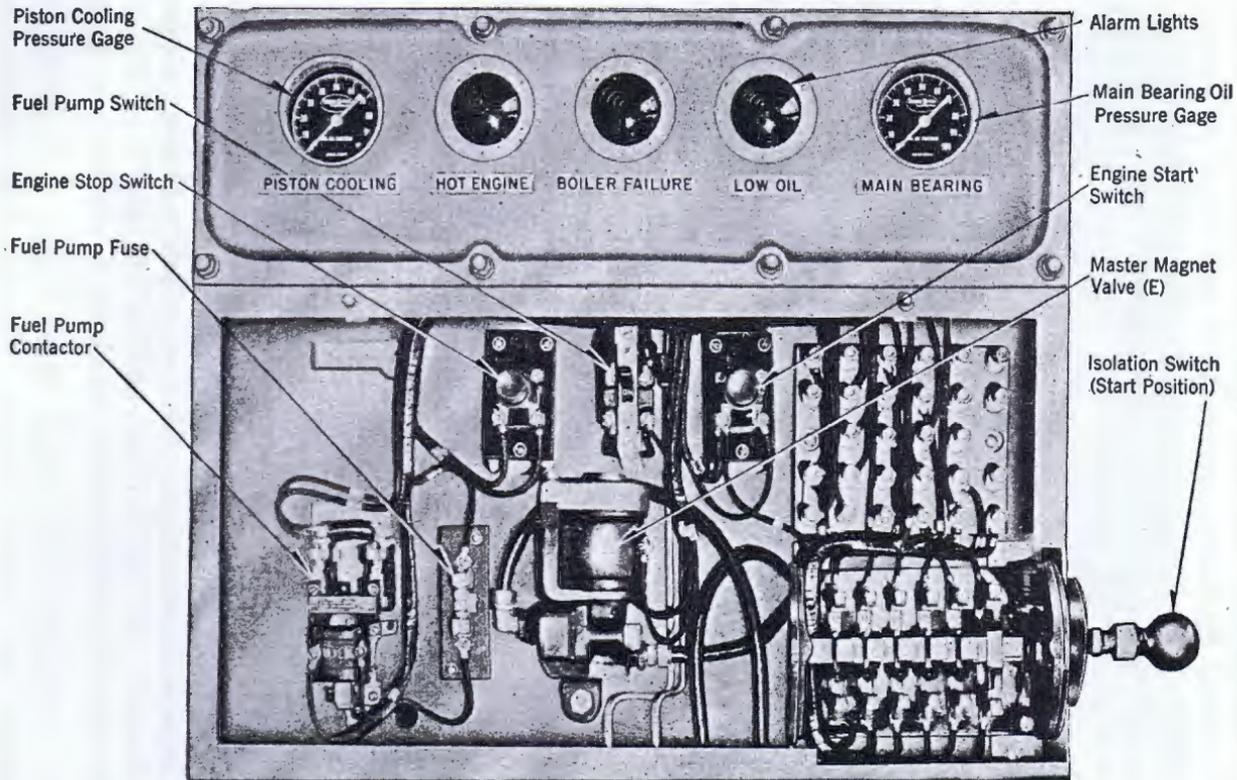


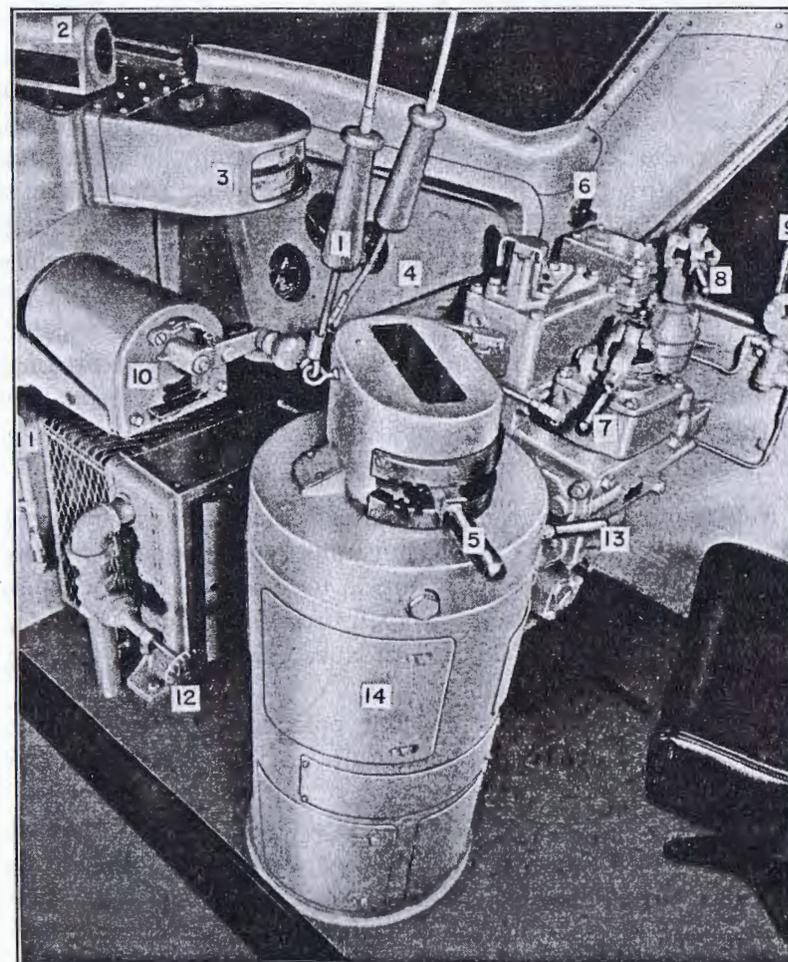
FIG. 3. ENGINE CONTROL AND INSTRUMENT PANEL

and pneumatically controlled contactors furnished to operate the various equipment are housed in high- and low-voltage cabinets on the side of the car. The door of the high-voltage cabinet should always be kept closed while the engine is running, because of the high voltages.

**6. Engineer's Controls.**—In Fig. 4 is shown a view of the engineer's controls in the cab of the A unit, and the parts are identified by the numerals shown in the legend. The horn cords, when pulled, sound the horns on the roof of the cab. The dynamic-brake warning light will light up when the dynamic-braking current becomes excessive. The transition indicator is an ammeter connected in the armature circuit of the No. 4 traction motor of the A unit, and it shows the proper position for the transition lever, based on the amount of current required by the traction motors. The instrument panel contains gages for the proper manipulation of the air brakes; a speedometer is provided on some instrument panels to indicate locomotive speeds up to 70 mph, and a wheel-slip warning light lights up intermittently to give warning when one or more pairs of wheels slip. The instrument panel is indirectly lighted for night operation.

The transition and dynamic-braking lever, the reverse lever, and the throttle lever are all located in the controller stand. The transition and dynamic-braking lever handle, when on the left-hand side of the dividing stop in its operating slot, controls the traction-motor connections. When lifted over to the right-hand side of the stop, the handle controls the dynamic braking. The reverse lever controls the setting of the reverser in the high-voltage cabinet, which changes the direction of the flow of current through the traction-motor leads to cause a reversal of locomotive movement. The reverse lever has three positions—forward, off, and reverse—and its position must always correspond to the direction in which the locomotive is moving.

**7. Dynamic Brake.**—Some Deisel freight locomotives are equipped for dynamic braking. With dynamic braking, the traction motors are converted into generators by special braking contactors and the current thus generated is directed into special



- |  |                           |
|--|---------------------------|
| 1—Horn Cords                           | 8—Independent Brake Valve |
| 2—Dynamic Brake Warning Light          | 9—Sanding Valve           |
| 3—Transition Indicator                 | 10—Unit Selector Switch   |
| 4—Instrument Panel                     | 11—Hood-Light Switch      |
| 5—Transition and Dynamic Braking Lever | 12—Cab-Heating Valve      |
| 6—Windshield-Wiper Valve               | 13—Reverser Handle        |
| 7—Automatic Brake Valve                | 14—Controller Stand       |

FIG. 4. ENGINEER'S CONTROLS

braking resistors or grids built into the roof of each section. The resistance of the traction motors to turning is thus employed to control the speed of the locomotive and train while drifting. As the traction motors are geared directly to the driving axles, anything that resists the turning of the motors also opposes the turning of the driving wheels. The d-c traction motors can be made to generate current by connecting the fields to a supply of direct current, and, as the main generator is always turning over at idling speed, or 275 rpm, when dynamic braking is necessary, the main generator is used to excite the field coils of the traction motors. The amount of excitation produced by the main generator is controlled by a variable resistor, which is operated by the transition braking lever. The braking of all motors is controlled by the engineer in the control cab of the leading section by a closed loop circuit and a field loop relay connecting the generator-battery field of all units.

8. The throttle lever, not visible, is located on the right-hand side of the controller, and it is connected electrically to the electro-pneumatic governor control to control the speed of the engine and generator. The throttle has a stop, an idle, and eight working positions to produce engine speeds varying between 275 and 800 rpm.

The unit-sector switch has four positions and it is set to correspond with the number of units in the make-up of the locomotive.

A push-button control box, not visible, is also mounted on the right-hand side of the controller stand. One button is provided to call the attendant from any of the units, two buttons are furnished for cutting in the master control, and one button each for control of the generator field, the fuel-pump contactors, the defroster blower, the number lights, the gage lights, and the classification lights.

9. A pneumatic control switch, not shown, is an air-operated electric switch located on the right-hand side of the cab below the window. This switch is installed to reduce the power of the locomotive by bringing the speed of the engine to idle when certain emergency air-brake applications take place. The

switch has a manual reset button, which must be pulled out after the brakes have been released. The switch is known as the PC switch.

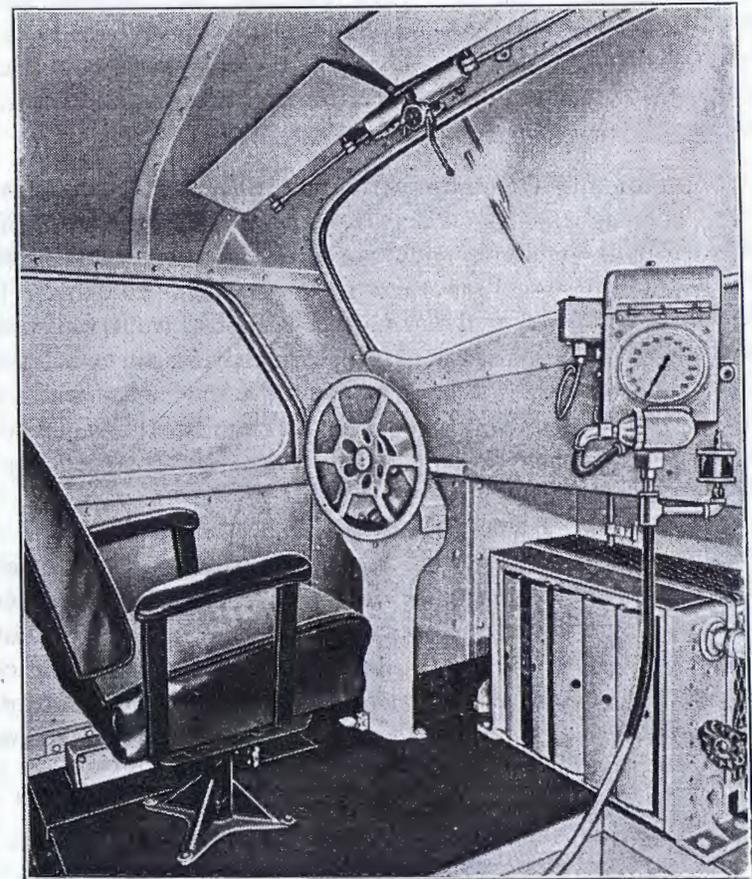


FIG. 5. HAND-BRAKE WHEEL AND SPEED RECORDER

A hand-brake wheel is located in the left-hand corner of the cab of the A unit, as shown in Fig. 5. The hand brake is set by depressing the foot-pedal, which lifts a ratchet latch while turning the wheel to the desired point. The latch engages a ratchet when the foot-pedal is released.

To release the hand brake, advance the hand wheel far enough to release the latch by means of the foot-pedal and

then let the hand wheel spin in the opposite direction until the brake shoes are fully released. The hand-brake wheel of the B unit is in the right rear. The hand brakes should always be applied when work is being done on the trucks or under parts of the locomotive. The hand brakes have been omitted by some railroads. When an A unit is equipped with the speed recorder shown, the speedometer is omitted from the engineer's instrument panel.

**10. Motor and Generator Armature Speeds.**—All rotating objects, such as wheels and armatures, are affected by centrifugal force to an extent depending on their size and construction. Armatures are designed for a maximum rotating speed, and this must not be exceeded or the armature will fail because of excessive rotation. The main-generator armature turns with the Diesel engine and, as it is known that the engine speed will not normally exceed 800 rpm or 880 rpm at the most, the generator armature is designed for this speed plus a suitable factor of safety.

The traction-motor armature in normal service attains a maximum speed of about 2,280 rpm; hence it is designed for this speed plus the usual factor of safety. The traction-motor rotation for a definite locomotive speed in miles per hour depends on the gear ratio. Table I lists all probable gear ratios found on axles having 40-in. wheels, the values of the ratios, the traction-motor speed factors, and the maximum locomotive

TABLE I

TRACTION-MOTOR SPEED FACTORS FOR FREIGHT, PUSHER, AND SWITCHING LOCOMOTIVES WITH 40-INCH WHEELS

Gear Ratio	Ratio Value	Rpm Factor	Max. Speed in Mph
65:12	5.42	45.53	45
62:15	4.13	34.70	65
61:16	3.81	32.00	70
59:18	3.28	27.55	80
58:19	3.05	25.60	89
57:20	2.85	23.94	95

speed, in miles per hour. To find the traction-motor speed, in revolutions per minute, of a locomotive with a certain gear ratio, multiply its speed, or rpm factor, by the speed of the locomotive in miles per hour.

## OPERATING THE LOCOMOTIVE

## STARTING OF ENGINE AND LOCOMOTIVE

**11. Engine-Starting Preparations.**—When about to start the Diesel engine, the position of the drain valves in the cooling-water system, the valves of the lubricating-oil system, the valves of the fuel-oil system, and the valves of the air reservoirs should be checked. The fuel-oil tanks must contain an ample amount of fuel oil and the cooling water and the lubricating oil must be at their proper levels. The lubricating-oil level in the Diesel engines, the engine governors, the fan drives, and the air compressors should be verified.

The engine cylinders are then checked for water accumulation by opening all of the cylinder test valves. The main-battery switch and the battery-charging switches in the low-voltage cabinet are closed and the isolation switch is placed in start position. The governor power piston is then held in shut-down position with the layshaft manual-control lever while the engine is turned over several revolutions by pressing the engine start button. As the engine turns over, the test valves are watched for a discharge of water or liquid and, if any valve shows a discharge, the engine must not be started until the cause of the discharge is found and corrected. If no discharge is found, the test valves are closed.

If any of the locomotive units have been out of service for repairs, the fuses are checked to see if they are in place. The control switch is then closed, and light or train-control switches are closed as required.

At the engineer's station, the throttle should be moved to idle position and the control push-button switch is now closed to energize the electric control circuit. The switch of the fuel-pump motor is pushed in to close the fuel-pump motor contactors in the engine control panels. This does not start the

fuel pumps unless the fuel-pump switches in the engine control panel are also closed. The PC switch is now reset if necessary.

The fuel pump in each unit is started just prior to starting its engine, by closing the individual fuel-pump switch. When fuel oil appears in the 5-lb relief-valve sight glass, it indicates that the fuel oil is circulating around the cylinder injectors. Only one Diesel engine is started at a time to avoid overloading the locomotive battery.

**12. Starting Engine.**—The isolation switch in the engine control panel is checked to verify its start position and the engine start button is pressed in until engine fires, provided it is not held in longer than 10 seconds (sec). If the engine does not start, it indicates something has been left undone or starting contactors may need attention. The lubricating-oil pressure will normally build up a few seconds after the engine starts, and the isolation switch is then moved to run position. The engine-water temperature must be allowed to rise to 125° F before a heavy load is placed on the engine. The main generator does not load the engine until the locomotive is moved, but the auxiliary generator, the air compressor, the traction-motor blowers, and the fan-speed increasers turn over with the engine. As the engine warms up, the throttle can be opened up a couple of positions to charge the main reservoirs more rapidly. Pneumatic controls require an air pressure of 80 lb for their operation and the engine cannot be stopped in the regular manner until this pressure is approached. Main reservoirs are charged up close to a pressure of 140 lb before any attempt is made to move the train.

**13. Moving Locomotive.**—When the air pressure is up preparatory to moving the locomotive, all hand brakes are released and, with the isolation switch in run position, the generator field switch on the controller is pushed in or closed to enable the main generator to generate current as required. The transition lever is then placed in No. 1 position and the reverse lever is placed in the position in which the locomotive is to move. The operator then depresses the deadman foot-pedal and releases the air brakes. The PC-switch setting should be

checked again and reset if necessary. If the train is long, it may take from 8 to 10 minutes (min) to release all of the train brakes. Diesel locomotives have a high starting tractive effort; hence, it is essential that the air brakes are completely released before attempting to start the train. It is rarely necessary to take slack, as this contributes to damaged couplers and parting of trains.

With the transition lever in No. 1 position, the throttle is placed in Run 1 for 2 or 3 sec and then in Run 2 for 2 or 3 sec and finally in Run 3 for 10 to 15 sec. If the train moves with the throttle in Run 3, the throttle is left in this position until all slack is out of the train. The throttle may then be moved to the required notch by pausing at least 4 to 5 sec in each position. The throttle movements are never made hastily; rather, all movements are thought out and made smoothly.

If the train does not start in Run 3 after a 15-sec pause, it may be moved to Run 4; but, as soon as the locomotive moves, it should be notched back to Run 3 until it is certain all slack is out of the train. If the locomotive stops while in Run 3, the entire starting process should be repeated. If the brakes are not fully released while in Run 4, or if the slack is not fully out of the train, the high tractive effort is likely to part the train. In any case, the throttle should not be left in Run 4 longer than 10 sec as a trial. The operator must learn to recognize brake drag and slack taking by the response of the train.

#### TRANSITION OF LOCOMOTIVE

**14. Connections of Traction Motors.**—The electrical connections of the traction motors can be changed within prescribed limits by movements of the transition lever. Acceleration of the locomotive and train is accomplished by four changes in the traction-motor connections. When the traction motors are connected in series, the full amount of current generated by the main generator passes through each motor, but the voltage output of the generator divides equally between the traction motors in the series circuit. Hence, the current or amperage is high and the voltage is low when starting the locomotive from rest, and this is an ideal connection for loco-

motive-starting purposes or for pulling at low speeds. As the tractive effort reduces as locomotive speed increases, less current is required, but the voltage increases and, as the output of the the main generator is limited to about 890 volts, a change must be made which will reduce the generator voltage and increase the amount of current for a higher locomotive speed. The generator voltage can be reduced and the current output increased by shunting resistance across the traction-motor fields. The locomotive speed can then be increased through a second speed stage before the voltage again rises to the maximum.

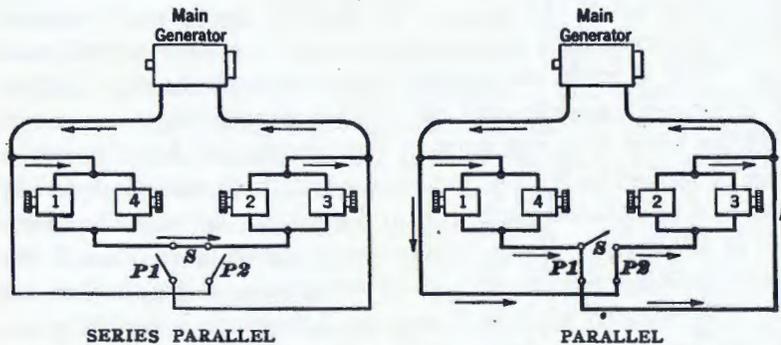


FIG. 6. DIAGRAMS SHOWING TRACTION-MOTOR CONNECTIONS

15. When the motors are connected in parallel, the current from the main generator divides equally between the motors in the parallel circuit, but the voltage does not divide and each motor receives full generator voltage. It is then possible to speed up the traction motors until the voltage rises to the voltage capacity of the main generator, or 890 volts. This then provides a third speed stage. When the point of maximum voltage is reached, the resistors are again shunted across the traction-motor fields for a fourth and final speed stage.

The traction motors of an E.M.D. freight locomotive unit are arranged in pairs as shown in the diagram Fig. 6. The No. 1 and No. 4 traction motors are permanently connected in parallel as are the No. 2 and No. 3 traction motors. Hence, the series connection mentioned in Art. 14 is in reality a series-parallel connection. Each traction motor, when connected

in series-parallel, receives one-half of the main-generator current or amperage and one-half of the main-generator voltage. When in parallel, each traction motor receives one-quarter of the main-generator current and full generator voltage. The generator current is highest at the beginning of each speed range and the voltage is lowest at this point, whereas at the end of each speed range the generator current is lowest and the voltage is highest. The ability to make changes in the traction-motor connections makes it possible to use a main generator designed for an output of about 60 per cent of the current and voltage which would be required if the traction motors were connected permanently in series or parallel. This greatly reduces the size and insulation of the main generator.

16. **Voltages at Transition Points.**—Transition is arranged to be made manually at points within a desired voltage spread for that motor connection rather than at the maximum voltage point of the main generator. When the traction motors are connected in series-parallel, the traction-motor voltage rises to about 400 volts at 580 rpm before making the change to series-parallel shunt. The generator current is then 800 volts, or about 90 volts less than its maximum voltage of 890 volts. In series-parallel shunt, the traction-motor voltage becomes 430 volts at 960 rpm, which gives a main generator voltage of 860, or 30 volts less than the main-generator maximum.

When the traction motors are connected in parallel, the main-generator voltage reaches 860 volts at 1,730 rpm of the traction motors. When the traction-motor fields are shunted again, the main-generator voltage reaches only 720 volts at 2,280 rpm, which is the maximum speed of the traction motors. As stated previously, a parallel connection of the traction motors with the main generator subjects motors and generator to the same voltage.

17. **Traction Motor Contactors.**—The *P1*, *P2*, and *S* contactors, shown in Fig. 6, are open in the off-position of the transition lever. When the transition lever is placed in No. 1 position and the throttle is opened, the *S* contactor, closes and

the traction motors are connected in series-parallel. A movement of the transition lever to No. 2 position does not change the connections shown, but the motor field shunting contactors, not shown, close to shunt resistors across the traction-motor fields. Thus, the No. 2 position of the transition lever is known as series-parallel shunt.

A movement of the transition lever to position No. 3 opens the motor-field shunting contactors and closes the *P1* contactor before the *S* contactor opens. The *P2* contactor then closes to connect the motors in parallel as indicated. When the transition lever is moved to No. 4 position, the *P1* and *P2* contactors stay closed, but the motor-field shunting contactors close again to shunt the resistors across the traction-motor fields. This position, or No. 4 position, of the transition lever is known as parallel shunt. The contactors and the traction-motor field resistors are not in or adjacent to the traction motors with which they are used. The resistors are housed in a separate cabinet with other high-voltage equipment.

**18. Transition-Lever Movements.**—The process of moving the transition lever to change the traction-motor connections to obtain the desired locomotive tractive effort and speed within the voltage and current limits of the main generator, is known as transition.

The transition-lever slot in the controller is notched on its upper and lower surfaces for the four positions of the transition lever. Two adjacent positions of the transition lever with the lever shown in cross-section are shown in Fig. 7. The lever has lugs on the top and bottom which engage the slot notches so that the lever can only be moved from one position to an adjacent position at a time. The upper lug is integral with the lever, whereas the lug on the bottom is spring-resisted so it can be depressed up into the lever.

To move the lever to the next position on the right, the lever, view (a), is lifted until the upper lug enters the upper notch and is swung to the right into contact with the edge of the notch as shown in (b). The lever is next moved down until the lower lug edges on the lower guide of the slot, and the lower lug is

compressed into the handle by forcing the handle down against the resistance of the spring. When the lug clears the upper notch, the handle is swung to the right far enough for the lower

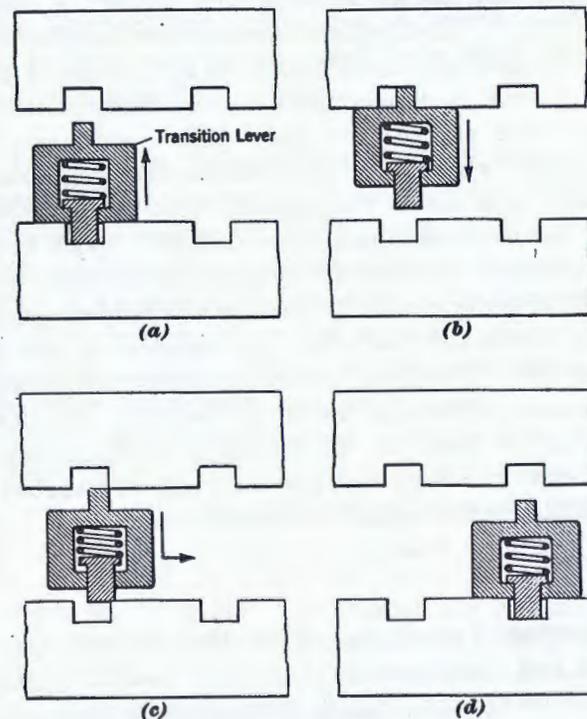


FIG. 7. MOVEMENT OF TRANSITION LEVER

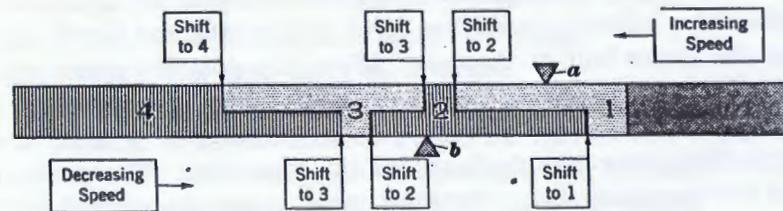


FIG. 8. DIAL OF TRANSITION INDICATOR

lug to drop into the notch of the next position as shown in (d). It will be noted that the upper lug is narrower than the lower one and the upper notch is wider than the lower notch to allow the lower lug to edge on the lower guide of the slot as shown

in (c). The transition lever cannot be moved more than one notch at a time and it is moved in accordance with the transition indicator.

**19. Transition Indicator.**—The dial of the transition indicator or meter, is arranged as shown in the drawing in Fig. 8. It is divided into four areas numbered 1, 2, 3, and 4 as shown. The No. 1 area is divided into two sections, namely, a red overload section on the right and a yellow section on the left. The No. 3 area is also yellow, whereas the areas numbered 2 and 4 are green to separate the sections from one another. The indicator has a movable pointer, not shown, which is operated by the current of the armature circuit of the No. 4 traction motor of the leading unit. The pointer therefore moves back and forth across the dial with the variation of the traction-motor current. The upper half of the dial is used in connection with increasing speeds as noted on the dial. The lower half of the dial is used in connection with decreasing speeds. A red triangle at *a* indicates the maximum continuous current of the traction motors with the transition lever in No. 1 position, and the lower red triangle *b* is used in conjunction with the dynamic brake.

**20. Forward Transition.**—When the locomotive is starting from rest and the locomotive speed is constantly increasing, the pointer on the dial, Fig. 8, moves from right to left and, as the locomotive is always started with the transition lever in No. 1 position, the transition lever is moved into No. 2 position when the pointer crosses the dividing line into the No. 2 area at the upper half of the dial. When the pointer crosses into the No. 3 area, the transition lever is moved into its No. 3 position and similarly, when pointer enters No. 4 area, the transition lever is worked into its No. 4 position. The position of the transition lever, therefore, must always correspond with the position of the pointer. This insures that transition will always occur at the proper speed of the traction motors as described in Art. 16.

The throttle setting need not be reduced when moving the transition lever, with one exception. When moving the transi-

tion lever from No. 2 to No. 3 position, the throttle setting must be reduced from No. 7 or 8 position to No. 6 or lower, because the transition lever is mechanically interlocked with the throttle in these positions to prevent an advance of the transition lever without a reduction in throttle position. The throttle position may be increased again after the transition lever is moved into No. 3 position.

**21. Summary of Events With Each Forward Transition Movement.**—The following is a summary of the events occurring for each forward movement of the transition lever.

1. From idle to No. 1 position of the transition lever or from idle to a series-parallel connection of the transition motors.

- The CS or cam-switch moves to motor position.
- The SH or generator shunt-field contactor closes.
- The BF or battery-field contactor closes.
- The S or traction-motor series contactor closes.

2. From No. 1 to No. 2 position of the transition lever or from a series-parallel to a series-parallel shunt connection of the traction motors.

- The motor-field shunting contactors close.

3. From No. 2 to No. 3 position of the transition lever or from series-parallel shunt to a parallel connection of the traction motors. The throttle must be in Run 6 or a lower position.

- The motor-field shunting contactor opens.
- The PR or parallel-relay contactor closes.
- The SH or generator shunt-field contactor opens.
- The BF or battery-field contactor opens.
- The VT or time-delay relay closes.
- The P1 or first parallel traction-motor contactor closes.
- The S or series contactor of the traction motors opens.
- The P2 or second parallel traction-motor contactor closes.
- The SH or generator shunt-field contactor closes.
- The BF or battery-field contactor closes.

4. From No. 3 to No. 4 position of the transition lever or from parallel to parallel-shunt position connection of the traction motors.

- The M or motor-field shunting contactors close,

**22. Maximum Current During Deceleration.**—A locomotive pulling a heavy load can operate at speeds approaching the maximum on level track. At maximum speed the traction motors are connected in parallel-shunt, and the voltage of the traction motors and of the main generator is at the maximum but the current is low. As the train encounters a grade, the pulling resistance increases and the traction motors take an increased current and, as the traction motors slow up under the increased torque, the voltage drops. As the generator current is equal to the sum of the current used by the four traction motors, it is evident that a higher motor torque increases the generator current rapidly and, if the grade is of considerable length, the generator will become overloaded. With the motors connected in parallel-shunt, the maximum generator current is approached when the traction-motor speed falls to about 1,475 rpm. At this point the traction-motor shunt resistors are dropped out, leaving the motors in parallel. When the shunt resistors are dropped out, the current required for each motor is reduced and the generator again operates at a safe current value. When the motor speed falls to about 790 rpm, the torque has increased to such an extent that the generator current is again near its maximum and the connections of the traction motors are changed to series-parallel, and a shunt is again connected across each traction-motor field. The main generator now supplies only two pairs of traction motors in parallel and, with the shunt in the traction motors, the generator is called upon to supply less than half the current supplied prior to the change. If the grade continues and the locomotive fails to hold its speed, the shunt resistors are again dropped out when the traction-motor speed drops below 580 rpm. The traction motors are then in series-parallel. If the load or the grade is heavy enough to reduce the traction-motor speed below 440 rpm with full throttle, the locomotive is overloaded and, if continued at this speed over too long a period, the electrical equipment will become overheated and will likely fail or burn out. The manufacturers have established a time limit for various conditions on certain loads. This time limit should be complied with, or it will likely result in a necessity for costly repairs.

**23.** It is evident from the foregoing that the traction-motor connections are changed during increasing speeds because of the voltage limits of the main generator, whereas the connections are changed during decreasing speeds because of the maximum current limits of the main generator. The turning torque decreases with increasing speeds, with a resulting drop in traction-motor current, and, when the voltage reaches its maximum value, any increase in locomotive speed will cause the generator to unload and the voltage will drop; hence, it is not likely to damage any of the electrical equipment unless the motor armature is damaged by excessive centrifugal force.

**24. Backward Transition.**—When the train speed decreases owing to a heavy pull on a grade, the lower half of the indicator dial is used to indicate the proper position of the transition lever. The transition lever is moved from No. 4 position to No. 3 position as the pointer of the indicator crosses from area 4 to area 3 on the dial. As the indicator crosses from area 3 into area 2, the throttle setting must be reduced to Run 6 or lower before the transition lever can be shifted from position 3 to position 2. If the pointer continues to move to the right into area 1, the transition lever is also moved to position 1 to correspond. The pointer should not pass to the right of the upper red triangle *a*, Fig. 8, or be allowed to remain there for any length of time, except in special cases where calculations of the manufacturer have indicated that it is permissible or for an instant while shifting the transition lever from position 2 to position 1.

If the pointer remains to the right of the upper red triangle with the throttle in Run 8 and the transition lever is in position 1, the train tonnage should be reduced except where the manufacturer's calculations allow the overload to continue for a specified length of time. However, if a helper locomotive is provided so that the pointer can be carried to the left of the upper red arrow, it will not be necessary to reduce the tonnage.

**25. Summary of Events for Each Backward Transition Movement.**—The following is a summary of the events occurring for each backward movement of the transition lever.

1. From position 4 to position 3 or from parallel-shunt to parallel.

The M or traction motor field shunting contactors open.

2. From position 3 to position 2 or from parallel to series-parallel shunt. The throttle must be in Run 6 or a lower position.

The PR or parallel relay opens.

The SH or generator shuntfield contactor opens.

The BF or battery-field contactor opens.

The VT or time-delay relay opens.

The P1 or first parallel traction-motor contactor opens.

The S or traction-motor series contactor closes.

The P2 or second parallel traction-motor contactor opens.

The SH or generator-field shunting contactor closes.

The BF or battery-field contactor closes.

The M or traction-motor-field shunting contactors close.

3. From position 2 to position 1 or from series-parallel shunt to series parallel.

The M or traction-motor field shunting contactors open.

4. From position 1 to off or traction-motor circuit open with throttle in idle position.

The S or traction-motor series contactor opens.

The SH or generator-field shunting contactor opens.

The BF or generator-battery-field shunting contactor opens.

*Note.*—The SH and BF contactors open or close together.

**26. Transition Movements on MPH Basis.**—The transition indicator dial is calibrated so that manual transition will be made at points close to the maximum generator voltage and current capacities of the main generator, which occur at definite traction-motor speeds as described in Art. 16. If at any time the transition indicator does not function properly or if the lead unit has been isolated, it will be necessary to make transition by reference to the locomotive speed, which varies in proportion to the speed of the traction motors. The speed of the loco-

tive compared with that of the traction motors varies according to the gear ratio used. Table II shows the approximate locomotive speeds, in mph, at which transition should occur. Transition movements, however, are always made in accordance with the transition indicator when the indicator is functioning properly. The maximum permissible speed and the minimum speed with maximum load when throttle is in Run 8 are also listed in the table.

**TABLE II**  
LOCOMOTIVE SPEEDS IN MPH WITH 40-IN. WHEELS

Move Lever from Position	to Position	Gear Ratio					
		65:12	62:15	61:16	59:18	58:19	57:20
		At Miles per Hour					
1	2	15	19	21	24	26	28
2	3	22	28	31	36	38	41
3	4	40	53	58	67	72	77
4	3	36	47	51	59	64	68
3	2	19	25	28	32	34	37
2	1	15	19	21	24	26	28
Maximum Speeds } Position	4	45	65	70	80	89	95
Minimum speed with maximum load and throttle in Run 8	}	11	14½	15½	18	19	21

No damage will result in failing to advance the transition lever with increasing speeds, because the main generator unloads and the voltage drops; but the electrical equipment will be overloaded and serious damage might result if the lever is not backed off at the point indicated when the locomotive speed is decreasing owing to a grade. The transition lever should be in No. 1 position before the locomotive comes to a stop. The lever is never moved more than one notch at a time.

**27. Wheel Slippage.**—On a heavy pull, one or both pairs of wheels in a truck may slip and cause the wheel-slip light to flash about once a second. The wheels will slip intermittently because the wheel-slip relay will reduce the power automatically

when the wheels slip. The reduction is only temporary, however, and the wheels will slip again when the power picks up; hence, the throttle setting should be reduced. Sand should not be applied to the wheels until the slipping has been stopped by reducing the throttle setting. The throttle may then be advanced again after the sanding has been started. With the 16 pairs of driving wheels on the 5,400-hp locomotive, sanding is necessary only under the very worst track conditions. Sand is very injurious to the traction motors; therefore, it should be applied sparingly and only after the wheel-slip light flashes. When the wheel-slip light flashes, it is possible that only one pair of wheels slip as the slipping of any wheel in the locomotive will flash the warning light in the engineer's cab. Under these conditions a wheel-slip indication usually means only a partial and temporary loss of tractive effort.

28. When it is necessary to keep the train stretched on a rolling grade with the train air brakes and the power on, the throttle should be reduced to at least Run 6. The locomotive brakes must be held in release when the locomotive is supplying power. When preparing to stop with the brakes and power on, it is necessary to reduce the throttle as the train speed decreases, because of the great pulling power of the locomotive at lower speeds. The throttle should always be moved to idle about 100 ft before a dead stop.

When crossing rough sections of track, such as railroad crossings, the traction motors will shake and vibrate to cause serious sparking of the brushes on the commutators if they are subject to a high current. If the throttle is reduced to Run 5 or lower while the power trucks are crossing the rough track, a minimum of current will be used and the sparking will be eliminated. The throttle should always be reduced at least one notch if it has been in Run 5 or 4.

When the locomotive consists of only an A and B unit the field loop jumper cable at the rear end of the second section must always be removed from its receptacle. A shorting bar is inserted in the receptacle to close the circuit. Clamps on the receptacle should be kept tight.

29. **Dynamic Braking.**—The transition braking lever also controls the dynamic brakes on the locomotive. The transition braking-lever slot in the controller contains a stop that separates the power movements from the braking movements. When braking is required, the throttle lever is moved to idle position and the transition braking lever is lifted over the stop to "off" braking position. After a delay of a few seconds the lever may be moved to the B-position to bunch the train slack gradually. The initial strength of the brake depends on the train speed, and the same care is used in applying the dynamic brake as is used when using the independent air brake. After the slack has been bunched, the lever can be moved counterclockwise for increased braking as desired. The pointer of the transition-meter dial, Fig. 8, indicates the traction-motor current when braking as well as when motoring. The lower red triangle of the meter indicates the maximum allowable motor current while braking, and the pointer should not move to the right of this mark. If the transition indicator is disregarded and the dynamic braking is excessive, the brake overload warning light on the transition-indicator meter will flash at the danger point and it will be necessary to apply the train air brakes until the light goes out. If the dynamic braking lever is backed off without applying the train brakes, the light will go out only for a moment, as the train speed will then increase and bring the motor current back to the high limit. Hence, the train brakes must be used when the warning light operates, and the air brakes on the locomotive are kept released to avoid wheel slide. The unit selector switch must always be set before beginning the trip and never disturbed during dynamic braking.

In the event the overload light comes on before the meter pointer reaches the red area, the train brakes should be applied to reduce the current, because the overload light is a clear indication of excessive current, and operating with it on may damage the motor and braking grids.

30. The braking effect of the dynamic brake decreases with the locomotive speed; hence, it is not practical to use

the dynamic brake to bring the train to a full stop because of the time it would consume. The dynamic brake is not very effective at speeds below 10 mph and the train is stopped with the air brake. The air brake on the locomotive and the dynamic brake should never be applied together except at low speeds because of the possibility of sliding the wheels.

The dynamic brake can be made inoperative on any unit by placing the isolation switch of that unit in the start position. The switch should not be opened while the transition lever is advanced to the right beyond its B-position except in case of an emergency. The isolation switch should not be closed to running position while the dynamic brake is in operation. If this precaution is not observed, the brake on this unit would result in an overload of the electrical equipment and the possibility of sliding the wheels. The braking power must be reduced to B-position before opening or closing an isolation switch.

**31. Isolating Power Plant While Braking.**—Isolation of a power plant while braking may become necessary owing to the failure of a Diesel engine. The engine is stopped by using the layshaft manual control lever in the usual manner and the fuel pump is turned off. The isolation switch on the engine control panel is then moved to start position. This opens the braking contactors, but the main-generator battery field is connected in series with the other generator fields throughout the locomotive. The position of the unit selector switch must not be changed.

**32. Stopping of Engine.**—When the locomotive is not to be used for some time, the engine should be stopped to avoid unnecessary wear and waste of fuel oil. To stop the engine, close the throttle to idle position and place the transition lever on the braking side of the stop and in off-position. The reversing handle is moved to neutral position and the handle removed. The generator-field switch is opened, but the control switch is kept closed, as it is impossible to shut down the engine with the stop button without the control. At the engine control panel the isolation switch is placed in start position and the

engine stop button is held in until the electro-pneumatic governor control causes the injectors to cut off the fuel oil from the cylinders and the engine comes to a complete stop. The fuel-pump switch is then opened to stop the fuel-pump motor. At the engineer's control station the control switch and the fuel-pump switch are opened, and at the distribution panel the main-battery switch and the control switch are opened.

**33. Trailing a Control Section.**—When a control or cab section at the rear of a 5,400-hp locomotive is used in the make-up of a locomotive, the various controls must be set in a manner to cause no interference with the controls of the leading section. The throttle is set in idle position and the transition braking lever is placed in off-position. The control push button is pulled, and then all remaining push buttons are pulled and the locking pin on the switch box is lifted. The reversing handle is placed in neutral and removed. The automatic brake valve is pinned in running position and the handle of the independent brake valve is removed. The double-heading cock on the brake valve is closed and the distributing valve is placed in "live" engine position.

**34. Towing of Locomotive.**—If a locomotive is to be towed by other power, the transition braking lever must be moved to off-position before the control button is pulled, in order to place the cam-switch in tow position. The traction motors will generate and hold back the locomotive if it is pulled with the cam-switch in motor (mot) position. The reverser drum should be locked in neutral position if the locomotive is to be towed in a train for any appreciable distance. A threaded locking pin is turned into the left-hand side of the reverser during normal operation. This is removed and inserted in the hole in the opposite side, and the drum is turned to its neutral position by hand so the pin will engage with the threaded hole in the shaft. The reverse lever is kept in off-position.

The engine isolation switches are placed in start position and, if it is necessary to keep engines idling for any reason

while towing the locomotive, the fuel pump and control switches may be left in closed position. When a B unit is separated from an A unit or when the jumper connectors between A and B units are removed, the cam-switch of the B unit must be placed in the tow position. If the cam-switch is left in mot position, the traction motors will regenerate and cause the wheels to slide.

**35. Isolating Power Plant Under Power.**—When an engine becomes inoperative while the locomotive is operating under power, it should be taken off the line. To do this, the speed of the engine is reduced with the layshaft manual control lever so that the traction motor contactors will not have to break the full motor current. The isolation switch is then placed in start position and the engine stop button is pushed to stop the engine. The fuel pump is then turned off. If the power plant of the leading section is isolated while the locomotive is under power, the transition meter will not function and transition changes must be made in accordance with the speedometer readings listed in connection with Art. 26. The exact speed at which each transition move is made depends on the gear ratio, which may vary on each locomotive.

**36. Placing Engine Back on Line.**—To place the engine back on line with the locomotive working, start the fuel pump and place the isolation switch in start position. The engine is then started by the starter button in the usual way. When lubricating-oil pressure builds up, the isolation switch is placed in run position. If the throttle is above Run 3, the governor injector linkage should be held off and released gradually to allow the engine to speed up gradually when starting, to the same speed as the other engines.

**37. Pumping Up of Main Air Reservoirs.**—When placing the locomotive back in service after the air reservoirs have been drained, the hand brakes should be set and all drain cocks closed. The reversing handle is placed in neutral position and the pneumatic control switch is set. The engines are started in the usual way but the generator field switch is not closed. The engines

are then allowed to idle for at least 5 min. After the transition lever is placed in No. 1 position, the throttle can be opened to increase the engine and compressor speeds, if necessary.

When the locomotive has been coupled to the train, the train line may be pumped up more rapidly by placing the reversing handle in neutral position, pulling out the generator field switch and placing the transition lever in No. 1 position. The throttle can then be opened to increase the engine and compressor speeds to the point desired for rapid pumping. This is seldom required because of the number of large air compressors provided on freight locomotives.

If the air pressure does not build up, the position of the angle cocks and the main-reservoir drain valves should be checked to see if they are in the proper position. The main-reservoir safety valve may be stuck open and, if so, a light tap may seat it. The filter and air-compressor governor should be blown out regularly.

**38. Engine-Starting Troubles.**—Engine-starting troubles are due mainly to defects in the electrical starting equipment, when the engine will not rotate, or to fuel-oil supply difficulties if the engine will rotate but not fire.

When the engine will not rotate, the customary sequence of operations used in starting the engine should be checked or repeated to insure that they have been made in the proper order. All fuses in the circuit should be checked for loose, missing, or burned-out fuses and if any defect is corrected an attempt should be made to restart the engine at once. The battery should be checked for power by turning on the engine-room lights and noting the extent of the dim-out when the starter button is pressed. Weak batteries should be replaced with fully charged batteries. If the starting contactors at the bottom of the low-voltage cabinet do not go in, they are defective. Assuming all other equipment is in order, the engine may be started in emergency by forcing the contactors into contact with the aid of two dry wooden blocks. The contactors should be held in tightly until the engine starts and picks up to a point near idling speed. The operator's eyes should be

averted to avoid possible harmful effects of the flash, which may occur when the contactors are released.

**39.** When the engine rotates but does not fire, the cylinder test valves at each cylinder should be checked to make sure they are closed. The 5-lb fuel sight glass should be checked to determine if the fuel oil is reaching the injectors and, if no fuel is showing, the fuel-pump switch, its fuse, and the fuel-pump unit should be examined to see if everything is in proper order. The fuel-pump shaft and its coupling may be defective or disconnected. The fuel supply should be checked and the position of the emergency fuel cut-off valve should be noted and corrected if closed. The injector linkage may be stuck in shut-down position or the overspeed trip shaft may not be latched in run position.

**40. Engine Fails to Stop.**—If the engine fails to stop with the throttle in shut-down position, check the linkage for binding or for improper governor control, faulty governor, or defective master "E" valve or "D" valve. The engine may be stopped with the layshaft manual control lever if the trouble can not be found readily.

**41. Cold Starting.**—If the engines will be required to stand longer than an hour, they should be shut down and restarted to allow sufficient time to pump up the necessary air if it has dropped below operating pressure. Cold engines that may have stood overnight, or the equivalent, should be idled approximately  $\frac{1}{2}$  hr with all shutters closed and fan clutches disengaged so that the engine will warm up in a minimum time. In this event, the air pressure will be up when the engine is warm.

**42. Running Through Water.**—Water up to 3 in. above the track can be passed through at speeds up to 3 mph. The locomotive must not be allowed to pass through water which is deep enough to touch the bottom of the traction-motor frames, as it will cause damage to the traction motors.

**43. Locomotive Starting Troubles.**—If the locomotive will not start when the throttle is opened, the pneumatic control

switch should be checked. The button should be pulled out to reset the control switch. The movements to release all hand and air brakes should be repeated and the brake shoes should be examined, if necessary, to insure that release has actually taken place. The generator-field switch at the control station should be checked to see if it is closed, and the fuse should be checked to see if it is in good condition. The electric-control air pressure should be up and the reversers and cam-switch should be checked to see if they are in proper position. The ground protective relays should be checked for proper position. Fuses, including the 60-amp control fuse on the distribution panel, the 30-amp control fuses opposite the control switch, the 80-amp battery field fuse in the low-voltage cabinet, and the 15-amp generator field fuse in the control switch box, should all be checked. The battery field contactors may be open or making poor contact and, if the starting contactor sticks shut, the generator of that engine will not deliver power. Some of the items listed will also cause a loss of power on the engine affected and a slow acceleration.

**44. Loss of Load on Engine.**—The loss of load on an engine may be detected by comparing the load indicator on the governor with the indicator on the back of the electro-pneumatic governor control after the engine and generator have had a chance to balance up. If the indicator on the governor is low, it may show that the motors across the generator are in series-parallel while all the other power plants are in parallel, or that the BF or SH contactors are open, a condition which may be caused by tripping of the ground relay, the starting contactor interlock open, or a stuck wheel-slip relay.

A low indicator on the governor may also disclose that the battery field fuse is blown or that contacts any place in the power or generator field circuits are dirty or poorly made. The power plant on which these defects are to be corrected must be isolated.

The engine overspeed trip on the engine cam-shaft may have operated if the engine even momentarily attained a speed of approximately 880 rpm. Overspeeding may be caused by a

sudden loss of electrical load, such as a wheel slipping or a ground relay tripping. The overspeed trip may be reset by turning the reset lever in a counter-clockwise direction until the trip mechanism latches in its normal position.

**45. Battery Ammeter Reading.**—When the battery-charging ammeter indicates no charge, the 30-amp auxiliary generator field fuse and the 150-amp battery-charging fuse in the low-voltage cabinet should be checked. The auxiliary-generator drive belts may be loose or broken. In the event the trouble proves to be elsewhere, the maintainer should be notified and the condition corrected.

**46. Locomotive Stops Suddenly During Operation.**—If the locomotive suddenly becomes inoperative, the fuses on the distribution panel and those in the box on the control station should be examined. The air pressure must be maintained or the air-operated contactors will become undependable. The leads on some of the electrical equipment may become loose or broken or the fuel supply may have failed. If the locomotive moves with a jerky, uncertain motion, the battery- and generator-field contactors may not be closing tightly or some pieces of equipment may be flashing over. The fuel supply may have failed or the PC switch may have opened.

**47. Exhaust-Smoke Indications.**—An occasional observance of the engine exhaust will often reveal defects in the performance of the various power plants. A light exhaust smoke may appear on locomotives with light loads or before engines are thoroughly warmed up, but constant smoke at the exhaust is usually an indication of poor combustion of fuel or an excess of lubricant passing into the combustion chamber. Fuel in a partly burned condition will cause a black exhaust and if the fuel is not properly ignited the exhaust may be blue. Improper fuel, incorrect timing, faulty injectors, insufficient air, or misfiring may also be the cause of exhaust smoke. A continuous engine overload due to improper pilot-valve adjustment, plugged pilot-valve feed line, or an inoperative load regulator may also cause smoke at the exhaust.

**48. Lack of Power.**—A lack of power in the engine may be due to poor combustion, insufficient air, lack of fuel or poor fuel, restriction in exhaust, incorrect timing, or leaky exhaust valves.

A low generator-field excitation, due to a faulty connection in the generator battery-field circuit, may be the cause of a lack of power in the electrical system. A faulty auxiliary generator or voltage regulator, a weak battery or an open generator-field contactor may also cause a low generator-field excitation. Other defects causing lack of power may be due to faulty traction motors, generators, or traction-motor contactors, a faulty load regulator, or pilot valve, or improper setting of pilot-valve linkage.

**49. Control-Station Interlocks.**—When controls must be operated in a definite sequence to avoid damage to electrical or mechanical equipment, they are provided with interlocks. The reversing handle can be thrown only with the transition braking lever in either No. 1 or off-position and it can be removed from the control stand only when the transition braking handle is in off-position.

The transition braking lever can be moved into dynamic braking only when the reversing handle is in forward position. When the transition braking lever is in braking or off-position, the throttle cannot be opened.

The throttle can be moved to off with any position of the transition braking or reversing lever, but the transition braking lever cannot be moved from 2 to 3 or from 3 to 2 with the throttle in position 7 or 8. Any power transition braking lever movement can be made in regular order when the throttle is in position 6 or lower.

**50. Operating Precautions.**—The economical operation of the power plants of the locomotive are dependent on proper engine temperatures, ample lubrication and fuel oil, a fully charged locomotive battery, and a control-air pressure ranging between 77 and 83 lb. The engine water temperature must be maintained within 15 degrees of 165° F by regulation of the

air shutters and cooling fans. The ideal lubricating-oil pressure is about 28 lb at full speed (800 rpm), and it should not be allowed to drop below 20 lb unless the cooling-water temperature can not be held below 180° F because of abnormal conditions. In the case of a hot engine, the engine should be stopped when the lubricating-oil pressure drops to 15 lb. The trouble can then be located and remedied before the low oil-pressure switches operate and cause delay. The piston cooling oil must be maintained at pressures between 20 and 30 lb at full speed. If the pressure drops to 15 lb, the cause should be investigated and corrected at once.

51. The fuel sight glasses should be observed occasionally so that it is known that an adequate supply of fuel is reaching the cylinder injectors. The battery-charging voltage is 74 and the ammeter should be observed periodically to note the charging rate. The specific gravity of the battery liquid should never be allowed to fall below 1.230.

All V-belts should be observed at regular intervals and the tension adjusted when necessary. The wear on the belts must be held within limits and the belts should be replaced when wear is excessive.

52. The traction-motor blowers must be checked periodically so that they may be maintained in excellent condition. If blowers are not efficient, the traction motor affected will overheat and will likely burn out; hence the power plant must be cut out of service if the blower cannot be properly serviced.

When a locomotive is made up of a unit with a variable dynamic brake and one with a non-variable or two-position dynamic brake, the dynamic brakes must not be used under any circumstances.

#### ENGINE WATER COOLING SYSTEM

53. **Description of Cooling System.**—The cooling system controls the operating temperature of the Diesel engine within predetermined limits. The cooling systems of the various engines in locomotives are independent of each other. The design is such that the water in the cooling system drains from

the radiators when the engine is shut down. Freezing of the radiators is thereby prevented during cold weather when the system is heated by steam. At this level, expansion overflow and loss of radiator compound is eliminated during operation. The expansion is approximately 15 gallons (gal). A water-level gage allows a visual indication of loss of water, and the necessity of filling the cooling system to overflow to determine the water level is eliminated.

Distilled water should be used in the cooling system to offset the accumulation of scale and foreign matter which contribute to overheating the engine.

54. A diagram of the cooling system in a leading section of a freight locomotive is shown in Fig. 9. It consists of a water tank combined with the lubricating-oil tank and cooler, two engine-mounted water pumps, and four groups of cooling radiators in the roof of the locomotive and the necessary connecting piping to circulate the water through the system and return it to the tank. The cab of the control section is heated by cab radiators, which are part of the system, but in other respects, the cooling system of the second section is similar.

55. **Operation of Cooling System.**—Water is drawn from the water tank, which is part of the oil cooler, water tank, and filter assembly, Fig. 9, by centrifugal water pumps located on the front end of the engine. These pumps circulate the water to the bottom of each cylinder liner, up through the cored passages of the cylinder liner and cylinder head, and out through the outlet manifold. From the engine, the water flows to four groups of radiator sections located under the roof of the locomotive. Here the water is cooled and returned through the oil cooler to the water tank.

The water-temperature gage provides a means of checking the temperature of the water in the cooling system. The ideal temperature is 165° F. While the manufacturers recommend an operating temperature of 150° F to 180° F, higher temperatures are not detrimental to the engine, if the water is not permitted to boil away. However, for best operating



**59. Checking Circulation.**—The water-temperature gage on the water tank may be used as a means of detecting an irregularity in the operation of the cooling system. High engine-water temperatures may indicate that the fan clutches are not engaged, that the shutters are not open enough, or that there is insufficient water or faulty circulation in the system.

**60. Draining of Cooling System.**—To drain the engine cooling system, open drain valves E, G, and H, Fig. 9.

To drain the complete water system in freezing weather, open valves as above, and remove drain plugs, not shown, from cab-heater lines and water pumps. The cab-heater drain plugs are  $1\frac{1}{4}$ -in. pipe plugs located under the rear of the cab floor, to the right and left of the steps leading into the cab. All other valves should be checked for trapped water in pipe lines.

**61. Freezing-Weather Precautions.**—Do not use any kind of antifreeze solution in the cooling system. If the locomotive is to be left standing where there is danger of freezing, steam may be supplied to the cooling system, or the system can be drained.

For supplying steam to the cooling system, each power plant has a connection with the main steam line through check-valves and globe valves A and D, Fig. 9. Check-valves prevent the water from draining into the steam line. Steam can be supplied by connecting an outside steam line to the train steam-line connection at the end of the locomotive, or by operating the steam generator, on locomotives so equipped.

When using an outside source of steam to heat the locomotive cooling systems, the steam line can be connected to the plugged steam-line connection at the front of the A unit. If a single unit is being heated, the steam line can be connected to the connector at the end of the unit. The train steam-line valve should be opened. Valves A, B, and D should be opened. Valve G must be opened so that the condensation will run out and not fill the radiators. When disconnecting the units from the steam feed, see that the steam valves are closed to prevent loss of water through the check-valves.

**62. Cooling Fans and Belts.**—A 90° bevel-gear drive and clutch at each end of the power plant operates a pair of cooling fans. The fans revolve at a speed of 1,200 rpm when the engine is turning 800 rpm.

One fan in each pair is driven directly by the vertical drive shaft. The second fan is driven by endless Vee belts off a sheave on the hub of the first fan. In the event a belt breaks a complete matched set should be installed.

**63. 90° Fan Drive.**—The 90° fan-drive unit is commonly called a "speed increaser" because it increases the speed of rotation of the fans at a ratio of two to three over the speed of the engine. A lubricating-oil pump, sight glass, strainer, and oil reservoir are self-contained within the unit. The oil level is checked with a bayonet gage. Pump operation can be determined by observing the oil in the sight glass.

**64. Fan-Clutch Operation.**—The cooling-fan drives are equipped with friction clutches. These clutches are not to be used in place of the shutters for adjustment of the engine temperature, but should be engaged or disengaged according to the outside temperature.

When the outside temperature drops so low that it becomes difficult to maintain the recommended engine temperature, the clutch at the front end of the engine should be disengaged. Close the shutters at this end and control the engine temperature by adjusting the shutters at the other end.

The engine-room temperature can be raised, when this clutch is disengaged, by removing the man-hole covers at the front end of the engine. This allows air to be drawn down through the warm radiators and into the engine room.

In cold weather, when warming up the engines after a layover, or if the engine temperatures cannot be maintained when idling, both clutches may be disengaged. Before loading the engine, one or both clutches should be engaged, depending on the outside temperature. In order to prevent damage to the clutch and fan assembly, the clutch *must not* be engaged with the engine above idle speed. When extreme cold weather is encountered, it may be necessary to operate with both clutches disengaged.

**65. Clutch Alinement.**—It is important that the alinement of the drive shaft from the engine and the speed increaser shaft carrying the clutch be held within reasonable limits to prevent excessive movement between the external teeth on the driven plate and the internal teeth of the drive housing.

Since the two shafts are piloted on a self-aligning bearing, no adjustment for radial alinement is necessary on the accessory-drive end.

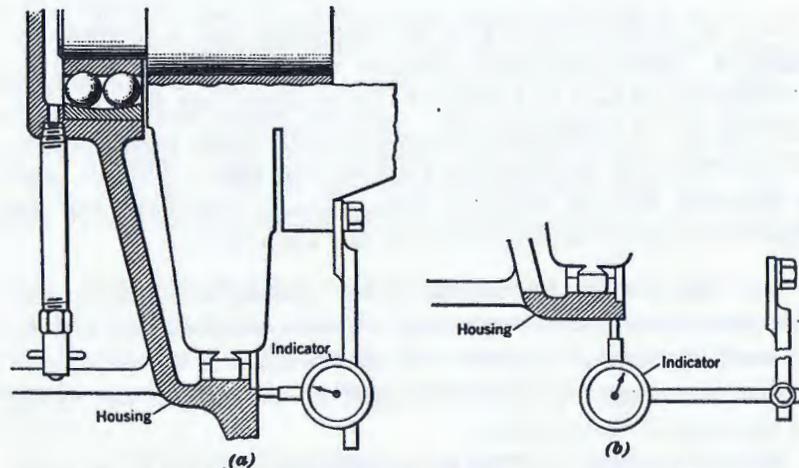


FIG. 10. CHECKING ALINEMENT OF SPEED-INCREASER DRIVE

To check the angular alinement, attach a dial indicator as shown in Fig. 10 (a), and *with the clutch engaged* rotate the engine. If the dial indicator is set at zero at the top, the indicator should not read more than .005 in. when the engine is turned through a complete revolution. Shims .005 in. thick under the speed increaser will correct the alinement so the indicator will read within .005 in.

The clutch on the compressor end does not have the two shafts piloted; hence, the radial alinement must also be checked. The indicator is set to indicate the outside diameter of the housing as shown in Fig. 10 (b). The run-out must not exceed a total indicator reading of .010 in.

**66. Clutch Adjustment.**—The twin disk clutches on the cooling-fan drive, Fig. 11, can be adjusted by removing the

guard around the adjusting yoke. The engine is turned with the bar until the lock-pin can be reached and pulled out. The yoke is then turned clockwise to tighten the adjustment or counter-clockwise to loosen. When properly adjusted, the hand lever will require a distinct pressure to engage. A new clutch may require several adjustments until the clutch facings wear in.

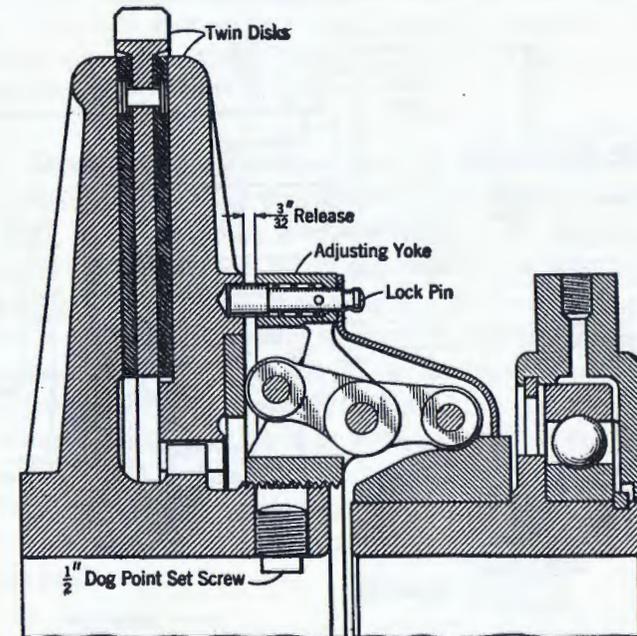


FIG. 11. FAN-DRIVE CLUTCH ADJUSTMENT

**67. Cab-Temperature Control.**—The temperature of the cab can be controlled by valves B in Fig. 9.

The cab heaters operate on hot water from the engine cooling system and are equipped with a motor-driven fan for maximum radiation and circulation.

#### FUEL-OIL SYSTEM

**68. Purpose.**—The fuel-oil system carries the fuel oil required for combustion in the Diesel engine and delivers it to the cylinder injectors in a clean condition at a rate in excess

of the amount used. Excess oil is returned to the tank. The fuel-oil systems in A and B units are independent and identical.

A schematic diagram of the fuel-oil system is shown in Fig. 12. The system comprises a 1,200-gal fuel-oil tank with two sumps and a sight fuel-level gage, a suction line filter, a duplex fuel-oil pump, a Ful-Flo filter, an engine-mounted duplex filter, a fuel-oil injector for each cylinder, a relief-valve sight-gage assembly and the necessary connecting pipes as shown.

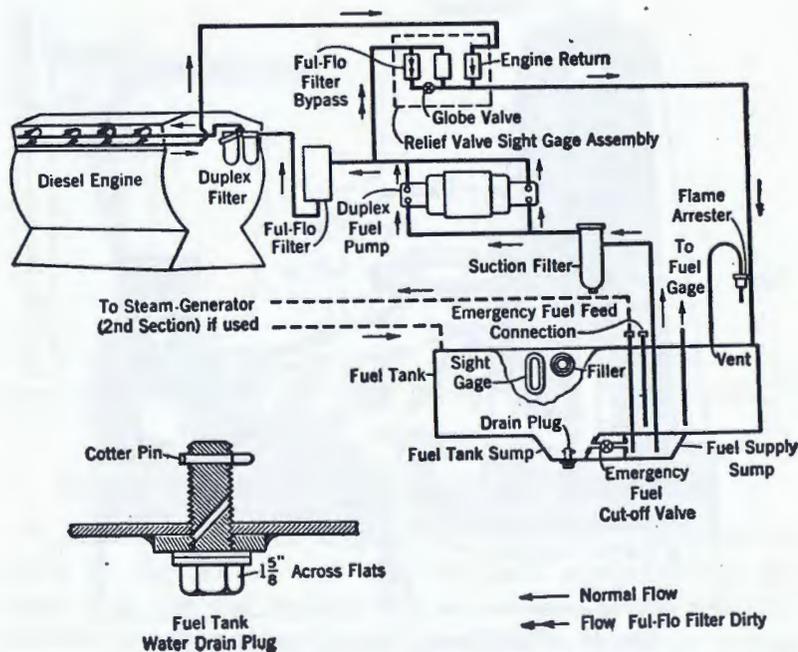


FIG. 12. DIAGRAM OF FUEL-OIL SYSTEM

The fuel-tank sump and the supply sump are connected through an emergency fuel cut-off valve. The fuel can not be drawn from the supply sump unless the emergency cut-off valve is open. The fuel tank is vented at each side of the tank, and the vent pipes are capped with 4-in. flame arresters.

The fuel pump draws fuel oil from the supply sump through a suction line and filter. After discharging from the pump, the fuel is forced through the filters to the injectors. The injectors use only part of the fuel pumped through them. The

surplus fuel oil lubricates and cools the internal mechanism of the injectors and then returns to the fuel tank through the 5-lb relief valve. The use of the correct grade of fuel oil is of the utmost importance.

**69. Filling Fuel Tanks.**—The fuel tanks can be filled from either side of the locomotive at a maximum rate of 250 gal per minute. Watch the level gage to prevent overflowing the tank. The fuel should be filtered through a reliable fuel filter before it enters the tank. Fuel oil must not be handled near an open flame.

**70. Draining Fuel Tanks.**—The fuel-tank sumps have two drain plugs for draining the tank and for draining any water that may have settled in the tank sump. By turning one of these plugs part way out, water can be drained from the sump.

Locomotive fuel-tank sumps and the fuel storage tanks should be drained periodically to prevent excessive accumulation of water. The drain plug should be removed from the supply sump occasionally for draining sediment.

During freezing weather it is good practice to put 3 to 5 gal of alcohol in the locomotive fuel tank. The alcohol will settle in the tank sump and prevent the water from freezing. If conditions warrant, it is advisable to add alcohol to the fuel storage tank.

**71. Fire Protection.**—Diesel locomotives have proved to be more vulnerable to fire hazards than the steam locomotives, but if the Diesel locomotives are kept free from oil and oil-saturated dirt both on the interior and exterior surfaces, the danger from fire hazards will be greatly eliminated. The engine rooms and the cab should be kept spotlessly clean at all times with clean lintless cloths, which should be removed after the cleaning has been done. Oily waste should not be used at any time, as lint from the waste is a fire hazard and the lint will be deposited on surfaces where it may find its way into the fuel-oil systems. Sparks from open wiring should also be guarded against.

The danger of fire from brake-shoe sparks should be foreseen and the underframe, fuel tanks, traction motors, and truck frames should be kept free from oil-impregnated dirt. The fuel tanks on some roads are protected from flying fragments from brake shoes or other small metallic parts that have been known to puncture the tanks or cause leakage of fuel oil. The locomotive should be provided with plenty of fire extinguishers and they should be located at convenient points.

In the event of fire, an emergency fuel cut-off valve is provided to cut off the fuel supply to the fuel pump. The valve is located in the feed line from the fuel-tank sump to the supply sump on freight locomotives.

On each side of the locomotive, attached to the underframe, is a small red box with a lift cover. Enclosed in this box is a pull ring on the end of a cable running to the fuel cut-off valve. A similar ring is located in each cab. The valve can be closed, and the fuel cut off, by pulling any one of these three rings. If closed, the valve underneath the fuel tank must be reset by hand to the open position.

**72. Suction Filter.**—Before the oil enters the supply pump, it passes through the Purolator filter, which has a .003-in.-spaced wire-wound drum. The handle that operates the drum scraper should be turned every hour while the engine is running. The filter housing should be drained monthly with the pump shut off.

To clean the element, wash it in a petroleum solvent and blow, in a direction opposite to the fuel flow, with clean, dry compressed air. Recent locomotives have a waste-packed filter in place of the screen Purolator. The pack is not cleanable and must be replaced when dirty.

**73. Ful-Flo Filter.**—The Ful-flo filter is connected between the fuel pumps and the sintered-bronze filter. Inside the filter housing are three elements made of closely wound string. When the 60-lb sight glass shows fuel by-passing, turn the handle on the duplex filter to determine whether it is the duplex or the Ful-flo filter that needs cleaning. If the Ful-flo filter is dirty,

all three elements should be replaced and the drain plug at the bottom removed. After reassembling the filter, trapped air should be vented through the valve on the top with the fuel pump in operation.

**74. Duplex Sintered-Bronze Filter.**—The duplex sintered-bronze filter is mounted on the front end of the engine. The two sintered-bronze elements are connected by a three-way valve so that the flow of fuel through the filter can be controlled by the position of the valve handle. When the handle is moved to the left, the left-hand element is cut off and fuel flows through the right-hand element. Moving the handle to the right cuts off the right-hand element. The handle should be to either the left or the right so that only one filter element is in use at a time.

If the element in use becomes dirty, fuel will flow through the 60-lb sight glass. Should this occur, turn the handle to the opposite side. If this does not correct the condition, it will indicate that either both elements are dirty or the Ful-flo filter ahead of it is dirty.

**75. Injector Filters.**—From the duplex sintered-bronze filter the oil flows to the fuel manifold on the engine. As the fuel enters the injector it is filtered for the fourth time by the sintered-bronze filter mounted in the injector body. The purpose of all this filtering is to protect the finely machined parts of the injector.

As the surplus fuel leaves the injector, it passes through another filter of the same type to prevent a reverse flow of fuel from carrying dirt into the injector when the engine is shut down. These filters should be discarded when dirty, and new ones installed.

**76. Fuel Sight Glass and Relief Valves.**—The fuel sight glass and relief-valve assembly is located above the fuel pump. Its purpose is to indicate the condition of the various filters in the fuel system and the flow of fuel oil through the engine. The left-hand relief valve is set at 60 lb, the center at 100 lb,

and the right-hand at 5 lb. These valves are adjusted at the factory and *should not be changed*.

The return fuel from the engine passes through the right-hand sight glass and relief valve (5 lb). A drop in the fuel level in this glass, or an empty glass, will indicate that the engine is not receiving its full supply of fuel. Air entering the fuel line at any point on the suction side of the fuel pump will cause the engine to miss fire or stop. Air or gas in the fuel system will appear in this glass in the form of bubbles. The presence of bubbles, with the engine shut down and the fuel pump running, indicates an air leak in the suction line. If bubbles appear only when the engine is running, the injectors are allowing gas to escape from the engine cylinder into the fuel line.

**77.** The left-hand sight glass will show fuel by-passing when any of the filters on the pressure side of the fuel pump collect enough dirt to build up a back pressure of 60 lb. This fuel by-passes the filters and engine and returns to the tank. In an emergency, the globe valve between the 60 lb relief valve and the return pipe to the tank can be closed to force the fuel through the filters. This permits operation of the engine until the maintenance point is reached. The engine should not be operated with the 60-lb valve by-passing longer than the required time to reach a maintenance point where filters can be cleaned or changed. Pressure above 60 lb places an overload on the fuel-pump motor. If the filters are neglected and the back pressure reaches 100 lb, the fuel will flow through the center, or 100-lb, sight glass and relief valve and return to the tank, by-passing the entire filter system and the engine.

**78. Air Leaks.**—An air leak in the fuel line between the tank and the pump will destroy the vacuum, that lifts the fuel to the pump. All gaskets and connections should be kept absolutely tight.

**79. Fuel Pump.**—The fuel-pump assembly consists of a motor and two fuel pumps, the pumps being connected in parallel to give sufficient pumping capacity. The pumps are of the internal-gear rotor type which drive an offset idler in such a

way that fuel is drawn in as the teeth come out of mesh on one side and is expelled as the teeth mesh on the other side. The pumps are driven from the motor shaft through flexible couplings. These should be inspected periodically for wear of the fiber spider. The pump should not be left running unnecessarily.

**80. Running of Fuel Pump.**—In starting the power plant, let the pump run only long enough to build up the desired pressure in the cross-flow line. The pump should not be left running for any length of time without the engine running. The oil will pass through the cross-flow system, but there is a possibility that fuel oil might leak into the combustion chamber if there is a faulty injector.

**81. Fuel Failure.**—If fuel does not show in the 5 lb sight glass with the motor running, check the fuel-oil supply in the tank; the position of the emergency fuel cut-off valve; the condition of the motor and pump shaft with flexible coupling; the supply line for loose, broken, or clogged filters; the seating of the 100 lb relief valve; the fuel-oil pump and the suction-filter gaskets for air leakage. If dirt becomes lodged under the 100-lb relief valve, the fuel oil will be by-passed back to the tank, and fuel-oil pressure will not be allowed to build up in the cross-flow line. The gaskets on the suction-filter covers must be kept tight or air will be drawn into the system.

If the pump motor is not running, check the fuel-pump motor fuses, the condition of the fuel-pump switch, the main-battery switch, the electrical connection to the motor, the contactor behind the engine control and instrument panel, and the fuel-pump motor brushes.

**82. Fuel-Level Gage.**—A direct-reading sight level gage is located on each side of the fuel tank adjoining the fuel fillers. The sight level gage indicates the fuel oil at a point  $4\frac{1}{2}$  in. from the top of the tank and the level should be observed while filling the tank to prevent overflowing.

**83. Remote-Type Fuel Gage.**—The remote-type gage shown in Fig. 13 (a) is air-operated and it can be used to indicate the quantity of fuel oil or water remaining in the tank. The

gage consists of a globe valve, an air strainer, a reducing relief valve, an indicating gage, a tank pipe, and connecting piping as shown.

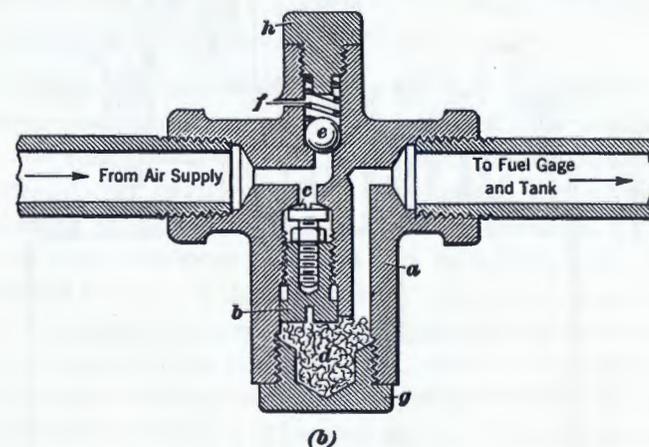
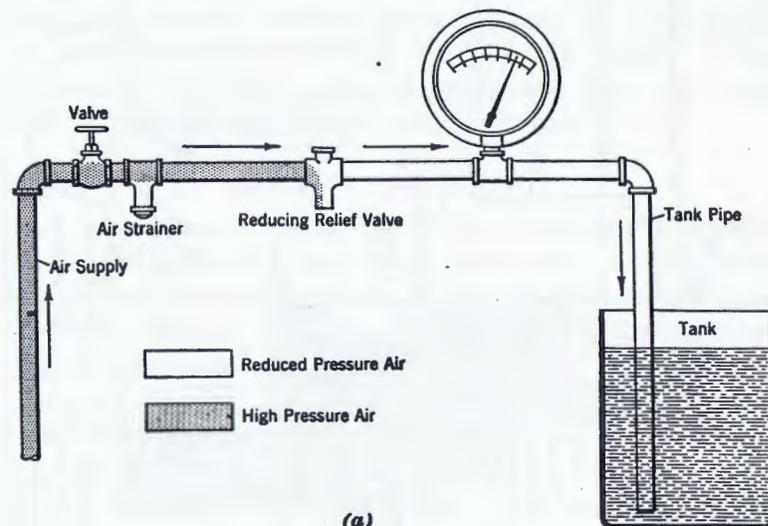
In operation, compressed air supplied by the main reservoir passes through the globe valve and the air strainer to the reducing-relief valve, which reduces the pressure and limits the flow. The piping conveys the air at a greatly reduced pressure to the tank pipe, where the pressure in excess of that required to balance the head of oil in the tank escapes through the oil to the surface and the atmosphere. The pressure of the air in the gage is therefore the pressure required to balance the head of oil in the tank, and the dial of the gage is calibrated in gallons.

The reducing relief valve, shown in an enlarged section in (b), is set for a pressure of 5 oz per square inch or a pressure in excess of that required to balance the head of oil in a full tank. The reducing relief valve has a built-in relief valve to protect the indicator against over pressure in case the low-pressure air line becomes plugged. The reducing valve is also equipped with an internal strainer to prevent it from plugging. This valve is set to reduce main-air-reservoir pressure to approximately 5 oz.

**84. Maintenance.**—About every 30 days each air strainer should be cleaned and repacked tightly with clean dry waste. To do this, the cleaning plug at the bottom of the strainer must be removed.

All connections should be *absolutely air-tight*. To check for leaks, close the globe valve in the high-pressure air line. If air leaks are present at joints and the globe valve is tight, an immediate dropping of the hand on the gage will be noted. Another indication of air leaks in the low-pressure line is a reduced tank capacity indication when the tank is filled. Then when all air leaks are eliminated, the hand on the indicator will indicate full capacity.

To reset the hand on the gage, close the globe valve, break a low-pressure-line connection, and, with atmospheric pressure on the gage, set the hand at zero graduation on the dial. Atmos-



- |                              |                |
|------------------------------|----------------|
| a—Reducing Relief-Valve Body | e—Ball Valve   |
| b—Throttle Screw             | f—Valve Spring |
| c—Adjusting Screw            | g—Lower Cap    |
| d—Wool Filter                | h—Upper Cap    |
| e—Ball Valve                 |                |

FIG. 13 REMOTE-TYPE FUEL-OIL GAGE



"oil dam." Oil flowing over this dam returns to the engine oil pan through the overflow to the engine sump. This keeps the scavenging-pump suction pipe under oil at all times.

With the engine running, the oil level should always be between the "low" and "high" marks on the bayonet gage in the engine oil pan. The oil level can be checked with the engine running at any speed.

88. Oil may be added by removing the oil-filler cover on the oil-cooler tank above the strainer chamber, and pouring required amount through the strainer basket.

When the engine is stopped, all the oil in the cooler-core chamber will flow through the pilot hole located at the top of the strainers and into the engine oil pan, which will bring the engine oil-pan bayonet-gage reading to "system charged." This level is below the "system uncharged" level because some oil is trapped in the lubricating-oil filter, oil lines, and engine. The total oil required per engine oil change is approximately 180 gallons on latest freight locomotives.

In early locomotives, oil is stored in the oil tank instead of in the oil pan of the engine, which fact classifies these as dry-sump engines. The oil tank is filled, then the engine is run for several minutes. The engine is then shut down and oil is added to bring the level in the oil tank to the full mark. The total oil required per engine oil change is approximately 145 gal. With the engine running, the oil level should not drop below 2 in. from the bottom of the sight glass.

89. **Draining of Oil System.**—The engine sump is drained by opening the drain valve of the engine sump after removal of a drain plug through a hand hole in one side of the sump. The oil tank is drained by opening the drain valves *A* and *B*, Fig. 14, and the filter is drained by opening a drain valve at the base of the filter. After the system has been prepared for refilling, the drain valves should be tightly closed.

When the pistons or cylinder liners have been removed because of scoring, the lubricating-oil system should be drained and flushed to eliminate worn particles of metal that may have

been circulated through the engine by the lubricating oil. This is a precautionary measure to avoid the possibility of scoring other cylinders of the same engine or the possibility of metallic particles finding their way to the main or connecting-rod bearings of the engine, where they may imbed themselves in the bearing metal and cut or scratch the fine finish of the bearings.

90. **Lubricating Oil Pressure.**—An ample lubricating-oil pressure must be maintained at all times to insure proper lubrication of all bearings and wearing surfaces. When a cold engine is being started, it should be allowed to idle for some time, and oil pressure should build up immediately to about 40 lb. When at a working temperature, the oil should maintain a pressure of 28 lb at 800 rpm and when idling at working temperature, the pressure should be at least 15 lb.

During normal operation of freight locomotives, the lubricating-oil pressure should not drop below 20 lb per square inch, with engine running at 800 rpm. However, if the water temperature cannot be held below 180° F it will be permissible to operate the engine with lubricating-oil pressure, at the rear end of the engine, as low as 15 pounds per square inch (psi). This low limit on pressure can only be permitted when the oil temperature is high as a result of the water temperature being above 180° F.

91. **Piston Cooling Oil Pressure.**—As the piston-cooling-oil system has no relief valve, pressure is dependent on oil temperatures, viscosity, and engine speed. Average pressure will be 20 to 30 psi with the engine running 800 rpm and 4 to 8 psi at idle, with a warm engine. If the pressure drops below 15 psi with the engine at 800 rpm, stop the engine, investigate the cause, and correct.

92. **Changing of Oil.**—It is recommended that the lubricating oil be changed after any one engine has consumed 18,000 gal of fuel. This is equivalent to about 12,000 miles for a freight locomotive. This will vary with the type of service and the kind of oil used. A more certain way to determine the life of oil is to have samples analyzed at regular intervals.

Where the assignments of the locomotive are such that runs terminate at slightly less or slightly greater mileage than this figure, the oil should be changed at the greater mileage.

**93. Low-Oil-Pressure Alarm Switch.**—A low-oil-pressure alarm switch found on late-type locomotives is connected to the oil-supply line to the blower in such a manner that failure of the lubricating-oil pressure will cause the switch contacts to open. When these contacts open, the master "E" valve will be deenergized, bringing the engine to idle, and the low-oil signal light will light and alarm bells will ring. Should this occur, do not attempt to load the engine until the cause of the low oil pressure has been located and corrected.

**94. Low-Oil-Pressure Shut-Down Switches.**—Engines on early freight locomotives are protected by two flow-type oil switches. If the piston-cooling or lubricating-oil pressure fails, the oil switch mounted on the respective oil-pump section will open, deenergizing the oil-pressure relay which deenergized the "E" master magnet valve, bringing the engine to idle.

The low-oil switches open at 100 to 125 rpm with a hot engine but they close at lower speeds when starting a cold engine. This is equivalent to a pressure of 2 to 3 lb.

These switches consist of a spring-loaded piston actuating a pair of electrical contacts. By artificially opening this circuit, one can test the operation of the switches and relay when the engine is running. If one of these switches operates, the engine must not be run until the trouble has been corrected.

**95. Oil Cooler.**—The gaskets between the oil-cooler core unit and the oil-cooler housing tend to compress after a short period owing to heat and vibration. This allows oil to enter the water cooling system, which is often mistaken as an indication of a broken oil-cooler core. Therefore, all nuts on the cooler should be tightened until there is no indication of leakage. This should also be done some time after an oil-cooler core has been replaced with a new one.

**96. Lubricating-Oil Strainers.**—The lubricating-oil suction strainers located in the tank should be removed and cleaned at

every oil change. The strainers in the engine oil pan should be removed and cleaned at the same time as the tank strainers. The basket strainers through which the oil is poured into the tank should be cleaned as inspection indicates.

**97. Lubricating-Oil Filters.**—The lubricating-oil filters remove sludge, dirt, and grit from the lubricating and piston-cooling oil as it is pumped through the waste-filled elements of the filter. When water or fuel oil become mixed with the lubricating oil, the mixture is not evident by inspection; hence, the viscosity of the oil must be checked at regular intervals with a Viscage to determine the extent of the dilution, as the water and fuel oil cannot be removed by the filter.

The filters are packed with a special waste known as Wastex, and the elements should be removed from the filter after each 4,000 miles of service or after each unit has consumed 6,000 gal of fuel oil. The dirty Wastex is removed and the elements are packed evenly with fresh Wastex. The filters are cleaned in this manner at each oil change and at regular intervals between oil changes. The use of clean lubricating oil is the best insurance against engine wear.

**98. Lubrication Troubles.**—Absence of oil in the tank-strainer chamber of the oil-cooler may be caused by an inoperative scavenging system or an open drain valve. Failure of the scavenging system may be due to a broken or loose oil-line connection causing an air leak, a faulty scavenging oil pump, or clogged suction strainers.

Low lubricating-oil pressure may be due to a stuck relief valve, broken oil lines, clogged strainers, excessive bearing wear, low oil viscosity, a faulty pump, or diluted oil.

Failure of the oil pump may be due to a sheared shaft, broken, housing, or damaged gears. If the relief valve sticks open, inspect for dirt lodged on the seat.

**99. Dilution.**—It is possible for fuel oil to get into the lubricating oil if an injector is defective or a fuel-oil line connecting the injector to the fuel-oil manifold should become loose or broken. If such a condition has existed, the viscosity of the lubricating oil should be checked.

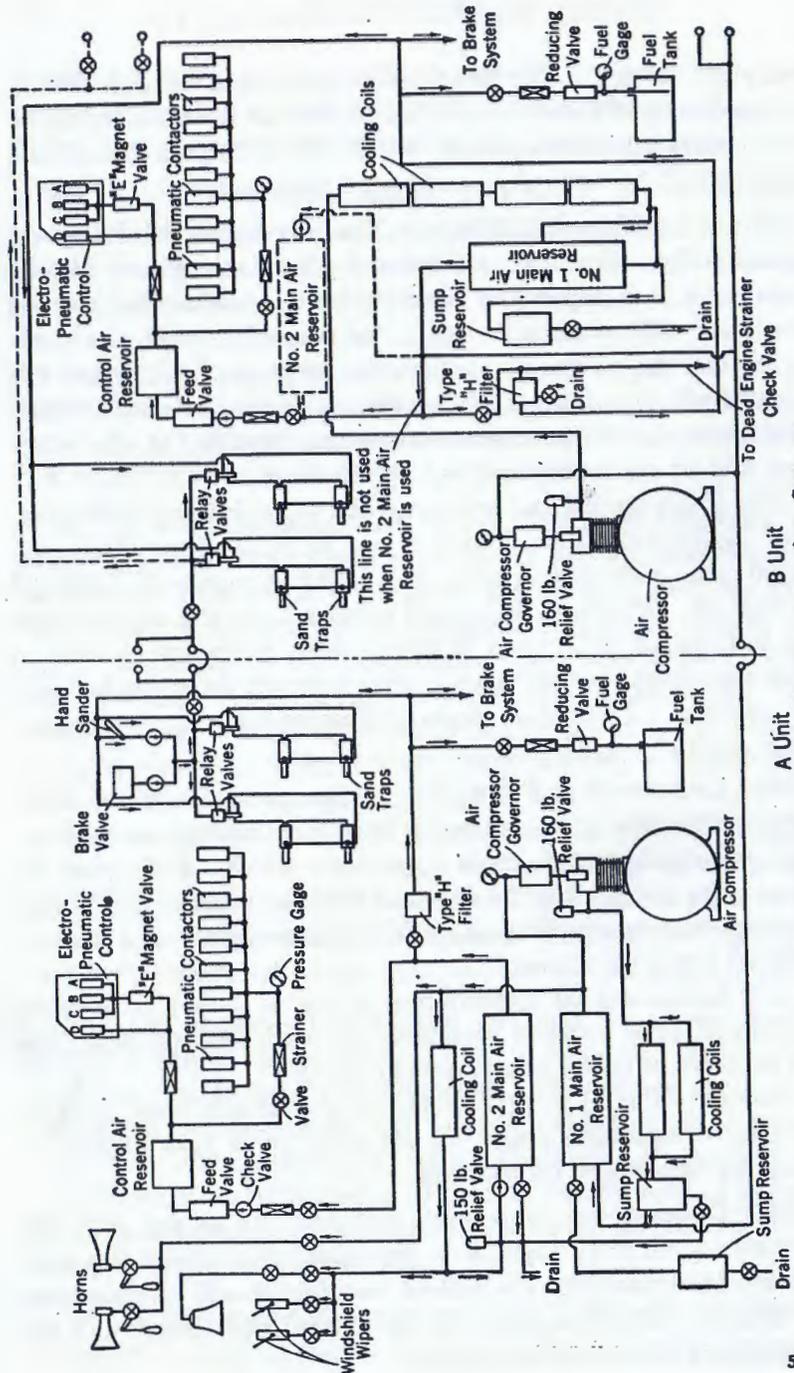


FIG. 15. SCHEMATIC DIAGRAM OF AIR SYSTEM

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**100. Excessive Oil Consumption.**—Excessive consumption of oil may be caused by an oil leak, broken or stuck piston rings, worn cylinder liners, improper grade of oil, excessive oil pressure, or clogged drain holes in piston under the oil-control piston rings. The cause should be investigated and corrected.

**101. Little or No Oil Consumption.**—Insufficient oil consumption may be due to water or fuel leaking into the oil, or to the use of too heavy an oil. The cause should be investigated and corrected.

**102. Air Separator.**—The oil tank of early freight locomotives contains a small reservoir with a valve at the top, to remove air from the oil returning from the scavenging oil pump. The valve should be at least  $2\frac{1}{2}$  turns open for proper operation. This valve is accessible by removing a small plate bolted to the side of the oil tank near the relief valve.

**103. Oil Separator.**—The oil separator is mounted between the engine blowers over the main generator. Vapor from the crankcase is drawn through the oil separator to the blower intake. The metal screen in the separator condenses oil from the vapor and returns the oil to the oil pan.

## AIR SYSTEM

**104.** An air-piping diagram showing the air-operated devices and pipe connections is given in Fig. 15. Each power plant in a freight-locomotive section is equipped with a type WXE air compressor, which is connected to an extension of the engine crankshaft by a flexible coupling; hence, the compressor operates at engine speed and has a capacity of about 56 cu ft per minute at idling speed and 178 cu ft per minute at 800 rpm. The four compressors of a 4-unit freight locomotive, therefore, have a capacity of 712 cu ft per minute at maximum engine speed.

The compressor is lubricated by oil in the compressor crankcase and an individual oil pump circulates oil under pressure to all bearings and wearing surfaces of the compressor.

The compressor air is delivered to the main reservoirs of each unit. The air operates the horns, bell, and windshield wipers of the leading unit; the control-air system and sanders of all units and the air brakes on the entire locomotive and train.

**105.** An air compressor cannot be stopped with a power plant in service; therefore, the compressor is provided with an unloader, which prevents air from being compressed when the air pressure in the main reservoir reaches 140 lb. When the pressure drops to about 130 lb through use of the air or because of leakage, the unloader allows the compressor to resume normal operation.

The air system as shown is provided with relief valves, feed-valves, and check-valves for maintaining the desired air pressure to certain of the devices and air filters, petcocks, and drain valves for removing condensate and dirt from the system. A sump reservoir is provided to allow the air system to drain off the condensate, and arrangements should be made to insure that all drains and petcocks are opened at prescribed intervals, depending on local conditions. The compressor unloader should be drained and blown out and the filter cleaned often enough to prevent trouble in service.

**106.** The control-air pressure must be maintained within 3 lb of 80 lb. If the control-air pressure gage above the high-voltage cabinet shows main-reservoir pressure, the reducing valve is likely stuck. If the trouble cannot be corrected by blowing out the filter and jarring the valve, its condition should be reported at the maintenance point.

The windshield-wiper blades should be replaced when the rubber becomes worn or hard. The wiper should never be operated on a dry window, as grit on the blade or glass will scratch the glass.

The sanders are normally operated by sanding valves in the cab and by remote-control valves in trailing sections. An emergency-air-brake application will usually operate the sanders automatically. The air-brake system is described in another text.

#### PURPOSE OF ELECTRICAL AUXILIARIES

**107. Alarm Bell.**—A bell that rings whenever any of the alarm indicator lights operate until the condition is remedied. The wheel-slip light does not operate the bell, however.

**108. Alarm Indicator Lights.**—Alarm lights for steam-generator failure, low oil, hot engine, wheel slip, and hot journals.

**109. Auxiliary Generator.**—A 10-kw 74-volt generator in each locomotive section for charging batteries in the A section and supplying all of the low-voltage power when the locomotive is operating. The auxiliary generator is mounted on, and is driven by, V-belt from the main generator. If either generator should become defective, it can be taken off the line by opening the battery charging switch in that section. The voltage output is maintained at 74 volts by the voltage regulator.

**110. Ammeter and Voltmeter.**—Devices that indicate generator output and use of current in the low-voltage circuits. The ammeter and voltmeter in the low-voltage cabinets indicate the operation of the auxiliary generator, whereas those on the distribution panel show the function of the storage battery.

**111. Battery.**—A 32-cell 64-volt battery in each A section furnishes lighting and starting power when power plants are not running. The freight-locomotive battery is rated at 426 amp-hr and is charged by an auxiliary generator in each section. The battery should be kept in charged condition with a gravity reading of 1.230 to 1.250 and the cells should be inspected after the engine has been running steadily for some time. Any bubbling should be reported. If the battery requires more than a small quantity of water, it should be reported to the maintainer. An overcharged battery will boil off the water, become overheated, and even become short-circuited.

**112. Battery-Charging Contactor.**—A power-operated contactor-type switch, controlled by the reverse-current relay, connects the battery to the auxiliary generator when the voltage is high enough to charge the battery.

**113. Battery-Charging Receptacle.**—The receptacle is an exterior battery connection used for charging the batteries from an exterior source. The charging circuit is protected by a 100-amp fuse and the amount of charge is checked by an ammeter. During external charging, the main-battery switch should preferably be open, but it may be closed, because, with the power plant shut down, the reverse-current relay opens the auxiliary-generator charging circuit. The external charging leads must be disconnected before the engine is started.

**114. Battery-Charging Resistor.**—A resistor connected in series with the output of the auxiliary generator to prevent overload of the auxiliary generator. If the battery is discharged or internally short-circuited, the resistor prevents damage to the auxiliary generator.

**115. Battery-Field Contactor.**—A contactor-type switch that connects the locomotive battery to the battery field of the main generator, when the transition lever is moved beyond off-position. During movements, between stops of the transition lever, the contactor is opened to decrease the generator output, thus preventing damage to the electrical accessories.

**116. Battery-Field Discharge Resistor.**—A discharge resistor that shunts the main-generator field to prevent high-voltage induction when the battery circuit to the battery field of the main generator is opened.

**117. Battery Load-Balance Switch.**—A double-pole double-throw reversing switch provided to balance the load between the two halves of the locomotive battery. When more current is consumed in one half of the lighting circuit than in the other owing to an uneven number of lamps, the switch should be reversed once each day.

**118. Brake-Control Rheostat.**—The dynamic brake-control rheostat located in the bottom of the control stand operates between B and maximum braking positions of the transition

braking lever to vary the resistance in series with the field loop circuit, and hence the braking effort of the locomotive.

**119. Brake Relay.**—The brake relay is energized when the transition braking lever is moved to the braking side of the control stand. An energized brake relay causes the cam-switch to throw to the tow position and closes the three braking contactors for dynamic braking.

**120. Brake Warning Relay.**—A double-coil current relay in the dynamic-brake circuit. The main coil is in the grid circuit of a traction motor and the other, a low-voltage coil, is opposed to the main coil and is energized only when the relay is closed. A closed relay lights a warning light in the cab to indicate excessive locomotive speed and the necessity of applying the train air brakes. When the speed is reduced low enough, the relay is kicked out by the low-voltage coil. The relay picks up at about 560 amp and drops out at about 540 amp.

**121. Braking Contactors.**—Three power-operated contact switches to connect the four traction-motor fields in series with each other across the main generator during dynamic braking. All contactors close at the same time when the traction braking lever is moved to the braking side of the controller.

**122. Cab-Heater Motor.**—A fan motor used in each of the two cab heaters to bring air into contact with the radiators and to circulate heated air through the cab.

**123. Cam-Switch.**—A cam-type switch operated by electrically controlled air valves. In motor position it connects the traction-motor armatures in series with their respective fields and disconnects the braking grids from the motor armatures. In tow position it disconnects the traction-motor armatures from their fields and it connects the four braking grids directly across each traction-motor armature. The switch has 16 pairs of main contacts and is interlocked on top to operate in sequence with other equipment.

**124. Charging Switch.**—A charging switch in each power plant normally connects the battery-charging equipment, consisting of the reverse-current relay, the battery-charging contactor, and the voltage regulator, to the battery when closed or isolates this equipment if open. As the generator-battery field also feeds through the charging switch, the auxiliary generator may be isolated by removing the 150-amp fuse in series with the auxiliary generator armature.

**125. Controller.**—The controller contains the throttle handle, the reversing handle, and the transition braking lever. The throttle handle, through electric contacts, operates the electro-pneumatic governor control that is connected mechanically to the engine governor to control the speed of the engine. The reversing handle also operates electric contacts to allow current to operate either the forward or the reverse magnet valves on the reverser in the high-voltage cabinet. When the electric circuit is open, there is no connection between the reversing handle and the reverser.

Regular movements of the transition braking lever during transition change the traction-motor connections from series-parallel to series-parallel-shunt, to parallel, and then to parallel shunt to obtain the desired locomotive tractive effort and speed within the voltage and current operating limits of the main generator.

Movements of the transition braking lever during dynamic braking operate a rheostat in the base of the controller to increase or decrease the main-generator traction-motor field exciting current to alter the dynamic braking power as required.

**126. Control and A.T.C. Knife-Switches.**—The control switch controls battery power to the control-equipment relays and contactors. The A.T.C. knife-switch connects the battery to the Automatic Train Control Equipment. Both switches are located on the distribution panel.

**127. Control Switches.**—Push-button switches on the right-hand side of the control stand for attendant, master control, generator field, fuel pump, defroster blower, number lights, gage lights, and classification lights.

**128. Defroster Motors.**—A blower motor in each of the windshield defrosters for keeping the windshield clear in frosty weather. The motors are operated on battery current.

**129. Distribution Panel.**—A panel containing switches to control main circuits throughout the locomotive.

**130. Blower Motor for Dynamic-Braking Resistor.**—Two blower motors in each locomotive section are driven by current generated by Nos. 2 and 4 traction motors during dynamic braking. A blower mounted on each end of the motor armature shaft drives air through the resistor grids for cooling purposes. The motors are rated at 320 volts, 7 hp, and 2,250 rpm and, if a blower unit should fail, all dynamic braking on that section must be cut out or the braking grids will burn out.

**131. Engine Starting Contactors.**—Two magnetic contact switches close to connect the locomotive battery to the main-generator starting fields and cause the main generator to act as a starting motor when the engine start-switch button is pressed. When the contactors close, interlocks open the generator-field circuit to prevent immediate generation of current. Only one engine of two permanently connected sections is started at one time to prevent overload to the storage battery.

**132. Engine Temperature Switch.**—A thermal switch located on the engine instrument panel connected to a thermal element in each of the two water-outlet manifolds of the engine. When the engine-water temperature exceeds 200° F the switch closes and operates a signal relay to light the hot-engine alarm light and ring the alarm bell.

**133. Field Loop Contactor.**—A contactor-type switch, which, in conjunction with interlocks on top of the cam-switch, operates to place the braking-control rheostat with resistors and the unit selector switch with resistors in series with the field loop circuit. The contactor is energized by contacts on the transition braking lever when the lever is on the braking side of the controller.

**134. Fuel-Pump Contactor.**—A magnetic contactor-type switch located on the engine control and instrument panel. The fuel-pump contactors in each control panel are controlled by the fuel-pump switch at the controller. When the contactor is closed, the fuel pumps can be controlled individually by a toggle switch on the engine control and instrument panel.

**135. Fuel-Pump Motor.**—One  $\frac{1}{4}$ -hp fuel-pump motor is provided for each engine and a fuel pump is mounted on each end of the motor armature shaft when 16-cylinder engines are used, as on freight locomotives. The motors are rated at  $\frac{1}{4}$  hp, 1,150 rpm, and they are driven from the locomotive battery circuit.

**136. Fuel-Pump Switches.**—A fuel-pump switch on the control stand controls the fuel-pump contactors and all of the fuel pumps in the other sections. A switch is provided in each engine instrument panel to shut off the fuel pump in that section.

**137. Fuse-Test Switch.**—A switch for testing light bulbs or fuses on the distribution panel. A fuse is tested by turning on the test lamp and placing the fuse across fuse test blocks. If the lamp goes out when the lamp switch is turned off, the fuse is bad. A light bulb is tested by turning it in its socket and throwing on the switch.

**138. Generator Shunt-Field Contactor.**—A contactor-type switch to connect the main-generator shunt field to the generator armature. The contactor opens during transition to reduce the generator output.

**139. Governor Control Master ("E") Magnet Valve.**—A magnet valve controlling the air supply to the A, B, and C valves of the governor control. If the valve is deenergized, the engine will be brought to idle or stop, depending on the position of the throttle lever.

**140. Ground Protective Relay.**—A relay to open the battery and shunt-field contactors and to bring the engine to idle when a ground occurs in the high-voltage system. The relay can be

reset by pushing in on the reset button after isolating the engine. If the relay repeatedly opens when the engine is put back on the line or when the engine speed is increased, the relay may be made inoperative by opening the knife-switch located on the high voltage panel. The engine should not be run with the knife-switch open unless absolutely necessary.

**141. Ground Relay Switch.**—A knife-switch to open the circuit to the operating coil of the ground protective relay to make the relay ineffective in cases of emergency.

**142. High-Voltage Cabinet.**—A cabinet containing the high-voltage electrical equipment subject to main-generator current. The equipment must not be serviced while the locomotive is in operation because of the danger of high voltages.

**143. Isolation Switch.**—The isolation switch is a two-position manually operated switch located on the engine control and instrument panel. When starting the engine, this switch is placed in start position, in which the engine is disconnected from the control circuit and hence the engineer's controller. While in start position, the engine alarm circuits are cut out and are ineffective. When the engine is started, the switch is moved to run position as soon as the lubricating-oil pressures build up to cut in the alarm circuits and make the engine subject to control from the operator's cab. If it becomes necessary to isolate a power plant, its isolation switch may be moved from run to start position to bring the engine to idle. The engine is usually brought to idle first, however, by the use of the layshaft manual-control lever.

**144. Journal Signal Relays.**—A relay rings a bell in all sections and lights a hot-journal light in the affected section when a journal thermocouple opens because of a hot journal.

**145. Load Regulator.**—The load regulator is divided into two sections consisting of a pilot valve attached to the governor, and a hydraulic rotary vane-type motor attached to a commutator-type rheostat. The regulator varies the load on the Diesel engine for any given speed, thereby allowing the engine

to determine the load that it can carry. If the engine governor demands more fuel than a predetermined setting, the load regulator reduces the load on the engine by reducing the field excitation of the main generator, thus reducing the speed of the locomotive. If the engine governor demands less fuel than a predetermined setting, the load regulator increases the load on the engine by increasing the field excitation of the main generator. This will bring about an increase in the locomotive speed. If some of the cylinders should become inoperative, an overload on the engine is thus prevented.

**146. Low-Oil-Pressure Switches.**—Switches consist of spring-loaded pistons actuating a pair of electrical contacts. The switches are located on the discharge side of the lubricating-oil and piston-cooling-oil pump and are nominally closed. Failure of the oil pressure causes the spring to open the contacts to deenergize the oil pressure relay which deenergizes the "E" master magnet valve, bringing the engine to idle.

**147. Low-Voltage Cabinet.**—A cabinet containing most of the electrical equipment for charging the battery. The contents of the cabinet are subject to auxiliary-generator or storage-battery voltage.

**148. Main-Battery Switch.**—A two-pole knife-switch to connect or disconnect all circuits from the battery except the external charging receptacle. The switch is always opened when leaving the locomotive or when doing maintenance work.

**149. Main Generator.**—A 600-volt generator operated by the Diesel engine to produce the direct current required for operating the traction motors. The generator is directly connected to the engine crankshaft by a flexible connection at one end of the armature, and the other end of the armature is carried by a bearing in the rear end of the generator housing. The generator is cooled by a fan mounted on the flexible coupling.

**150. Motor-Field Shunting Resistor.**—A resistor that is connected across the traction-motor field by the closing action of the shunt contactor to allow more current to flow through

the traction-motor armature, thus increasing the speed of the locomotive.

**151. Parallel Relay.**—A relay energized by the transition lever in positions 3 and 4 to close the P1 and P2 traction-motor contactors to place the traction motors in parallel. The relay also causes the SF and BF contactors to open during transition from positions 2 to 3 and from 3 to 2 of the transition lever.

**152. Oil-Pressure Relay.**—A relay operated by the low-oil-pressure switches on the engine lubricating-oil pumps. When the oil pressure fails, a low-oil signal light is lighted and the circuit to the master "E" valve is opened by the relay. The air supply to the governor-control valves is thus cut off and the engine is brought to idle.

**153. Pneumatic Control Switch.**—The pneumatic control switch, also known as the PC switch, is an electric switch located on the right-hand side of the cab below the window. The purpose of this switch is to reduce the power of the locomotive by bringing the engines to idle when certain emergency airbrake applications take place. The switch has a manual reset button, which must be pulled out after the air brakes have been released. As the operation of the switch may vary on on certain locomotives, the wiring diagrams of the various circuits should be consulted to determine the effect on that circuit.

**154. Reverser.**—An air-operated reversing switch that changes the direction of the flow of current through the traction-motor fields, causing the motors to turn in the opposite direction.

**155. Reverse-Current Relay.**—A relay to prevent the battery current from motoring the auxiliary generator. The relay opens the battery charging contactor when the auxiliary-generator voltage drops below the battery voltage.

**156. Signal Relay.**—A relay that operates the alarm bell and lights the warning lights when the oil pressure fails or the engine temperature becomes excessive.

**157. Signal-Relay Resistor.**—A 6-ohm resistor connected in parallel with the signal-relay coil to allow enough current to flow through the circuit to light the alarm lights.

**158. Shunt-Field Resistor.**—Resistors connected in series with the generator shunt field to limit the shunt-field current.

**159. Shunt-Field Discharge Resistor.**—A resistor to prevent burning of the contacts of the shunt-field contactor or damage to the generator due to high inductive voltage, which might otherwise occur if the contactor is opened with the generator operating at top speed.

**160. Speedometer.**—A speed indicator consisting of three units, namely; a generator mounted on an axle, an indicator on the engineer's instrument panel, and a resistance box that can be adjusted to compensate for wheel wear. The units should be kept in matched sets and returned to the manufacturer every 3 years to be cleaned and recalibrated. This type of speedometer was applied to a few of the early-type locomotives and has been largely replaced by the speed recorder shown in Fig. 5.

**161. Start and Stop Switches.**—Engine start and stop switches are effective only when the isolation switch is in start position. The start switch operates the engine-starting contactors. The stop switch energizes the D magnet valve in the governor control and causes the engine to stop if air pressure is up. The engine can be started with no air pressure but, if it becomes necessary to stop the engine before air pressure is pumped up, the injector layshaft manual-control tool must be used.

**162. Tachometer.**—A device that indicates the revolutions per minute of the engine crankshaft and is mounted on, and mechanically operated from, the governor end of the engine.

**163. Time-Delay Relays.**—A delay relay provided to give the generator fields time to die out before transition from positions 2 and 3 takes place. A similar relay is provided for the same reason before transition from position 3 to 2 takes place.

**164. Traction Motor.**—Motors on the driving wheels of each locomotive section which are driven by the direct current produced by the main generators, to provide the tractive effort for moving the train. Four traction motors are used with each unit or section.

**165. Traction-Motor Contactors P1, P2, and S.**—Pneumatically operated contactor-type switches for changing the traction-motor connections from series-parallel to parallel or the reverse. Magnet valves controlling the air cylinders of the contactors are energized by contacts on the transition braking lever.

**166. Traction-Motor-Field Shunting Contactor.**—A magnet valve and air cylinder operating four pairs of contacts to connect the four motor-field shunting resistors across the traction-motor fields to decrease the resistance of the circuit. This allows more current to flow through the armatures, thus increasing the torque of the motors and increasing the locomotive speed.

**167. Unit Selector Switch.**—A drum-type, four-position switch set to agree with the number of sections in the make-up of the locomotive. The switch provides additional resistance in the field loop circuit in case the locomotive consists of less than four sections. The switch must not be moved during dynamic braking.

**168. Voltage Regulator.**—A device to maintain the output of the auxiliary generator at a constant voltage regardless of the speed of the engine or the gravity of the battery. This provides a constant source of excitation for the main generator and it keeps the battery charged.

**169. Wheel-Slip Relays.**—Relays that operate to light the wheel-slip light and shunt out the shunt-field operating coil, causing the SF and the BF contactors to open and the generator of the affected section to stop the delivery of power when one or more pairs of driving wheels slip. When the wheel-slip light flashes, it is necessary to throttle down until the wheels stop slipping. The throttle should then be reopened more gradually to prevent slipping, if possible.

# OPERATION OF DIESEL FREIGHT LOCOMOTIVES

Serial 5718

Edition 1

## EXAMINATION QUESTIONS

**Notice to Students.**—*Study the Instruction Paper thoroughly before you attempt to answer these questions. Read each question carefully and be sure you understand it; then write the best answer you can. When your answers are completed, examine them closely, correct all the errors you can find, and see that every question is answered; then mail your work to us.*

- (1) How is the hand brake released?
- (2) (a) What part of the main-generator current is used by a traction motor when the motors are connected in series-parallel? (b) in parallel?
- (3) How long may an engine be operated in an emergency with a closed globe valve between the 60-lb relief valve and the fuel-return pipe?
- (4) When the transition lever is moved from position 2 to position 3, in what order do the series and parallel traction-motor contactors operate?
- (5) (a) What is the maximum rotation of the main-generator armature in normal service? (b) of the traction motor armatures?
- (6) How is a power plant isolated or taken off the line in a locomotive unit under power?
- (7) (a) What is the maximum main-air-reservoir pressure? (b) the control-air pressure?
- (8) (a) If the engine will not rotate when an attempt is made to start the engine, where are defects likely to be found? (b) if the engine will rotate but not fire?

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DIESEL FREIGHT LOCOMOTIVES

- (9) (a) Why are traction-motor connections changed during increasing speeds? (b) during decreasing speeds?
- (10) When starting the engine, what is the position of (a) the throttle? (b) the control push button switch? (c) the isolation switch? (d) the engine-starting contactors?
- (11) How is the throttle lever connected to control the speed of the engine?
- (12) With the throttle in Run 8, what is the approximate rotation of (a) the air compressor? (b) the engine water cooling fans? (c) the fuel-pump motor?
- (13) How is the engine placed back on the line with the locomotive in operation?
- (14) What arrangement is used to insure that the transition lever can not be moved through more than one notch at a time?
- (15) What is likely to happen if the train slack is not out or if the brakes are not fully released and the throttle is permitted to remain in Run 4 or higher?
- (16) When about to move the locomotive after starting the engines, what is the position of (a) the isolation switch? (b) the transition lever? (c) the generator field switch? (d) the PC switch?
- (17) What is the purpose of the transition indicator?
- (18) What is the advantage of changing the traction-motor connections during the various speed stages of the locomotive?
- (19) What use is made of the lower red triangle on the scale of the transition indicator?
- (20) When the brake warning light indicates excessive braking current, what is the proper procedure?
- (21) How is the dynamic brake made inoperative on a unit of a locomotive in service and what precaution is observed?

(22) If the engine will not start because of defective engine starting contactors, how may the engine be started in an emergency?

(23) When the locomotive is to be towed a considerable distance by other power, give the proper position of: (a) the cam-switch; (b) the reverser drum.

(24) How may the loss of load on an engine be detected?

(25) When the engine cooling-water system of a hot engine is drained, what danger lies in refilling it immediately?

(26) At what engine speed should the clutch of the fan drive be engaged?

(27) (a) If air bubbles appear in the right-hand sight glass with the fuel-pump running while the engine is shut down, what is the indication? (b) if bubbles appear only when the engine is running?

(28) At what engine speed can the level of the lubricating oil in the engine oil pan be checked?

(29) What special attention should be given to the lubricating-oil coolers on new locomotives?

(30) When the transition lever is to be moved to braking position, in what position are the throttle and the reverse handle to be placed?

**Mail your work on this lesson as soon as you have finished it and looked it over carefully. DO NOT HOLD IT until another lesson is ready.**

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