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THE RAILWAY EDUCATIONAL BUREAU

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STUDY CLEARS THE ROAD TO PROGRESS

INSTRUCTION PAPER

UNIT N. 25

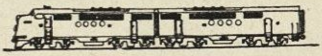
SUBJECT:

DIESEL LOCOMOTIVE OPERATION

RUNNING ELECTRO-MOTIVE PASSENGER LOCOMOTIVES—PART 1

MAGNETISM—MOTORS

OMAHA—POSTAL ZONE 2—NEBRASKA



No instructions are given in this text concerning the operation or testing of the brakes on Diesel locomotives in passenger service. It must be understood, however, that complete terminal tests of the brakes must be made before starting out with a train and that the required running tests must be made immediately after starting, in accordance with standard operating rules. The terminal tests will include the test of the train communication signals in addition to the brake tests. Similarly, all other operating rules must be obeyed.

This text contains another section on Electrical Action. It is a continuation of the subject Magnetism. It explains the principle of the Electric Motor and tells something about the traction motors used on Diesel locomotives. The principle of Dynamic Braking which is used with Diesel locomotive operation also is explained.

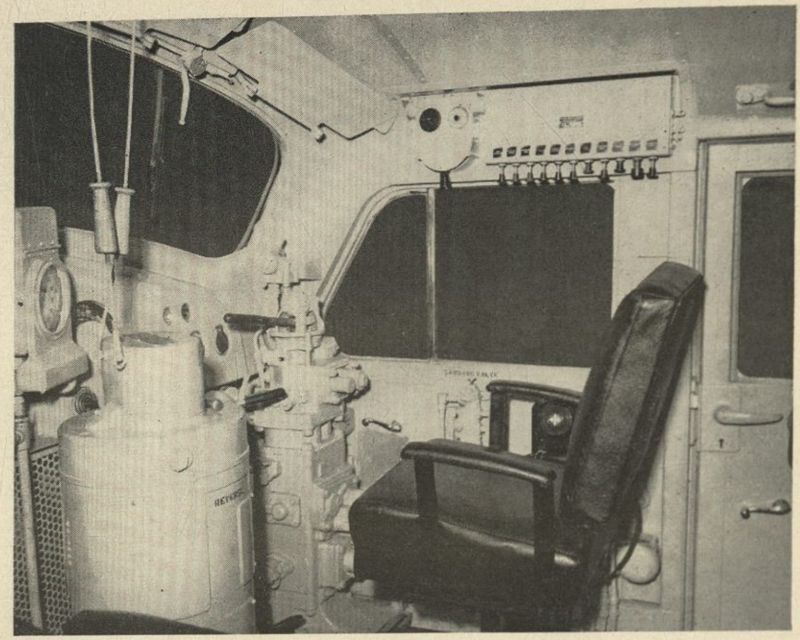
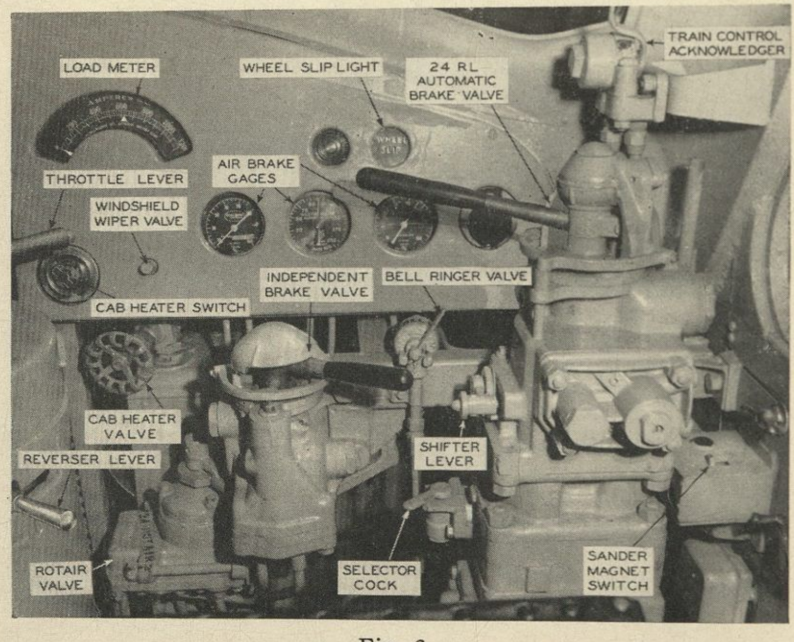


Fig. 1



LOAD METER
WHEEL SLIP LIGHT
24 RL AUTOMATIC BRAKE VALVE
TRAIN CONTROL ACKNOWLEDGER
THROTTLE LEVER
AIR BRAKE GAGES
WINDSHIELD WIPER VALVE
INDEPENDENT BRAKE VALVE
BELL RINGER VALVE
CAB HEATER SWITCH
CAB HEATER VALVE
REVERSER LEVER
SHIFTER LEVER
ROTAIR VALVE
SELECTOR COCK
SANDER MAGNET SWITCH

Fig. 2

DIESEL LOCOMOTIVE OPERATION

RUNNING ELECTRO-MOTIVE PASSENGER LOCOMOTIVES—PART 1

General

1. This text deals with the operation of Diesel locomotives in passenger service. The type of locomotive described is the E-7, manufactured by the Electro-Motive Corporation. This has been their standard passenger locomotive for several years. It is but little different from the types of passenger locomotives which were manufactured by the Electro-Motive Corporation previously. Such differences are pointed out in the text. In 1949, manufacture of a new type of passenger locomotive—the E-8—was begun. It is described in a following text.

2. During the war a dual-purpose (freight and passenger) locomotive, known as type F-3, was manufactured. In 1949, manufacture of a new type of freight locomotive, known as the F-7, was begun; this locomotive also can be used in passenger service although it is designed primarily for freight service. Both of these locomotives are described in the text on freight locomotives.

3. Figure 1 is a view of the engineer's side of the cab of an E-7 locomotive. Fig. 2 shows the apparatus as seen from the engineer's seat. This locomotive is equipped with the No. 24 RL Air Brake Equipment. Fig. 3 shows the same locomotive control apparatus, but with No. 8 EL Air Brake Equipment instead of No. 24 RL Equipment.

4. Both Fig. 2 and Fig. 3 show the names of the various control levers, gages, meters, etc. Referring to Fig. 3: The control stand or station at the left of the illustration carries the reverser lever and the throttle lever.

The reverser lever is moved forward when the locomotive is to travel forward and is pulled clear back when the locomotive is to travel in the opposite direction. The center position is its neutral position.

5. The throttle of this locomotive has ten positions or notches. The button at the end of the throttle lever must be pressed in before the lever can be moved to its

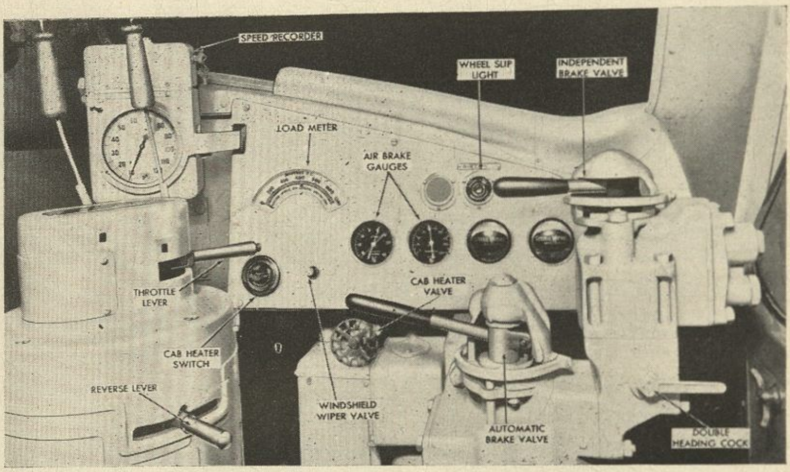


Fig. 3

extreme forward notch. This is the OFF or engine shutdown position. The throttle can be moved back from the OFF position to the IDLING position and then to notch No. 1 and on to notch No. 8. These eight notches are the power regulation notches which vary the speed of the engine from idling to full power.

6. Further reference to Fig. 3 will show a small opening or peephole just above the end of the throttle lever slot. Words or numbers appear in this opening that correspond with the position of the throttle lever. When the throttle lever is clear forward, the word OFF appears. When it is moved to the idling position, the word IDLE appears. When it is moved to the first notch, the number 1 appears and so on up to the number 8 for full power. The second peephole above and to the left of this first peephole is a transition indicator. This will be explained later.

7. The speed recorder indicates in miles per hour. The load meter indicates the electrical load on the motors. This will be explained later, as will the meaning of the wheel-slip light. The other names are self-explanatory except in the case of the No. 24 RL Air Brake Equipment. These parts will be explained when the air brake equipment is explained.

8. The light switches and control switches of this locomotive are above the engineer's seat, as shown in Fig. 1. These switches from right to left are named and marked as follows:

Engineer's light
Attendant's call
Control
Generator field
Fuel pump
Defroster
Number and gage lights
Classification lights
Headlight—dim
Headlight—bright
Mars light

The switch immediately in front of the bank of control switches is for the operation of the oscillating warning light. With the handle in the position shown, the light is off. With the handle forward, the warning light is bright. With the handle pulled back, the warning light is dim. The black snap-switch at the top of the box is turned on to cause the reflector behind the warning light to oscillate. The push button to the right of this black switch can be pushed to spot the light for any reason.

9. All passenger locomotives of the "E" types have two separate engine-generator sets in each power unit. Both engines are controlled from the single set of con-

trols in the cab. When the locomotive is made up of more than one power unit, all engines of all units are controlled from the one set of cab controls.

10. The cab throttle lever and the reverser lever are interlocked mechanically.

(a) The reverser handle cannot be shifted ahead or back unless the throttle lever is in the IDLING position.

(b) The throttle lever must be in IDLING position before the reverser handle can be removed from the control station.

(c) The throttle lever cannot be moved away from the IDLING position when the reverser handle has been removed from the control station.

11. There is a safety control pedal connected with the air brake system. This pedal must be kept depressed by the foot; otherwise, the brakes will apply automatically.* When the locomotive is standing at a station or elsewhere, the safety control feature can be kept inoperative by setting the locomotive brakes with about a 25-pound application with either brake valve, and leaving them set.

12. On most road locomotives there is a pneumatic control switch (P. C. switch) that is connected into the air brake system. This pneumatic control switch is located on the side of the cab to the right of the engineer's seat. It is not visible in Fig. 1. When the P. C. switch is tripped, the reset button is tight against the box. If it is tripped it must be pulled out about ¼ inch to reset it. It gives a distinct snap or click as it is reset.

13. When the pneumatic control switch is tripped, it breaks certain electrical control circuits to the loco-

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*Safety control application can be prevented by pressing down the handle of the main brake valve and holding it horizontal. This makes it possible to remove the foot from the foot pedal.

This foot pedal often is called the deadman's pedal. It can be seen in Fig. 1, near the floor, between the control stand and the air brake pedestal.

motive throttle control or to the controls of the fuel pumps. The locomotive cannot be run unless the P. C. switch is pulled out.

To Move the Locomotive

14. When preparing to move the locomotive, the independent brake valve handle should be in application position. All engines in all units should be started and all isolation switches moved to the run position. Then the hand brakes of all units should be checked to make sure that they are released. The procedure when ready to move the locomotive is as follows:

(1) Press in the generator field switch.

(2) Move the reverser lever from its center notch to its forward or backward notch, according to the direction in which the locomotive is to be moved.

(3) Push down and hold down the safety control pedal.

(4) See that the automatic brake-valve handle is in the release-running position.

(5) Check the pneumatic control switch to see that it is pulled out.

(6) Move the independent brake-valve handle to its running position.

When these preliminaries have been accomplished, the throttle lever may be moved from its IDLING position to the No. 1 notch to start the locomotive.

15. Power is shut off from the traction motors by moving the throttle lever to its IDLING position. All engines can be shut down by moving the throttle lever to its OFF position. The reverser lever should not be moved to reverse the motion of the locomotive until the locomotive has been brought to a dead stop; otherwise, damage may be done, especially to the electrical equipment.

STARTING A TRAIN

16. When the locomotive is coupled to a train, the start should be made by moving the throttle lever to the No. 1 notch. There will be sufficient power in this throttle position for the locomotive to begin to gather the slack of the train. The throttle lever should be left in the No. 1 notch until the locomotive has taken all the slack it can pull, then it should be moved to notch No. 2. If this does not furnish sufficient power to start the train rolling, the throttle lever should be moved to notch No. 3.

17. In extreme cases, where the train will not start with the throttle lever in the No. 3 notch, it can be moved to notch No. 4. The locomotive should have power to start the train rolling when the throttle lever has been moved as far as the No. 4 notch. If the train will not start under normal conditions with the throttle lever in the No. 4 notch, the lever should be moved back to its IDLING position. Then the train should be checked to see whether the air brakes are released and, if so, that there are no hand brakes set.

18. The throttle lever should not be moved from the No. 1 notch to the No. 2 notch nor from the No. 2 notch to the No. 3 notch without a pause of about 4 seconds. This much time is necessary to allow the load regulator to adjust to give the full power of each notch. It is not necessary to pause more than a couple of seconds in going through the remaining notches to accelerate the train. It is well to make similar pauses in returning the throttle lever to lower notches.*

19. After the slack is out and the train begins to move, the throttle lever can be moved from the starting notch on to the fifth, sixth, seventh, and finally to the

*An easy way to time by seconds is to count *slowly* one thousand one, one thousand two, one thousand three, one thousand four, etc. If one will practice counting this way slowly and evenly, the count of one thousand sixty will be almost exactly on the minute. It is a very practical way of telling when three or four seconds or any number of seconds have elapsed.

eighth notch. Each time the throttle lever is moved a notch, the amount of fuel oil being supplied to the Diesel engines is increased and additional power is supplied to the traction motors to accelerate the train.

20. Movement of the throttle lever from the No. 1 notch to the No. 2 notch results in an increase in the speed of each Diesel engine of about 75 revolutions a minute. The same increase takes place as the throttle lever is moved to each higher notch. The engine speed reduces about this same amount when the throttle lever is moved from one notch to the next lower notch. Nothing is gained by moving the throttle lever from one notch to another until the engine speed has adjusted to the previous change. The sound of the engines will indicate when this speed adjustment has occurred. It will take from 2 to 4 seconds.

21. When it is necessary to shut off the power to the traction motors quickly, the throttle lever may be moved from any notch to the *No. 1 notch* without pause. This is better practice than to return the lever to the idling position before the electrical load on the motors has been reduced sufficiently to prevent possible damage. The throttle lever should be moved to IDLING position before the locomotive brakes are applied.

22. Many roads issue their own instructions to engineers as to the way in which heavy trains should be started on grades. Speaking generally, when ready to start uphill on a heavy grade the locomotive brakes should be held applied with the independent brake valve. The train brakes should be released so that the slack will run out. When the slack has had time to run out, the locomotive throttle lever should be advanced gradually to the No. 3 notch; then the *locomotive brakes* should be released with the independent brake valve and the throttle lever advanced to the No. 4 notch or in extreme cases to the No. 5 or No. 6 notch to start the train moving. When the train is in motion, the throttle lever should be eased back from the No. 5 or No. 6 notch to about the No. 3 notch. Then it can be moved to the No. 4 and higher notches again to increase the speed of the train. It should not be necessary to take the slack as with a steam locomotive. The Diesel locomotive should start the train with the slack clear out.

23. Many railroads issue local instructions which specify maximum permissible load meter readings while a train is operating under various conditions. As a general rule, the pointer of the load meter must not be allowed to remain above the 625 ampere mark after the train is under way. A small, red triangle is located below the dial to indicate this marking (see Fig. 2). It is permissible for the pointer to pass beyond the red triangle for a limited time while starting or pulling a train up a grade. It should be safe to operate with the load meter indicating about 920 to 975 amperes for a distance up to 2 miles. Likewise, it is considered safe to operate for a distance up to 5 miles if the pointer does not exceed about 825 amperes. Operation for a distance up to 20 miles may be safe if the pointer of the indicator is beyond 625 but not beyond 695. If the operating conditions are such that the train cannot be handled beyond the distances specified without the pointer returning to the left of the red triangle, the power must be shut off and time allowed for the traction motors to cool.

TRANSITION—SERIES TO PARALLEL

24. On passenger locomotives of the "E" type, the circuits of each electrically connected pair of traction motors change automatically from series to parallel at about 34 miles per hour. This circuit change is called TRANSITION. Another automatic circuit change takes place at about 75 to 85 miles per hour. This transition is from parallel to parallel-shunt. The exact speed at which a transition circuit change takes place varies on different locomotives because of different traction motor gear ratios or other reasons.

25. When transition takes place, the circuit changes are made between the two traction motors of each locomotive truck. Each engine-generator set furnishes the power to the one pair of traction motors of one truck.

26. Transition occurs for each electrically connected pair of traction motors when the voltage of the generator that supplies current to THAT PAIR increases sufficiently to operate its transition relay and contactors. This voltage may be reached at a different speed for each connected pair of traction motors.

27. With a light train or on a down grade "transition speed" may be reached while the throttle is in notch No. 7. Usually, however, transition does not take place until the throttle is in notch No. 8. Sometimes, while pulling up a heavy grade, the train speed may not increase sufficiently for transition to take place, even with the throttle in notch No. 8.

28. The circuit of the wheel-slip indicator happens to be arranged so that the wheel-slip light on the instrument panel will flash when transition takes place on any pair of motors. If there are six pairs of motors, and, consequently, six generators, the wheel-slip light should flash six times for the six separate transitions. It is possible that transition may occur at the same instant at two generators. However, the engineer should count the transition flashes. If there are less flashes than the total number of engines on the locomotive something may be wrong, such as the tripping of a ground relay which would return one engine to idling speed (it might cause the engine to shut down).

29. Mention has been made of a second peephole on the control stand. The number 1, 2, or 3 may appear at that peephole. The number 1 indicates that the pair of traction motors supplied by the one generator connected with the indicator is operating in series. When the number 2 appears at the peephole, it indicates that transition to parallel has taken place. When the number

3 appears, it indicates that transition from parallel to parallel-shunt has occurred. The indication, however, is for but the one generator—the one that is connected with the indicator.

TRANSITION—PARALLEL TO PARALLEL-SHUNT

30. When the train speed reaches from 75 to about 85 miles per hour, a further change in the traction motor circuits is necessary in order to get additional speed. This change is accomplished by introducing a shunt across the circuit to the field magnets of the traction motors. This circuit change is called PARALLEL-SHUNT TRANSITION.

31. The shunt of the traction motor field circuits takes place when the generator voltage builds up sufficiently, after the first transition, to cause the transition relay to close a second time. This second closing operates shunting contactors which connect resistors across the motor field circuits. (This is explained further in the electrical section.) The relay now stays closed until the train speed drops considerably below the speed at which this parallel-shunt transition took place or until the generator voltage drops, due to the reduction of the throttle lever setting.

32. BACKWARD TRANSITION FROM PARALLEL-SHUNT. Backward transition from parallel-shunt to parallel usually does not take place while the throttle is fully open unless the speed drops to about 69 miles per hour. (See paragraph 24.) Then the transition relay drops and the shunt circuit of the field of each traction motor is opened. This, however, does not affect the parallel circuit which was set up when the circuits changed from series to parallel. This relay action is automatic when the generator voltage drops a certain amount.

33. BACKWARD TRANSITION, PARALLEL TO SERIES. If, because of a heavy grade or for any other reason, the train speed drops to about 25 miles per hour at any time after transition to parallel has taken place, the circuits must be restored to series *by the engineer.*

34. Backward transition can be accomplished by the engineer whenever desired by the movement of the throttle lever to the IDLING position. This opens the traction motor circuits. Then, when the throttle lever is moved to notch No. 1 again, the circuits are returned to series, the condition they were in at starting.

35. If the engineer desires to make backward transition to obtain more power when the speed has dropped to about 25 miles per hour, the throttle lever can be moved gradually from the IDLING position to the desired running notch. The traction motor circuits will remain in series under these conditions unless the speed picks up sufficiently for the transition relay to operate again. If the throttle lever is moved to IDLING position when the train speed is higher than the speed at which parallel transition takes place, the circuits will shift from parallel to off as usual. When the throttle lever is moved to notch No. 1 the circuits are connected in series as already explained. Now, if the lever is notched out too rapidly, transition from series to parallel will take place again as soon as the throttle lever reaches notch No. 7 or notch No. 8. However, if the lever is notched out gradually, the circuit will remain in series.

OPERATION OF PASSENGER TRAINS

36. When starting a train from a station or other stop where no speed restrictions interfere, the throttle lever should be advanced step by step until notch No. 8 is reached. It should be left in notch No. 8 until transition from series to parallel has taken place on all motors and as long thereafter as necessary to accelerate the train to the desired speed. If the train is light or the prevailing grade will permit, the throttle lever should be returned from notch No. 8 to whatever lower notch will supply the necessary power to maintain the desired speed.

37. When the power is to be reduced, the throttle lever can be notched back to the seventh, sixth, fifth, or earlier notches as desired. In fact, the lever might be run in notch No. 1 with a very light train on a downgrade.

38. The brakes never should be used to check acceleration where the same result can be accomplished by returning the throttle lever to a lower notch. If it is necessary to use the brakes to reduce the speed at a curve or other speed-limiting point, the throttle setting should be reduced two or three notches before the brakes are applied. In the operation of high-speed passenger trains, first attention is given to getting over the road on schedule without undue wear of the equipment, rather than to fuel economy. High-speed train operation requires the slowing down of the train at speed restricting points. The best method of manipulating the throttle lever and the brakes to maintain schedule requires very careful thought.

39. As just stated, the brakes never should be used to check acceleration where the same result can be accomplished by notching back the throttle lever. In approaching a curve where the speed must be reduced, the throttle lever should be notched back two or three notches before the brakes are applied. The throttle lever always should be notched back before applying the brakes to make a full stop. Each road has its own instructions as to how the brakes and throttle lever should be handled. Local instructions always should be followed.

40. Some engineers, when starting out, move the throttle lever to the eighth notch promptly to accelerate the train as quickly as possible. When transition has taken place and maximum permissible speed has been reached, they will "fight the brakes" to prevent overspeed or to reduce speed at a curve or other speed limiting point, rather than notch back the throttle lever.

41. Some of the most successful passenger engineers will accelerate to a suitable speed and then notch back the throttle lever to maintain the desired high speed with as little variation as possible. For example, if an average speed of 65 miles an hour, including slowdowns and stops, will maintain the schedule over a district, they may set the throttle lever where it will hold a speed of between 80 and 85 miles an hour on the straightaways. Then, as the grade changes, they will move the throttle lever to a higher or to a lower notch as necessary to hold this average speed.

42. When necessary to slow down for a curve, they will ease the throttle lever back a notch or two and then will apply the brakes so that the speed will be reduced to the required amount just as the locomotive reaches the point of the curve. They will release the brakes as the locomotive enters the curve. Then they will move the throttle out a notch at a time if necessary to maintain speed on the curve.

43. The method of handling the throttle lever just described results in smooth handling of the train through curves and helps to maintain a high average speed. It gives much better results than to run with a wide open throttle all of the time. A man who runs with a wide open throttle and continually fights his brakes may have difficulty making schedule. Also, he may earn a reputation for rough handling of his train.

The Power Control Switch

44. The Power Control switch will trip if the brakes are set in emergency, or if the brakes are set due to the release of the safety control foot pedal, or if the brakes are applied because of the operation of the automatic train control, or if the overspeed control operates.

45. Usually, the train control alarm will sound before the P. C. switch trips. A bursted hose which would set the brakes in emergency would be one exception. If the alarm is sounded because the speed limit is being exceeded, the brakes can be applied to prevent the automatic application of the brakes. Likewise, when the alarm sounds because of an automatic train control penalty, prompt speed reduction followed by the operation of the acknowledging valve will forestall the penalty.

46. When the automatic train control operates to trip the P. C. switch, the electrical circuits of the locomotive throttle controls or perhaps of the fuel pump controls, or both, are broken, depending on how the locomotive is wired. The braking of the throttle control circuit will cause all engines to slow to idling speed. In this case, movement of the throttle lever to notch No. 1 will have the usual effect on the Diesel engines. Movement of the lever beyond the No. 1 notch will have no additional effect. Very little power will be available to move the locomotive while this switch is tripped.

47. Where the tripping of the P. C. switch shuts down the fuel pumps, the locomotive can be operated as usual for about 3 or 4 minutes; then, the fuel supply to the engines will be exhausted and the engines will die. This should not be allowed to occur. There is danger that the injectors will be scored if the fuel supply runs out. The engines should be stopped by moving the throttle lever to the OFF position unless the P. C. switch can be reset properly within 3 to 4 minutes.*

48. The P. C. switch cannot be reset after a penalty application of the brakes until normal conditions have been restored. This means that if the brakes were set because the foot pedal was released, the foot pedal must be depressed again and the brakes released. If the application was caused by automatic train control action, the train control apparatus must be reset and the brakes released.

49. When ready to release the brakes after a penalty application, the throttle lever must be in IDLING position. Then the brake-valve handle should be *moved* to

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*The road foreman of engines or the Diesel locomotive supervisor should be consulted as to definite procedure on different locomotives.

lap position and left there until the application pipe pressure gage shows 90 pounds.* Then the brake-valve handle can be moved to running position, after which the P. C. switch can be reset. It may take anywhere from 6 seconds to a minute for the application chamber pressure to build up to 90 pounds, depending on what caused the penalty application.

Gages and Alarms

50. Road locomotives do not have *dials* on the cab instrument panel to indicate power plant temperatures or oil pressures. If anything goes wrong at one of the engines that will cause the oil pressure to drop below a certain set value (usually about 12 pounds), the automatic controls are supposed to idle that engine before damage is done. On some locomotives there are three alarm lights in front of the fireman's seat in the cab, similar to the three alarm lights on each separate engine panel. These alarm lights indicate Low Oil, Steam Generator Shutdown, and Hot Engine, respectively. They are cut in so that if there is low oil pressure in any one engine, or if any one engine begins to heat unduly (above 200 degrees), the corresponding alarm light will glow. Similarly, if any one of the steam generators that may be in operation shuts down, the corresponding warning light will glow. Even if these cab lights are not provided, the usual engine-room alarm bells will give due warning.

51. Firemen, when they have opportunity, should check each individual engine.

(a) Engine temperature should run between 150 and 180 degrees.

(b) Main bearing lubricating oil pressure should be not less than 20 pounds per square inch when the engine is running at full speed.

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*The air brake action which must be completed is the movement of the application piston to its normal position. The way to tell when the piston moves is to watch the application pipe pressure gage hand as it nears 90 pounds. The gage hand flips down a little when the piston moves.

(c) Piston cooling oil pressure likewise should be from 20 to 30 pounds—never less than 15 pounds.

(d) Control air pressure at the high-voltage cabinets should be 80 pounds per square inch. (This is not to be confused with the control pipe pressure of the H.S.C. brake, which is variable and which is under the operator's control.)

52. The various safety controls, lights, and gongs which are provided are the best friends enginemen can have while operating a Diesel locomotive. Each is devised for some particular purpose connected with safety of operation or the prevention of a locomotive failure. The safety control or the automatic train control, of course, will apply the brakes and stop the train should either be called into action. The various warning lights may indicate the heating of an engine, lack of proper lubricating oil pressure in an engine, excessive oil suction pressure, or the shutdown of a steam generating plant. Alarm gongs sound whenever one of these conditions occurs.

53. Special hot-journal detectors are installed on some locomotives. They are connected electrically with the usual alarm gongs. The sounding of the gongs may be to call attention to a possible hot journal.

54. An engineer should be *completely* familiar with the meaning of every alarm or signal. Some alarms require the immediate stopping of the train so that the difficulty can be corrected before damage is done. Other alarms may indicate nothing more than that one engine has stopped or that one steam generator has shut down. There is no need to stop the train on such an alarm. In case of doubt, the safe course should be taken and no risks run.

55. A signal that indicates that something is wrong on one of the Diesel engines does not necessarily require stopping the train. The moment an indication is given that an engine is heating or lacks proper lubrication, that engine must be located and shut down if it has not already shut down automatically. Its isolation switch must be moved up to cut it out from cab control. No train delay need occur while the trouble is being located.

56. If a signal indicates that a steam generator has shut down, proper checks must be made to locate the trouble so that the steam generator can be restarted.

57. A flashing light on the engineer's instrument panel indicates wheel slippage. (A series of flashes occurs when transition takes place, as previously explained.) If the same light glows steadily when a train is pulling away from a stop, it is probable that one or more pairs of wheels are sliding. Flashing of the wheel-slip light, other than for transition, indicates that the throttle lever should be moved to a lower notch and left for a moment or two after the flashing ceases before being returned to its former notch. If necessary to use sand to prevent recurring slipping, the sander valve must not be opened until sufficient time has been allowed to insure that the slipping has ceased. If the sander is opened while the wheels are slipping, serious damage is likely to occur.

58. Two alarms require the immediate stopping of the train:

(1) The *constant* glow of the wheel-slip light when pulling away from a station or other stop. *This light is not a positive indication that driving wheels are sliding.* Nevertheless, if this signal lights up and continues to glow when pulling away from a station, the train should be stopped and the cause determined. If the reverser handle at the control stand in the cab was reversed during the stop, as when switching, the light might indicate that the reversing drum in one of the high-voltage cabinets had not re-

sponded to the movement of the reverser handle in the cab. In this case, the driving wheels connected with that one engine-generator set might start to turn in the reverse direction to the motion of the rest of the driving wheels of the locomotive. The light, also, might indicate nothing more than a stuck wheel-slip relay.

(2) If the hot-journal alarm indicator glows and the alarm gongs sound, the engineer must stop the train and locate the journal that has caused the alarm and be governed by experience. He must learn from the road foreman just what must be done if it is a false indication instead of a hot journal.

An individual engine may cut out automatically when there is no apparent engine trouble. The ground relay may have tripped and may trip again after the engine is started and put under load. In a case of this kind, the safe procedure is to stop the train and check the corresponding traction motors to make sure that there is no bearing trouble or fire in the motors.

SANDING

59. If the train is heavy or must be started on a grade, or if the rail is slippery, it is possible that the driving wheels may slip in starting. Wheel slipping will be indicated by the flashing of the wheel-slip light on the cab instrument panel. The throttle should be notched back *until the signal shows that the slipping has ceased.* Sand should not be used until the wheels have stopped slipping. Sand never should be used around traction motors unless really necessary.

60. When applying the brakes on a passenger train, sand should be used with great discretion. When sand is to be used, it should be turned on in time so that the rails under the entire train will be sanded before the brakes are applied. This wait is not necessary when all *cars* are equipped with individual sanders. Once the brakes have been applied without the use of sand, it is very risky to use sand during that application. If a pair of car wheels is sliding, the use of sand probably will cause a flat spot large enough to require that the car be set out.

61. An engineman has no signal to tell him when a pair of wheels on a *car* in the train is sliding. Some cars are equipped with an automatic device to prevent damage from wheel sliding. This device operates so that if a pair of wheels on a car starts to slide, the brakes on that truck will be released automatically.

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62. The air compressors do not always supply as much air as needed when the engines are idling. If more air is required to charge the train pipe to proper pressure or to maintain the proper pressure when coasting downgrade, it can be obtained by pulling out the generator field switch in the cab (the throttle lever *must* be in idling position before pulling this switch), after which the cab throttle lever can be moved two or three notches to increase the speed of the Diesel engines. No electricity will be generated as long as the generator field switch is out. The Diesel engines will idle faster as the throttle is notched out and the compressors will pump more air at the higher engine speed.

Shutting Off the Engines

63. The cab throttle lever is moved to the IDLING position to shut off the power of the locomotive. *To shut down all engines in case of an emergency,* the throttle lever is moved to the OFF position. The throttle lever button must be pushed in to move the throttle lever past the IDLING position to the OFF position. The fuel pump switch can be pulled out in case of fire hazard. When this switch is pulled, it shuts off all fuel pumps. This should not be done except when the throttle lever is in its OFF position.

64. At the end of the run, the engines usually are left running with the cab throttle lever in the IDLING position. The reverser handle should be left in its mid-position and the air brakes left applied. The rules of some roads provide that the reverser handle shall be removed if the locomotive is to be left unattended.

65. If it is the duty of a crew at the end of a run to shut down the engines, each engine should be shut down at its own control panel. Procedure is to move the isolation switch up and press in the stop button at the engine control panel. This should be repeated at each engine. Air pressure must be maintained for the operation of the control switches or this procedure will not stop the engines.

OLDER PASSENGER LOCOMOTIVES

66. Figure 4 gives a view of the cab of an older type "E" Diesel passenger locomotive. This particular locomotive has high-speed control (H.S.C.) brake equipment.

67. The control switches of this locomotive are located on the right side of the control stand. The light switches are located on the left side of the control stand. There is some difference in the instrument panel. There are no peepholes above the throttle lever slot. There are differences in the fuel oil, lubricating oil, and water tank capacities. Otherwise, the locomotive is quite similar to the type E-7 which has been described. There is no practical difference in its operation.

MISCELLANEOUS

68. All that has been said in a previous text about running a switching locomotive through water, slush, rain, and snow applies to passenger locomotive operation. Likewise, the instructions for operating over railroad crossings is the same.

69. During heavy rainstorms there always is a temptation to close the shutters *on the older locomotives* to keep water out of the engine room. This is not practical because, if the shutters are closed, it will prevent the necessary air from reaching the radiators. As a result, the engine cooling water may heat and boil. The shutters cannot always be closed enough to keep out rain without danger of interfering with the engine cooling. However, the engine room *ventilators* may be closed if the rain is very heavy or of long duration.

LIGHT SWITCHES

1. Headlight—dim
2. Headlight—bright
3. Instrument panel
4. Number lights
5. Classification lights

CONTROL SWITCHES

1. Control
2. Generator field
3. Fuel pump
4. Attendant's call
5. Defroster

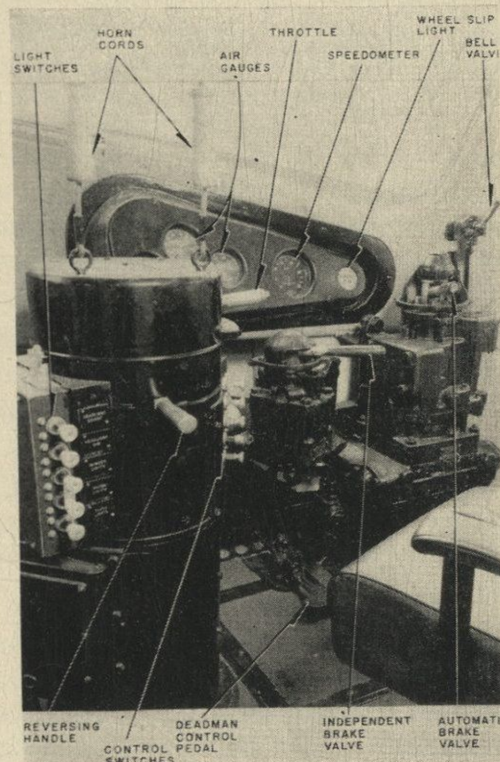

Fig. 4

70. Locomotives are equipped with a main fuel pump switch in the cab. It should be left in at all times except for emergency use or when control is changed to the other end of a double-end locomotive. If this button is pulled out while the engines are running, it will shut down all of the fuel pumps and consequently cause the shut down of all of the engines for lack of fuel. This is an emergency feature and should not be used except to prevent fire. The fuel injectors are lubricated by the fuel oil; consequently, there always is the risk that some injectors may be scored if the engines are stopped by shutting down the fuel pumps. When necessary to shut down all engines quickly, it should be done by moving the throttle lever to the OFF position.

71. When the cab throttle lever of a passenger locomotive is moved past the IDLING position to the OFF position, valves on each engine (known as "D" valves) operate the electro-pneumatic governor control of that engine. As a result, all of the power plants will shut down. This "D" valve is one of the four valves which form a part of each electro-pneumatic throttle control unit.

72. With a heavy train, after the throttle lever has been moved out at regular intervals to notch No. 8 and all engines are running at full speed, the full locomotive power is available at the traction motors. Thereafter, the acceleration of the train will be entirely in accordance with the load and the grade.

73. The locomotive builders recommend a maximum allowable speed for Electro-Motive passenger locomotives of from 85 to 117 miles per hour, depending on the gear ratio of the individual locomotive.* These locomotives can creep around curves as sharp as 21 degrees. Some of them are designed to take a curve as sharp as 24 degrees. They should not be overloaded or the traction motors will heat excessively and be damaged. They are overloaded if they cannot make 30 to 40 miles per hour normally. They can be allowed to pull at 25 to 35 miles per hour for from one-half hour to an hour. Local rules should be followed.

*Local rules should be checked. These figures are not the same on all roads.

74. The fuel oil tanks of each locomotive unit hold about 1200 gallons. The lubricating oil tank of each engine is filled with about 165 gallons of oil. The cooling water tanks for each engine are filled with 190 gallons of water at low level or with 245 gallons at high level. The steam generator water tanks of each locomotive unit hold 1200 gallons.

75. Speaking very generally, the fuel oil should take the usual Streamliner about 750 miles. The cooling water tanks should not require filling during a trip unless leaks occur.

76. The water for the steam generator will last only about 4 hours in ordinary winter weather. It should last for 10 hours in summer if used only for steam in the diner and for hot water in the other cars. If steam is used for air conditioning, as much may be required for this purpose in summertime as for heating the train during winter weather.

H.S.C. Brake Valves, Double-heading, Etc.

77. The instruction on Running Passenger Locomotives is in two parts. The second part contains some information about the H.S.C. brake valves. Also, it gives definite instructions about how to couple up for double-heading, that is, how to get at the coupler of the Diesel locomotive when a steam locomotive must be coupled ahead of the Diesel locomotive. Part 2 also gives full instructions on how to change control from one cab to another on a double-end locomotive. It tells how to uncouple one of the units of a multiple-unit locomotive and how to switch a "B" unit by the use of the "B" unit hostler's station. It includes other general information.

78. The Electrical Section of Part 2 explains Relays and Solenoids and tells something about how they are used in Diesel control circuits.

EXAMINATION QUESTIONS

1.... Explain how the cab controls must be operated in order to move the locomotive—after the engines are running and the isolation switches are in the run position.

2.... Explain the positions in which the cab throttle and reverser handle are "interlocked" and what interlocked means.

3.... Tell how properly to shut down all of the Diesel engines of a locomotive from the cab.

4.... Explain two special uses for the fuel pump switch in the cab of a road locomotive.

5.... What is the purpose of the safety control pedal?

6.... Why should there be a pause of 3 or 4 seconds after the throttle lever has been moved to one notch, before it is moved to the next notch?

7.... If the P.C. switch has tripped due to an automatic train control penalty application of the brakes, what procedure must be followed to reset the switch?

8.... Describe how a train should be started.

9.... Tell how the throttle and brakes should be handled when approaching and while passing through a speed restricting curve.

10.... At what speed should transition from series to parallel take place?

11.... How can a check be made to know that transition has taken place on all engine-generator sets of the locomotive?

12.... Tell what causes backward transition from parallel-shunt to parallel when the train speed is reduced considerably due to a grade.

13....Tell how to make backward transition from parallel to series.

14....What alarms require that the train should be stopped immediately to ascertain the cause for the alarm?

15....What should be done if an alarm indicates that an engine has low oil pressure?

16....If you are an engineman, tell how to start a train on a heavy grade.

17....If you are an engineman, explain the instructions in effect on your road concerning the reading of the load indicating meter.

THE ELECTRICAL SECTION

ELECTRICAL ACTION

MAGNETISM—MOTORS

E-1. ALMOST ANY GENERATOR CAN BE CONVERTED INTO A MOTOR at any time by the simple process of passing an electric current through its armature circuit instead of taking current from the armature. The magnetic field of the generator must be maintained while current is passed through its armature circuit or the armature of the generator will not revolve as a motor.

E-2. Anyone can demonstrate THE PRINCIPLE OF A MOTOR by a few simple experiments. A wire can be offset and suspended above one pole of a magnet as shown

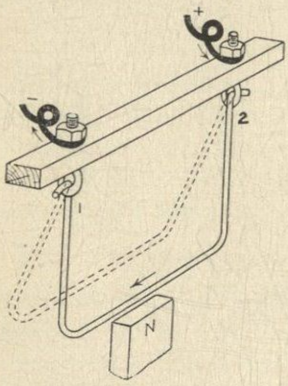

Fig. E-1

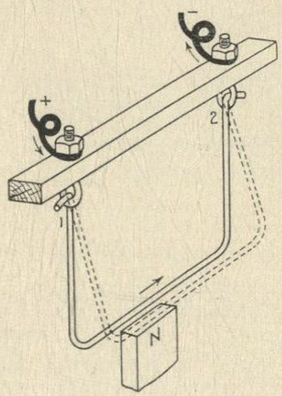

Fig. E-2

in Fig. E-1. If a current of electricity is passed through this suspended wire, the wire will be deflected one way or the other across the face of the magnet. The direction in which it will be deflected will depend on the direction in which the current is flowing through the wire and on the polarity of the magnet. With the current flowing in the direction shown in Fig. E-1, the deflection from the north pole of a magnet will be as shown by the dotted lines.

E-3. If the direction of the current in the wire shown in Fig. E-1 is reversed, the wire will be deflected in the opposite direction as shown in Fig. E-2. Now, let the flow of *current through the wire continue in the same direction (Fig. E-2), but turn the magnet so that the south pole of the magnet is opposite the wire instead of the north pole. When this has been done, as shown in Fig. E-3, the wire will be deflected back again in spite of the fact that the direction of the current through the wire was not reversed. Only the polarity of the magnet was changed.*

E-4. The experiments just outlined explain the fact that THE DIRECTION OF TURNING OF THE ARMATURE OF A MOTOR CAN BE REVERSED either by

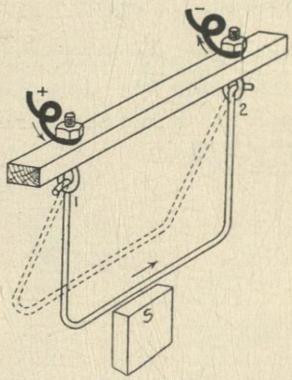

Fig. E-3

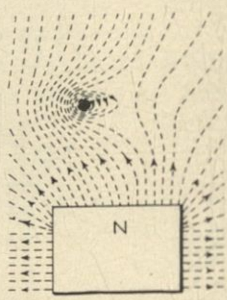

Fig. E-4

reversing the direction of the current through the armature circuits or else by changing the polarity of the magnets in the field in which the armature revolves.

E-5. Figure E-4 illustrates the magnetic field around the end of a magnet and around a conductor (a wire) in this field. This is a setup similar to the examples illustrated in the previous figures. Current is flowing through the wire as in Fig. E-2. The lines of magnetic force around the wire and the lines of magnetic force at the end of the magnet are visualized by lines. The magnetic field around the wire disturbs the field of the magnet. Fig. E-4 indicates that some of the lines of force from the magnet curve or cramp around the wire. It is not hard to imagine from a study of Fig. E-4 that this disturbance of the magnetic field results in a magnetic action that moves the wire across the face of the magnet.

E-6. Figure E-5 shows a loop of wire as though it were suspended or pivoted in a magnetic field. If a current of electricity flows through this loop, the loop will start to turn as indicated by the arrows. This action is the same as the movement of the wire in Fig. E-2. The turning force will continue until the loop reaches the position shown in Fig. E-6. The magnetic forces are balanced when the loop is at a right angle to the lines of force between the poles of the magnet. However, if the direction of the current in the loop is reversed just as the motion of the loop carries it

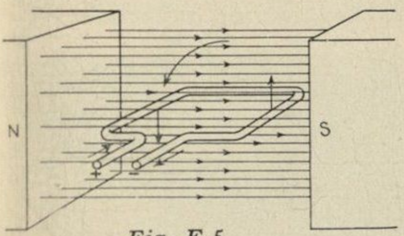

Fig. E-5

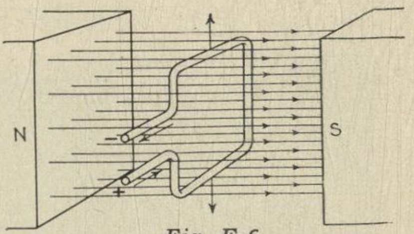

Fig. E-6

beyond this position, the motion will continue through another half revolution. THE LOOP WILL CONTINUE TO TURN as long as the current is reversed properly each half revolution. This explains the action which causes the armature of a motor to revolve.

E-7. The generators used on Diesel locomotives supply direct current to the traction motors. This direct current must be COMMUTATED before it enters the armature circuits. This means that the direction of the current through the loops (coils) of the armature must be reversed properly during each revolution of the armature. This reversal of the current is accomplished by a commutator on the armature shaft. The method is just the reverse of the way in which generator current is commutated to give direct current.

E-8. Motors can be designed to operate on either direct current or alternating current. They are made in all sizes and in a variety of designs which meet every conceivable requirement.

QUESTIONS FOR SELF-EXAMINATION

1. . . . Under what conditions can a generator be used as a motor?
2. . . . Will the generator act as a motor if its field magnets are not energized?
3. . . . By what two methods can the direction of rotation of the armature of a motor be reversed?

TRACTION MOTORS FOR DIESEL LOCOMOTIVES

E-9. DIRECT CURRENT TRACTION MOTORS are used for Diesel locomotives. They consist of a stationary outer portion or shell around which are located two pairs of electromagnets which form the magnetic field. An armature is free to revolve in this magnetic field. The construction is very similar to that of a generator. If a motor is to operate on direct current, it will have a commutator on the shaft of the armature so that the direction of the current

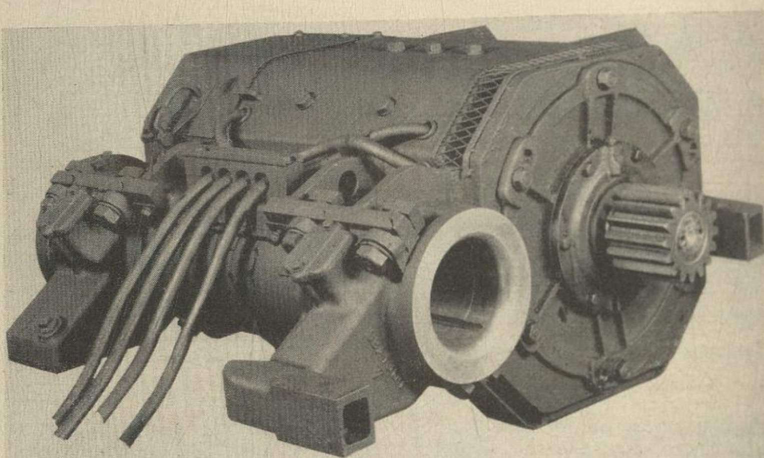

Fig. E-7

supplied to the loops or coils of the armature winding will be reversed properly during each revolution.

E-10. Figure E-7 illustrates one type of traction motor used for Diesel locomotives. The motor housing or case is carried by two split sleeve bearings which are fitted over its driving axle. It is kept in position on the axle, that is, it is kept from rotating with the axle, by a spring-cushioned connection with the truck. A driving pinion is fitted at the end of the armature shaft of the motor. This pinion drives a matching gear which is fastened to the driving axle. The housing of this gear is shown next to the right-hand wheel in Fig. E-8. Current to drive the motor comes from the Diesel engine-generator set. Four connecting cables are *shown; two lead to the commutator brushes of the armature and the other two to the circuits of the field magnets.*

E-11. The circuit to the pairs of electromagnets which form the field of the motor is arranged so that THE DIRECTION OF CURRENT THROUGH THE COILS OF THESE FIELD MAGNETS CAN BE REVERSED when desired. When the current flows through the coils of the field magnets in one direction, the armature of the motor will revolve in one direction. When it is desired to reverse the direction of travel of the locomotive, the circuits are

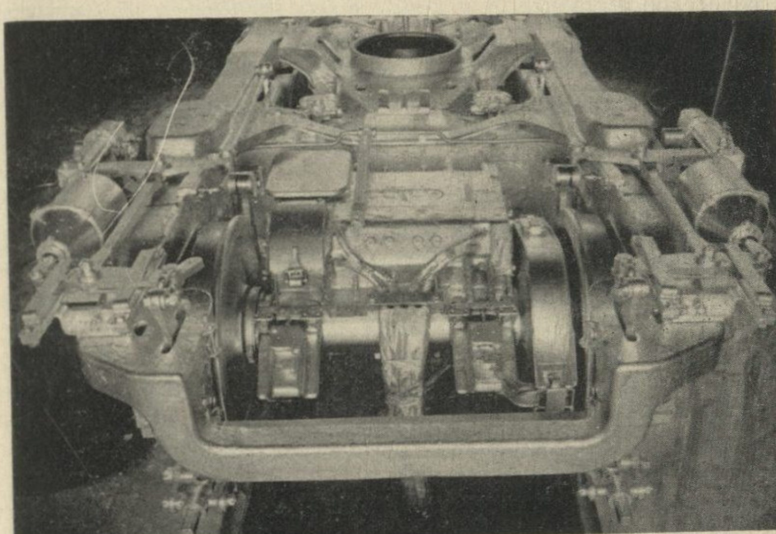

Fig. E-8

changed so that the current flows through the coils of the field magnets in the opposite direction. This CHANGE OF THE POLARITY OF THE FIELD magnets is all that is required to reverse the direction of rotation of the traction motors of a Diesel locomotive.

E-12. The reversal of the motors could be accomplished by leaving the motor field circuits alone and changing the direction of the flow of current through the coils of the armature of the motor. Either change will cause the reversal of the direction of revolution of the armature. The principle involved was pointed out in paragraph E-4.

QUESTIONS FOR SELF-EXAMINATION

4.... What kind of a drive is there between the traction motor of a Diesel locomotive and its driving axle?

5.... What circuit change is made to reverse the direction of rotation of the armatures of the traction motors of Diesel locomotives?

COUNTER ELECTROMOTIVE FORCE

E-13. It has been stated that almost any generator can be operated as a motor. It is likewise true that EVERY MOTOR TENDS TO GENERATE CURRENT THE MOMENT ITS ARMATURE STARTS REVOLVING. When the armature of a motor starts turning in its magnetic field, the machine becomes a generator as well as a motor. It generates a voltage that would cause a current to flow back through the motor armature circuit except for the fact that a stronger current already is flowing toward the motor from the main generator. No generated current actually flows from the motor under ordinary conditions. However, the generating action of the motor builds up a potential at the brushes of the commutator. This potential represents a definite electrical pressure or voltage which acts as a back pressure or apparent resistance against the current flowing to the motors. This phenomenon of a motor generating an electrical pressure which opposes the free flow of current being supplied to it, always occurs when the motor is operating. The generated voltage is called COUNTER ELECTROMOTIVE FORCE.

E-14. When the motors of a Diesel locomotive are at rest and current is turned into the motors to start the train, there is no counter electromotive force to oppose the free flow of current to the motors. When the train first gets under way and the speed still is low, the counter electromotive force generated in the motor is very small in comparison with the voltage at which current is being supplied to and used by the motor. In other words, the counter electromotive force is a negligible factor at low speeds.

E-15. As the speed of the motor increases, the counter electromotive force, set up by the generator-action of the motors, will increase proportionately. In time, a speed will be reached where the counter electromotive force will almost equal the voltage at the main generator. This will cut *down the flow of current to the motors to such an extent that it will limit the speed. If additional speed is required, or if the speed is to be maintained when the train reaches an ascending grade, the EFFECTIVE VOLTAGE of the motor circuits must be increased. This can be done either by increasing the voltage supplied to each motor by the generators or by decreasing the counter electromotive force at the motors.*

E-16 Circuit changes called transition were explained in Unit N. 23. The reason for these circuit changes now will become apparent.

TRANSITION—SERIES TO PARALLEL

E-17. The traction motor circuits of many Diesel passenger locomotives are in series at starting; all of the current being supplied by a generator goes through each of its two motors. However, THE VOLTAGE AT EACH MOTOR WILL BE ONLY HALF OF THE VOLTAGE AT THE GENERATOR. This was explained when series and parallel circuits were discussed in the Electrical Section of Unit N. 23. As the speed increases and the counter electromotive force offers more resistance to the flow of current to the motors, the voltage at the generator builds up higher and higher until a pressure of about 980 volts is reached. The transition relay "picks up" at about 980 volts. When it picks up it closes contactors which switch the traction motor circuits from series to parallel.

E-18. When the circuits are switched from series to parallel, the voltage at the motors will be the same as the voltage at the generator. This higher voltage forces more current through the traction motors which, in turn, causes the generator voltage to drop accordingly. The transition relay drops out again at about 700 volts, but when it drops out it does not change the circuits back from parallel to series.

E-19. This change of circuits (transition) is regulated to take place before the increasing counter electromotive force cuts down the net or EFFECTIVE voltage at the motors sufficiently to hinder the acceleration of the train. The jump in voltage at each motor when this transition *takes place increases the net or effective voltage materially. Consequently, enough more current can be forced through the motor armature circuits to increase the speed of the train sufficiently for ordinary operating requirements.*

DECREASING THE COUNTER ELECTROMOTIVE FORCE

E-20. After the transition just described has taken place, the speed may increase until no further reserve power is available at the Diesel engines. Then any increase in grade will result in a decrease in the speed of the train. As soon as the speed of the train decreases, the counter electromotive force at the motors will decrease also. A decrease in counter electromotive force results in an increase in effective voltage at the motors. This allows more current from the generator to flow to the motors. Thus, the decrease in train speed may be quite gradual unless the grade change is very heavy. This is a negative way of reducing the counter electromotive force. The result is obtained at the expense of a loss in train speed.

E-21. There is a direct way to decrease counter electromotive force and thus allow an INCREASE OF TRAIN SPEED. This is ACCOMPLISHED BY REDUCING THE STRENGTH OF THE MAGNETIC FIELD OF THE MOTOR. It will be remembered that the voltage at which any certain amount of current is produced at any generator varies with the speed of its armature and the strength of its magnetic field. If the strength of the magnetic field of a generator is reduced, the voltage will drop. Similarly, the counter electromotive force will drop if the strength of the field of the traction motors is reduced.

E-22. The direct method used to reduce the strength of the field of the traction motors of a Diesel locomotive is to place a SHUNT across the motor field circuit. This is done by cutting in a by-pass circuit in parallel with the circuit through the field coils. There is a resistor in this by-pass circuit.

E-23. The shunt circuit is used as a detour through which a part of the current, which otherwise would flow *through the field coils of the motor, is diverted. The amount of current flowing through the circuits of the motor field winding is reduced in proportion to the amount diverted through the shunt. This causes a corresponding reduction in the strength of the field and, consequently, of the counter electromotive force.* As a result, the net or effective voltage at the motors is materially increased. Enough more current can flow to the motors to give still higher speed.*

TRANSITION—PARALLEL TO PARALLEL-SHUNT

E-24. The shunting of the field of the traction motors or the change of the traction motor circuits from parallel to so-called parallel-shunt is an additional transition. This transition is accomplished when the increase in counter electromotive force causes the generator to build up a pressure of 980 volts again. This causes the transition relay to pick up a second time and to operate the shunting contactors which cut in this shunt circuit. This relay stays closed as long as the generator voltage stays above the drop-out point, which is about 700 volts.

BACKWARD TRANSITION

E-25. When the speed of the train is reduced for any reason, the counter electromotive force drops automatically and thus eliminates the need for the shunt across the motor field circuits. Again, if the grade eases up so that less power is required to maintain the train speed, the locomotive throttle will be notched back. In either case there will be a drop of the generator voltage that will be sufficient to let the transition relay drop out. This will cause the traction motor circuits to change automatically from parallel-shunt back to parallel. This is what is called BACKWARD TRANSITION FROM PARALLEL TO PARALLEL-SHUNT.

E-26. An additional backward transition is from parallel back to series. The traction motor circuits change from parallel to OPEN CIRCUIT whenever the locomotive throttle is moved to the idling position. Then, when the throttle is

**The shunt causes some additional current to flow through the armature also.*

opened again, the contactors will connect the motors in series as at first. The change can be made by the locomotive engineer whenever it is necessary.

QUESTIONS FOR SELF-EXAMINATION

6. . . . When the traction motors of a Diesel locomotive are driving the locomotive, do they act also as generators?

7. . . . What is meant by counter electromotive force?

8. . . . Is there any counter electromotive force when the traction motors are at rest, that is, at the instant current is turned into the motors to start the train?

9. . . . What is the effect on the counter electromotive force that builds up in the traction motors as the speed of the train increases?

MISCELLANEOUS ITEMS

E-27. It has been said that direct current traction motors have a very high TORQUE when starting. All of the power supplied to the traction motors of a locomotive is converted into torque or turning effort at the drivers when starting a train from rest. No counter electromotive force is present in the motor circuits until the motors start to turn, and then this force is but little in comparison with the total amount of power available.

E-28. When a long, heavy passenger train is stopped on a grade, THERE IS NO NEED TO TAKE THE SLACK WHEN STARTING. There are eight pairs of driving wheels on a two-unit Diesel passenger locomotive. The drivers are small in diameter compared with steam locomotive drivers. The traction motors give a perfectly uniform starting torque. There is sufficient power available to supply this steady turning effort on the drivers to the limit of adhesion, that is, to the point where the power is sufficient to spin the drivers. If an engineer on a Diesel locomotive, because of his steam locomotive experience, bunches the slack with a heavy train and then turns on his electric power quickly, it is possible to tear the train in two. A Diesel passenger locomotive will start any train on a grade that it can haul up the grade at allowable slow speed. This is not so with a steam locomotive. A steam locomotive often can drag a train up a grade at 10 to 15 miles an hour that it could not start on the grade without a helper.

E-29. It has been explained that the MAIN GENERATOR IS USED AS A MOTOR for cranking the Diesel engine. There is a special winding in the field of the main generator which is used for magnetizing the field while the generator is being used as a motor. This winding is heavier than the other windings of the magnets of the generator field. This field circuit is in series with the armature circuit on starting and thus has to carry the full storage battery current being supplied for the motoring action. The starting winding is not used at any other time except when the generator is being used as a motor.

DYNAMIC BRAKING

E-30. The action of the motors of a Diesel locomotive as generators has one practical application which is used on some Diesel locomotives. When a train is coasting down a long grade, the power (flow of current) from the generators to the armatures of the traction motors is shut off. However, THE FIELDS OF THE MOTORS ARE KEPT ENERGIZED. This causes the motors to act as generators. If this current that is generated in the motors is passed through a circuit of very low resistance, the motors will work under a heavy electrical load. The circuit of low resistance is provided by turning the current generated by the motors into heavy grids that are located in the roof of the locomotive units. The ELECTRICAL ENERGY IS CONVERTED INTO HEAT as the current passes through these grids. Suitable fans are provided to get rid of this heat.

E-31. DYNAMIC BRAKING is the name given to the method of controlling the speed of a freight train on a heavy downgrade by putting a varying electrical load on the traction motors while they are acting as generators. The load is varied by increasing or decreasing the flow of current through the grids. The power required to generate this current in the motors forms a drag on the locomotive that can be controlled by the engineer as desired. The train can be controlled satisfactorily until the speed drops to about 10 miles per hour. Then the dynamic brake should be switched off and the train stopped with the air brakes. The generative action of the motors is greatly reduced at low speed and ceases entirely when the motor armatures stop *rotating. (The counter electromotive force drops to zero.) The train must be held on the grade with the air brakes.*

E-32. The motor fields, of course, must be energized if the motors are to act as generators. For dynamic braking this is accomplished by setting up a circuit from each main generator through the fields of the four motors with which it is connected.

E-33. The main generators will be running at idling speed while there is use for dynamic braking. Movement of the transition and braking lever to the braking position closes contactors which set up a circuit from the storage battery through the unit selector switch and the transition braking lever contacts and through a field winding of each main generator. As a result, although the engines are idling, a certain amount of current will be produced by each generator. The amount of current that each generator will produce will depend on the amount of storage battery current flowing through the generator field windings. The amount of storage battery current flowing through the generator field windings is regulated by the position of the transition and braking lever.

E-34. All of the generator current that is produced at each generator goes directly through the field windings of the traction motors connected with that generator. The circuit from the generator to the four traction motors is a series circuit. The amount of current generated by the traction motors for dynamic braking will be in proportion to the amount of generator current flowing through the field of the motors.

E-35. The amount of current generated by the main generator can be varied by the engineer as he moves the transition and braking lever from one position to another. The retarding force of the dynamic braking at any speed will be in proportion to the amount of generator current flowing through the fields of the traction motors.

QUESTIONS FOR SELF-EXAMINATION

10.... *What is meant by the starting torque of a motor?*

11.... *Why is it unnecessary to take the slack when starting a train with a Diesel locomotive?*

12.... *Explain how the effective voltage at the motors is increased when transition takes place.*

13.... *What is the purpose of putting a shunt across the circuit of the field of the traction motors at high speed?*

14.... *What effect does a reduction in the speed of the train have on the counter electromotive force?*

15.... *What is meant by dynamic braking?*

(END OF ELECTRICAL SECTION)