DEPARTMENT OF THE ARMY TECHNICAL MANUAL **TM 55-202**

DEPARTMENT OF THE AIR FORCE TECHNICAL ORDER **TO 45A2-2-1-2**

OPERATION AND MAINTENANCE OF DIESEL-ELECTRIC LOCOMOTIVES

This copy is a reprint which includes current pages from Changes 1 through 3.

DEPARTMENTS OF THE ARMY AND THE AIR FORCE

OCTOBER 1965

Change No. 3

DEPARTMENTS OF THE
ARMY AND THE AIR FORCE
Washington, D.C., *16 February 1973*

OPERATION AND MAINTENANCE OF DIESEL-ELECTRIC LOCOMOTIVES

TM 55-202/TO45A2-2-1-2, 25 October 1965, is changed as follows:

Page 141, paragraph 127, line 25, is changed to read: ....figure 74. Location of handholds and couplings of a foreign service type locomotive are shown in figure 75.

Page 160, paragraph 134, General, is changed to read:

134. Operation

a. General. Routine operation of a diesel-electric locomotive is controlled by the throttle, reverse lever, and brake valves. Various instruments, gages, protecting and regulating devices contribute to efficient, safe operation. Specific information for individual types is best obtained from the operational manuals issued by the respective manufacturers.

b. Operator Qualification. A thorough general knowledge of various types of locomotives and a careful observance of prescribed rules and operating procedures are essential to efficient operation. Locomotive operators (or enginemen) must possess an SF 46 (US Government Motor Vehicle Operator's Identification Card). It will be annotated on the reverse side to indicate the type of locomotive the individual is authorized to operate, in accordance with paragraph 2*a*(5), AR 600-58. The commander of the rail unit or other activity to which locomotives are assigned is responsible for the selecting, training, testing, and licensing of locomotive operators. Railway operating and safety rules are contained in TM 55-200.

Page 195, paragraph 186d, Pending revision of DD Form 1336, title is changed to read: "Thirty Day and Annual Locomotive Unit Inspection and Repair Report."

Page 195, paragraph 186d, as changed by Change 1, the following is added at end of paragraph: A copy of the DD Form 1336, annual report, will be forwarded to MECOM, ATTN: AMSME-MMR, (for retention in their files), by all ITO and rail activities.

Page 200, figure 93, heading of DD Form 1336 is changed to read: Annual Locomotive Unit 30 Day Inspection and Repair Report.

Page 200, figure 93, title of DD Form 1336 and caption are changed to read: Annual/30 Day Locomotive Unit Inspection and Repair Report.

Page 237, paragraph 2-15c(7), is deleted.

Page 237, paragraph 215, subparagraph *d* is changed to read:

d. Marking Front. The letter "F" shall be legibly shown (4 inch characters) on each side of every locomotive unit near the end, which for identification purposes, will be known as the front end. The unit number shall be legibly shown (4 inch characters) on each side of every locomotive unit and shall be shown on the specification card (report of inspection) displayed in the cab. The front of a locomotive is the direction the engineman faces looking forward, when he and the controls are on the right side.

Page 270, paragraph 1, Army Regulations, AR 600-58. "Mechanical Equipment Operator-Selection, Training, Testing, and Licensing" is added.

By Order of the Secretaries of the Army and the Air Force:

CREIGHTON W. ABRAMS
General, United States Army
Chief of Staff

Official:
VERNE L. BOWERS
Major General, United States Army
The Adjutant General

JOHN D. RYAN, *General, USAF*
Chief of Staff

Official:
DWIGHT W. COVELL, *Colonel, USAF*
Director of Administration

Distribution:
To be distributed in accordance with DA Form 12-25D (qty rqr block no. 800), Operator requirements for Rail Equipment, All.

CHANGE }
No. 2 }

DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON, D.C., *11 August 1971*

OPERATION AND MAINTENANCE OF DIESEL-ELECTRIC LOCOMOTIVES

TM 55-202/TO45A2-2-1-2, 25 October 1965, is changed as follows:

Page 3. Paragraph 1d, line 11, add: Procedures for the maintenance of U. S. Army-owned diesel-electric locomotives performed by foreign government railways in Germany, Vietnam and Korea, are discussed in TM 55-205.

Page 3. Paragraph 2, line 12, change to read: Directorate of Doctrine Development, Literature and Plans, Fort

Page 9. Paragraph 10*a*, line 19, change Cummings to Cummins.

Page 12. Paragraph 12, lines 5-6, change to read: (figs. 2, 3, and 4).

Paragraph 14*a*, line 2, change to read: figures 5 and 6.

Add Figure 4.

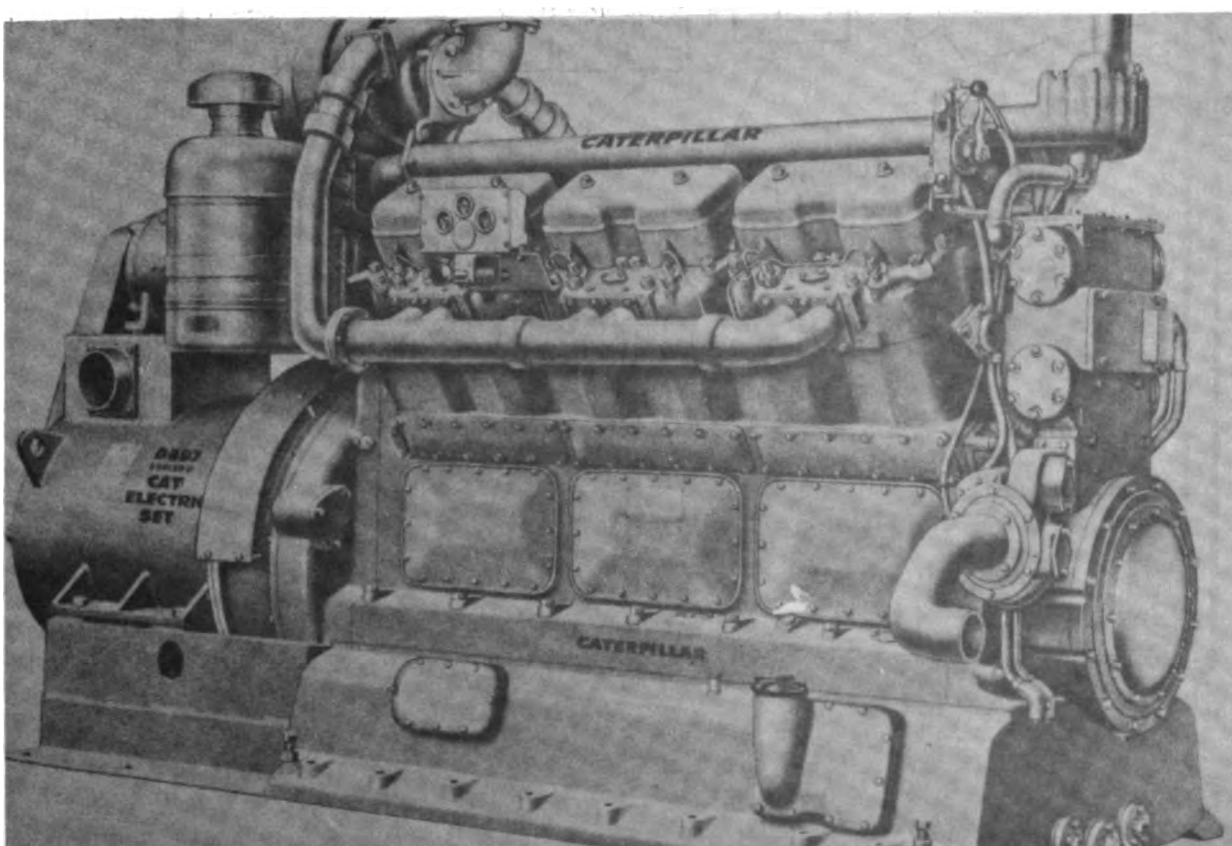


***Figure 4.** V-type diesel engine, side view (Caterpillar D-397 model).*

Page 14. Paragraph 14*b*, line 3, change to read: (fig. 7).

Paragraph 14*c*, line 1, delete (fig. 7)

Page 15. Figure 4, redesignate, Figure 5.

Page 16. Figure 5, redesignate, Figure 6.

Page 17. Figure 6, redesignate, Figure 7.

Paragraph 14*i*, line 1, delete (fig. 10) and change line 9 to read: * * * each cylinder head is * * *

Page 18. Figure 7, delete in entirety.

Figure 8, change to read: Cylinder block, ALCO-244-F engine.

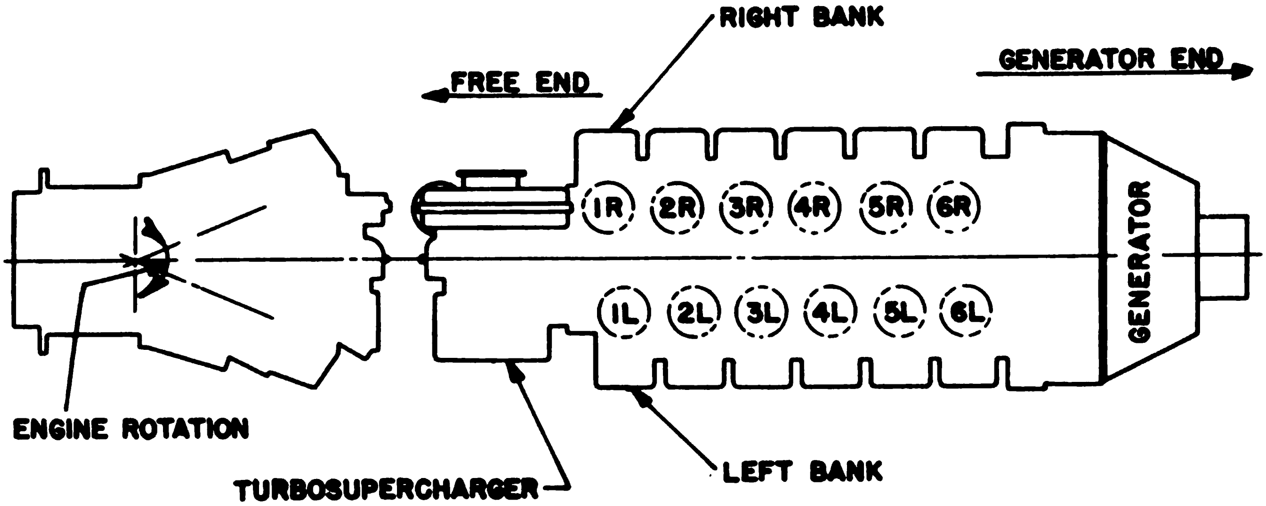
Page 20. Figure 10, change to read: Cylinder head components.

Paragraph 14*j*, lines 2-3, delete (fig. 11).

Figure, 11, change to read: Figure 11, Camshaft, EMD 567 engine.

Page 21. Paragraph 14*k*, line 10, change to read: smoke. The three cams which regulate fuel injection and exhaust are shown in figure 11. Figure 12 illustrates the firing order of the ALCO 244 engine. The point * * * crank shaft.

Page 22. Figure 12 is superseded as follows.



FIRING ORDER
1R-1L-4R-4L-2R-2L-6R-6L-3R-3L-5R-5L

Figure 12. Firing order, ALCO 244 engine.

Page 24. **Figure 13 is superseded as follows:**

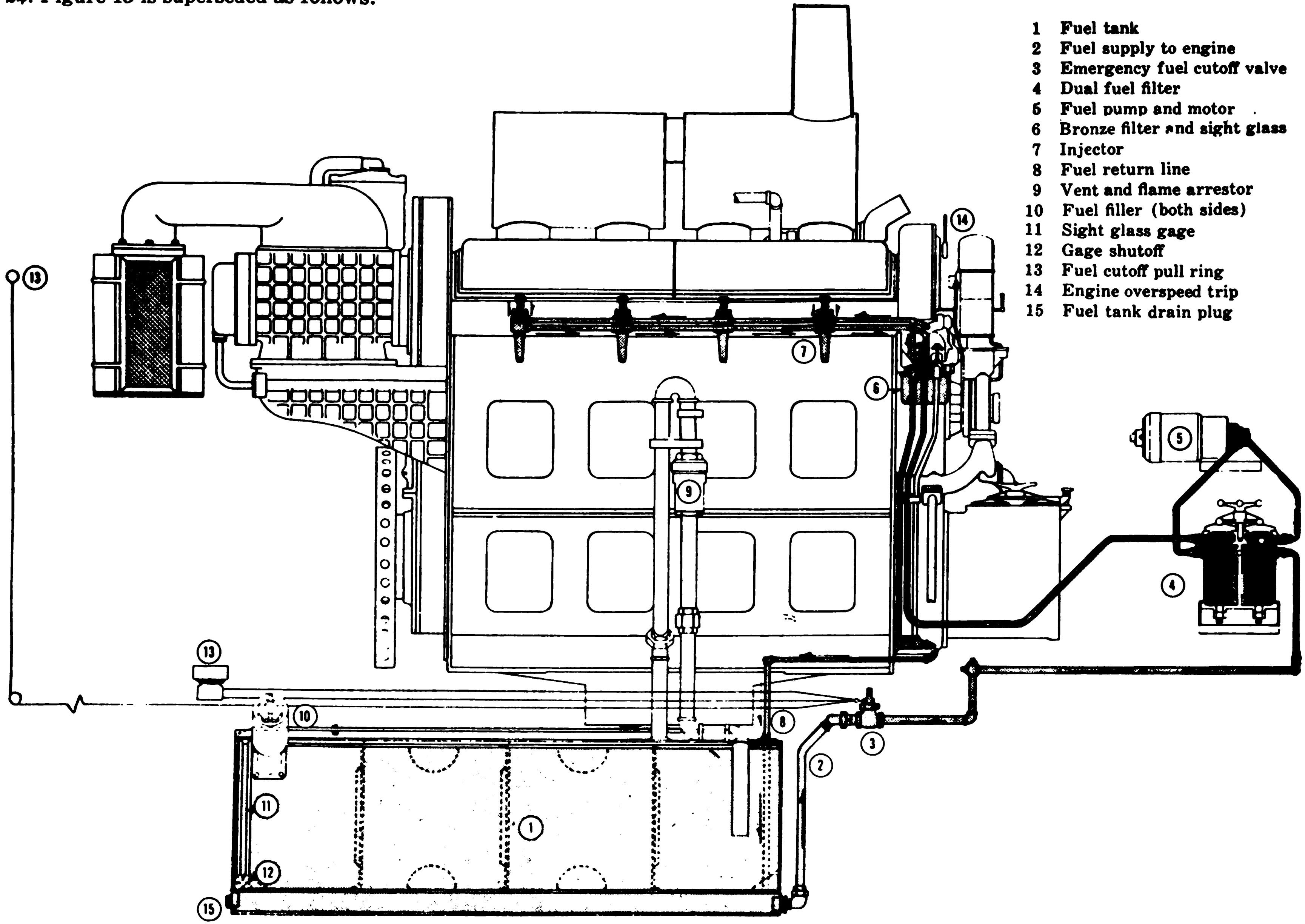


Figure 13. Diagram of EMD SW-8 fuel oil system.

Page 25. Paragraph 18*b*, line 11, delete sentence "A duplex fuel oil filter is shown in figure 14."

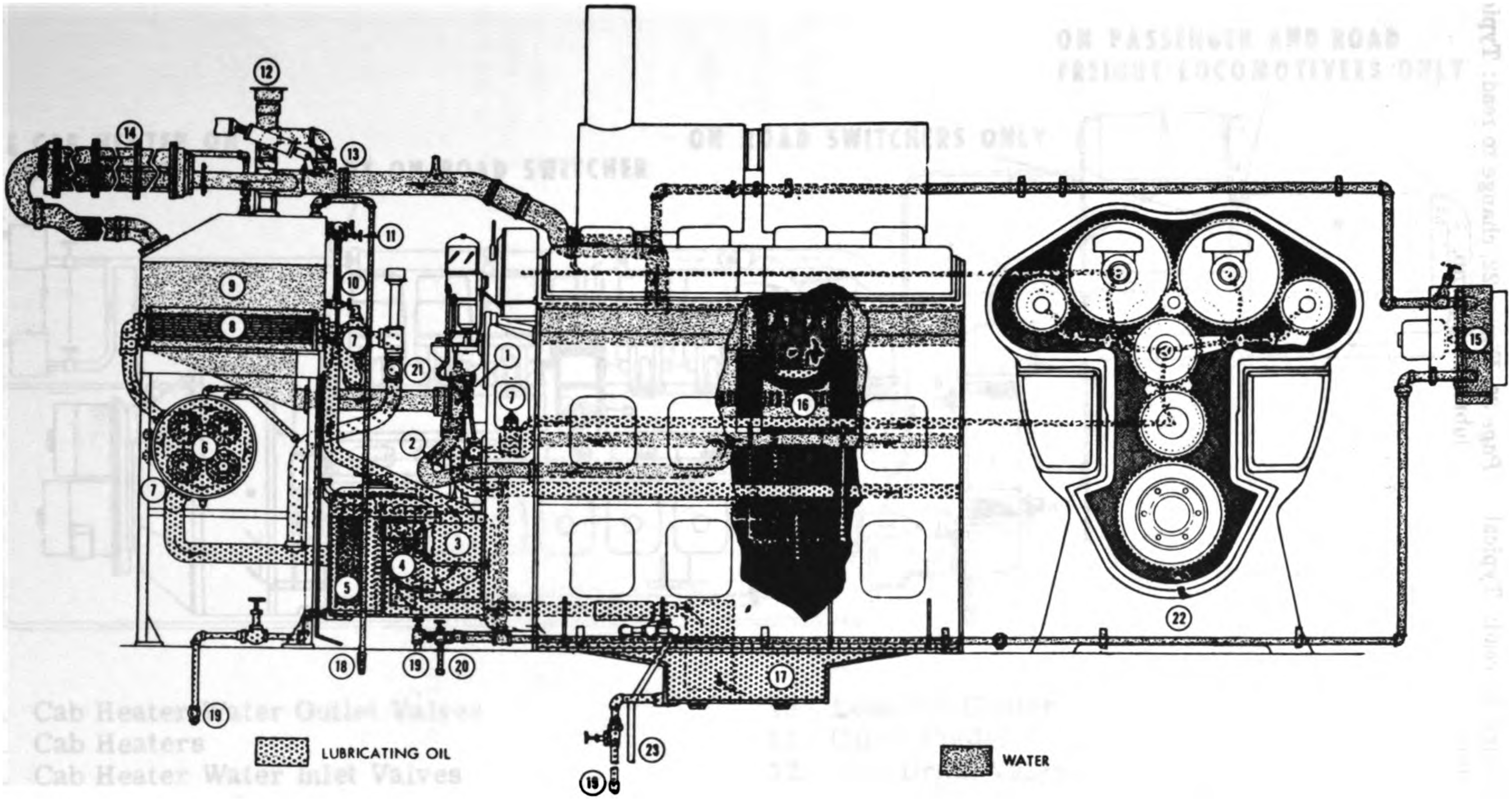
Paragraph 18*d*, line 7, delete (fig. 14).

Page 26. Figure 14, delete in entirety.

Page 27. Figure 15, Change to read: Typical fuel oil supply pump system.

Page 28. Figure 16, change to read: ALCO 244-F fuel injection pump.

Page 33. **Figure 20 is superseded as follows:**



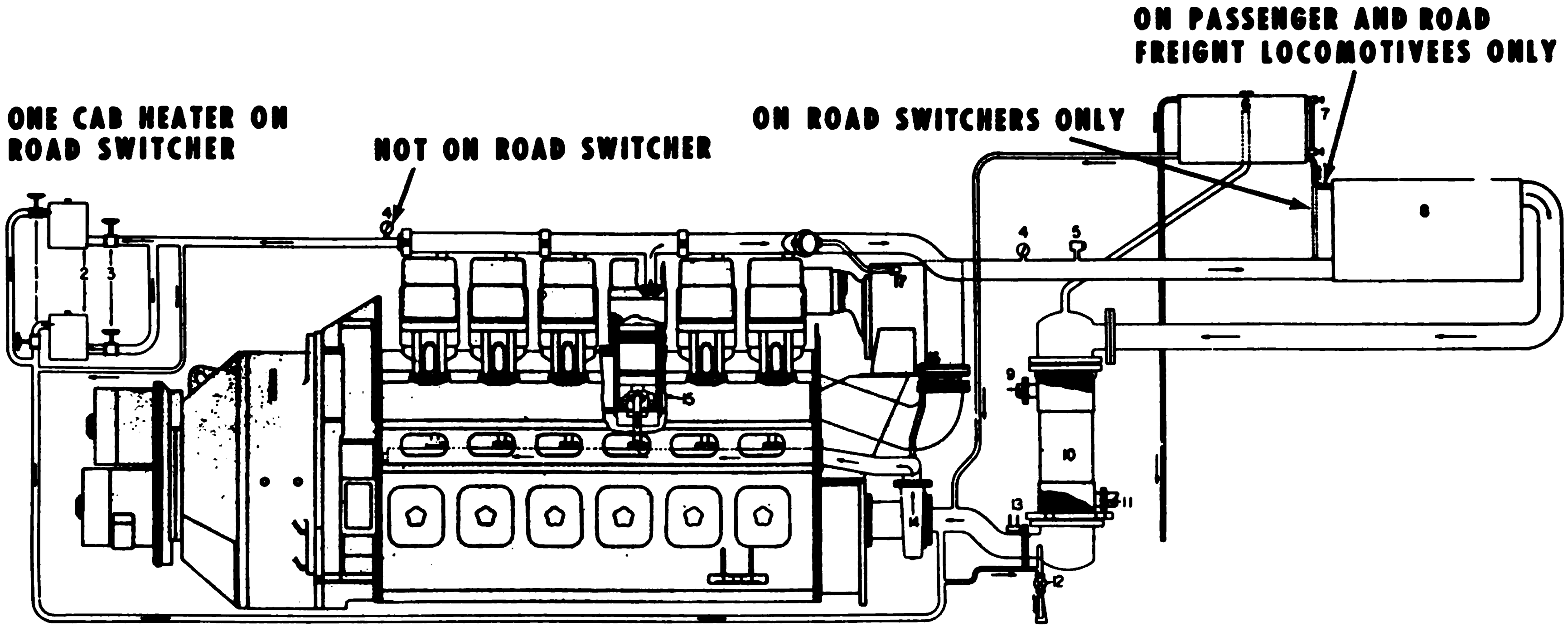
1	Water pump
2	Lubricating oil pump (piston cooling)
3	Scavenging oil pump
4	Sump oil strainer
5	Lube oil strainer
6	Lube oil filter
7	Lube oil relief valve
8	Lube oil cooler
9	Cooling water tank
10	Water level gauge
11	"G" valve
12	Roof filler
13	Water bypass valve
14	Water radiator
15	Cab heater
16	Cylinder liner
17	Engine sump
18	Side water filler
19	Drains
20	Steam admission valve
21	Lube oil bypass sight glass
22	Camshaft drive gear train
23	Air box drain

Figure 20. Schematic diagram of EMD SW-8 cooling and lubricating oil system.

Page 35. Figure 21, change to read: **Typical type of lubricatng oil filter.**

Page 37. Figure 22, change to read: **Typical oil lubricating pump.**

Page 40. Figure 24 is superseded as follows.



1. Cab Heater Water Outlet Valves
2. Cab Heaters
3. Cab Heater Water Inlet Valves
4. Temperature Gauge
5. High Temperature Switch
6. Expansion Tank
7. Expansion Tank Sight Glass
8. Radiators
9. Oil from Cooler
10. Lube Oil Cooler
11. Oil to Cooler
12. Fill-Drain Valve
13. Fan and Shutter Control Thermostat
14. Water Pump
15. Water Jacket, Jumper and Liner Assembly
16. Water Inlet to Turbo
17. Water Outlet from Turbo

Figure 24. ALCO 244 cooling water system.

Page 41. Figure 25 is superseded as follows:

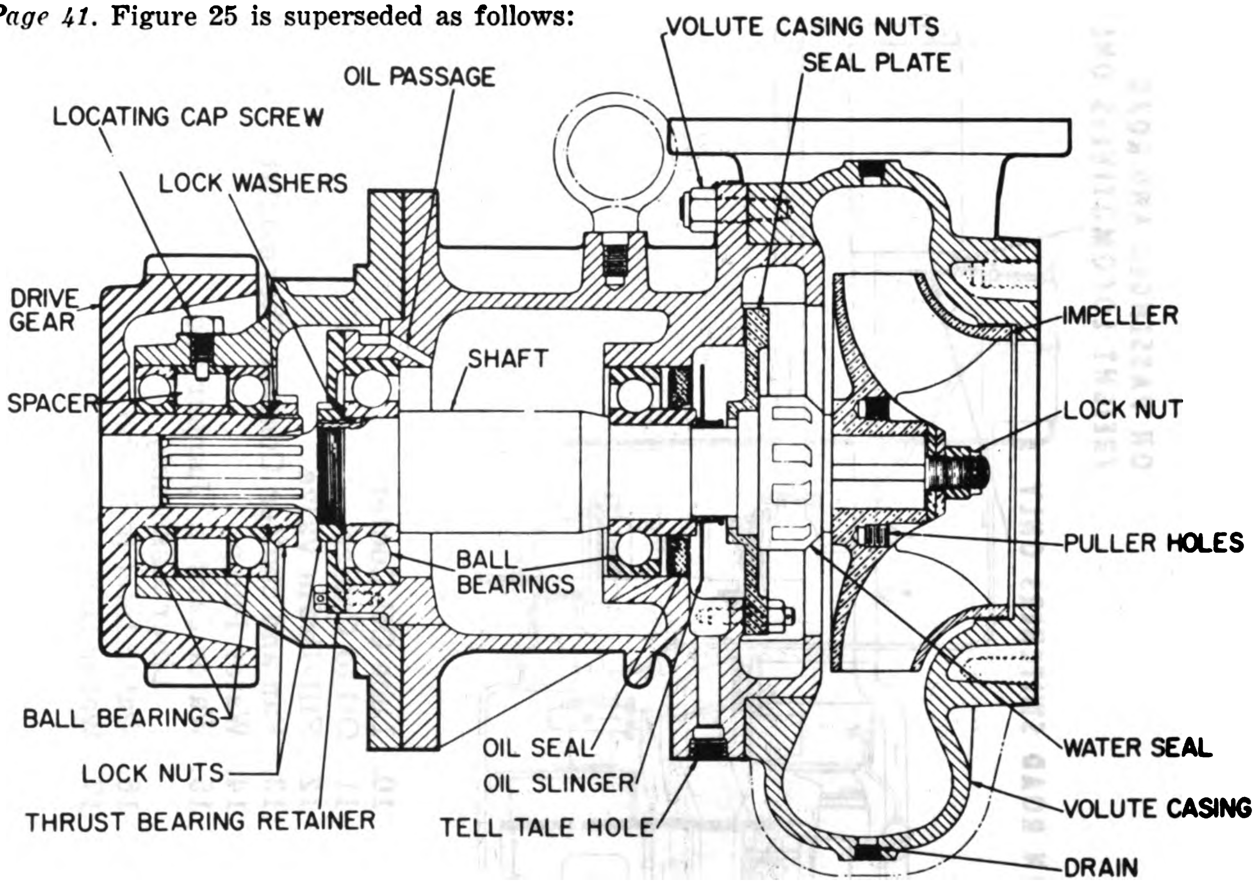


Figure 25. ALCO 244 water pump and drive.

Page 43. Figure 26, change to read: Schematic diagram of engine water temperature control system.

Page 50. Figure 30, change to read: Cross section of EMD blower.

Page 51. Figure 31, change to read: EMD blower.

Page 52. Figure 32, change to read: ALCO turbo-supercharger, 244 engine, right side.

Page 53. Figure 33, change to read: ALCO * * *, left side.

Page 92. Figure 54 is superseded as follows:

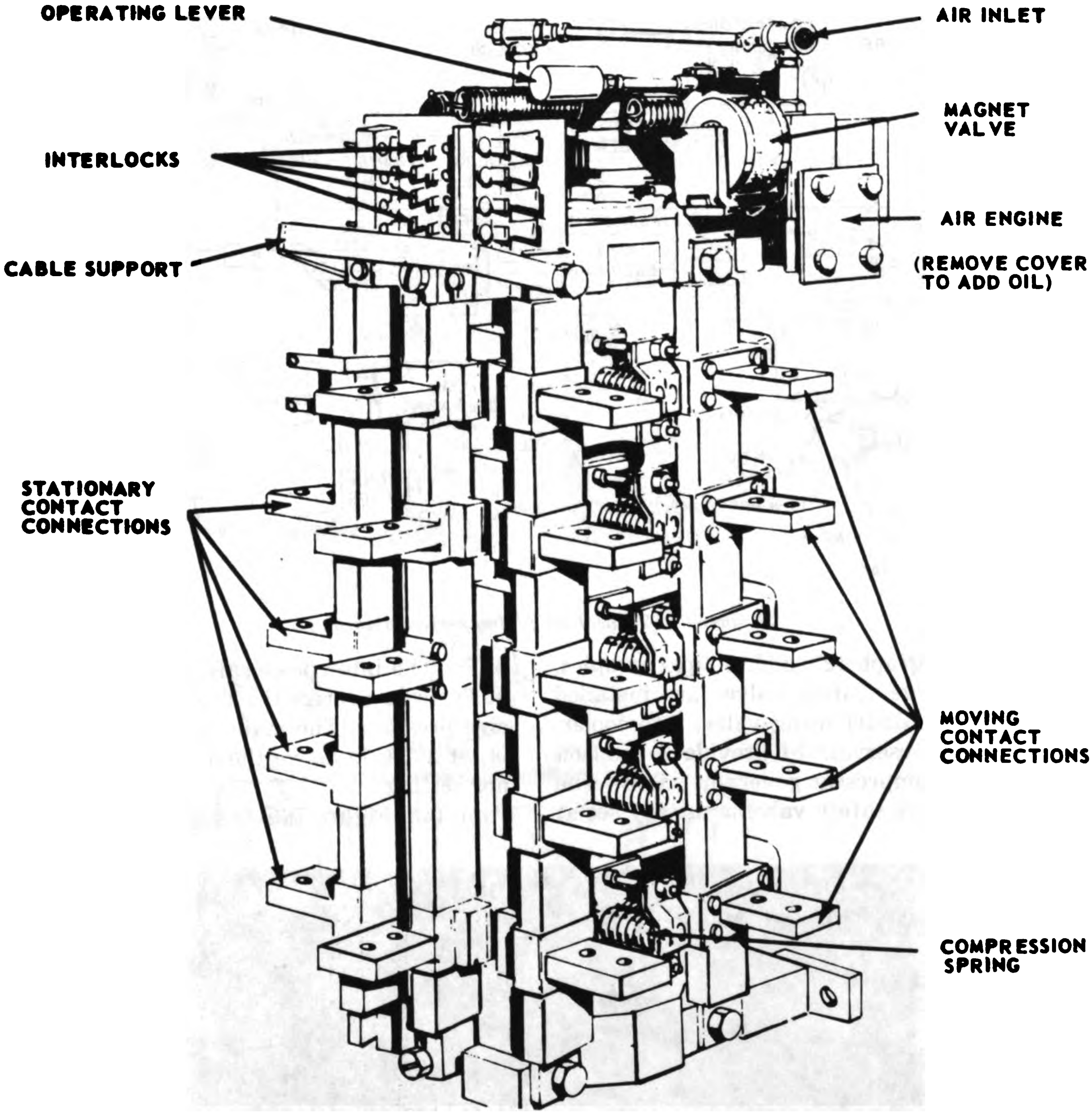


Figure 54. ALCO 244-F reverser.

Page 102. Figure 58, change to read: Typical control panel.

Page 128. Figure 69 is superseded as follows.

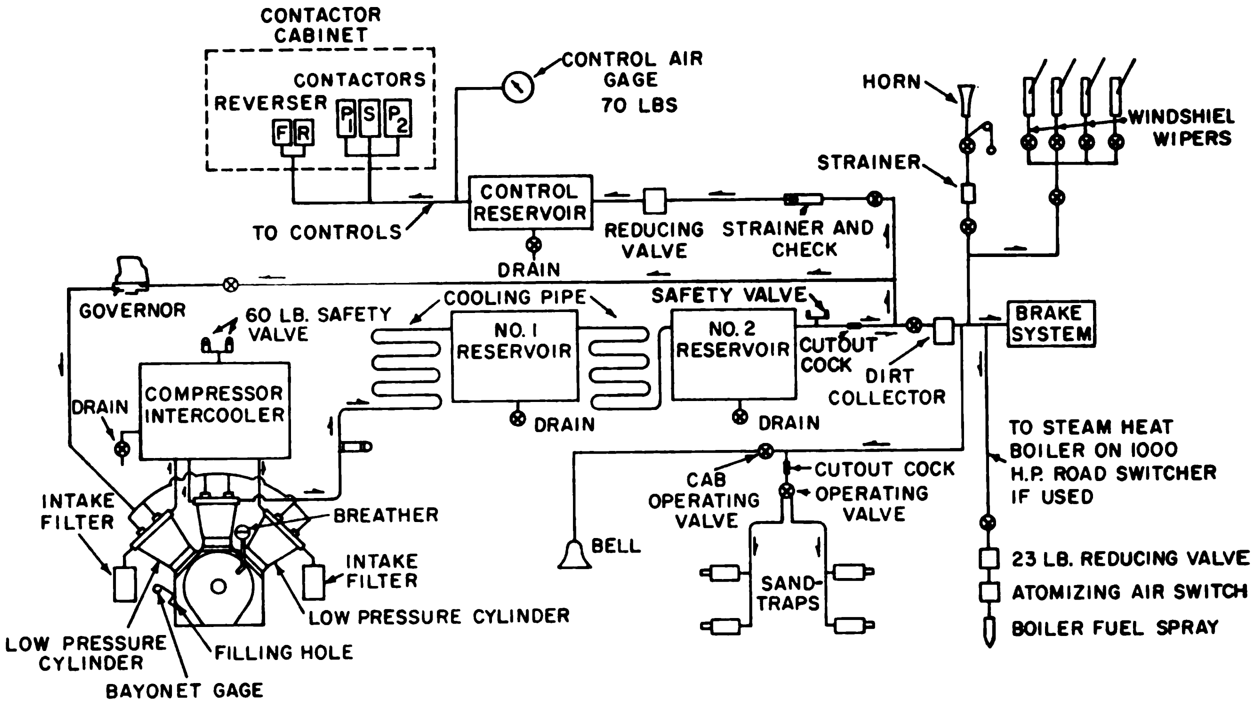


Figure 69. Typical air piping system diagram.

Page 134. Paragraph 120, add: subparagraph *i*.

i. Safety Valve. Safety valves are installed adjacent to the distributing valve, intercooler, and the main reservoir to provide protection in case of air compressor governor failure. The distributing valve safety valve is usually set at 68 lb. The intercooler safety valve is set to lift at 60 lb to protect the intercooler from excessive pressure. The main reservoir safety valve is set at 10 lb above the air compressor governor setting.

Page 146. Figure 76① is superseded as follows:

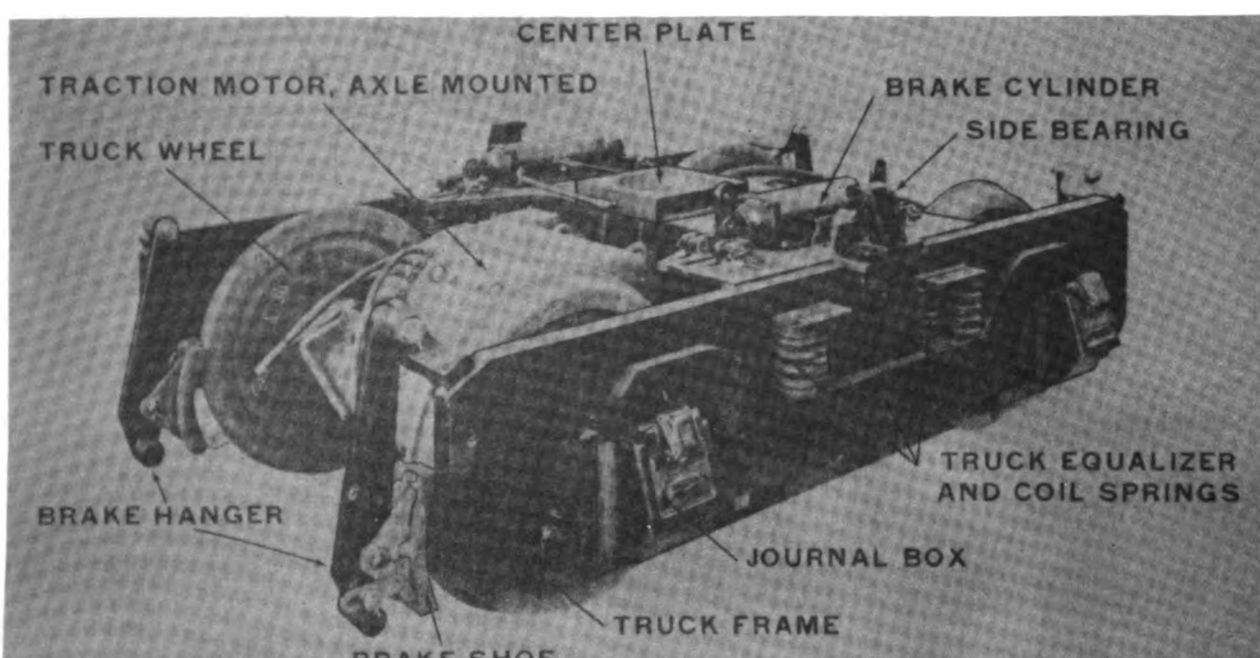
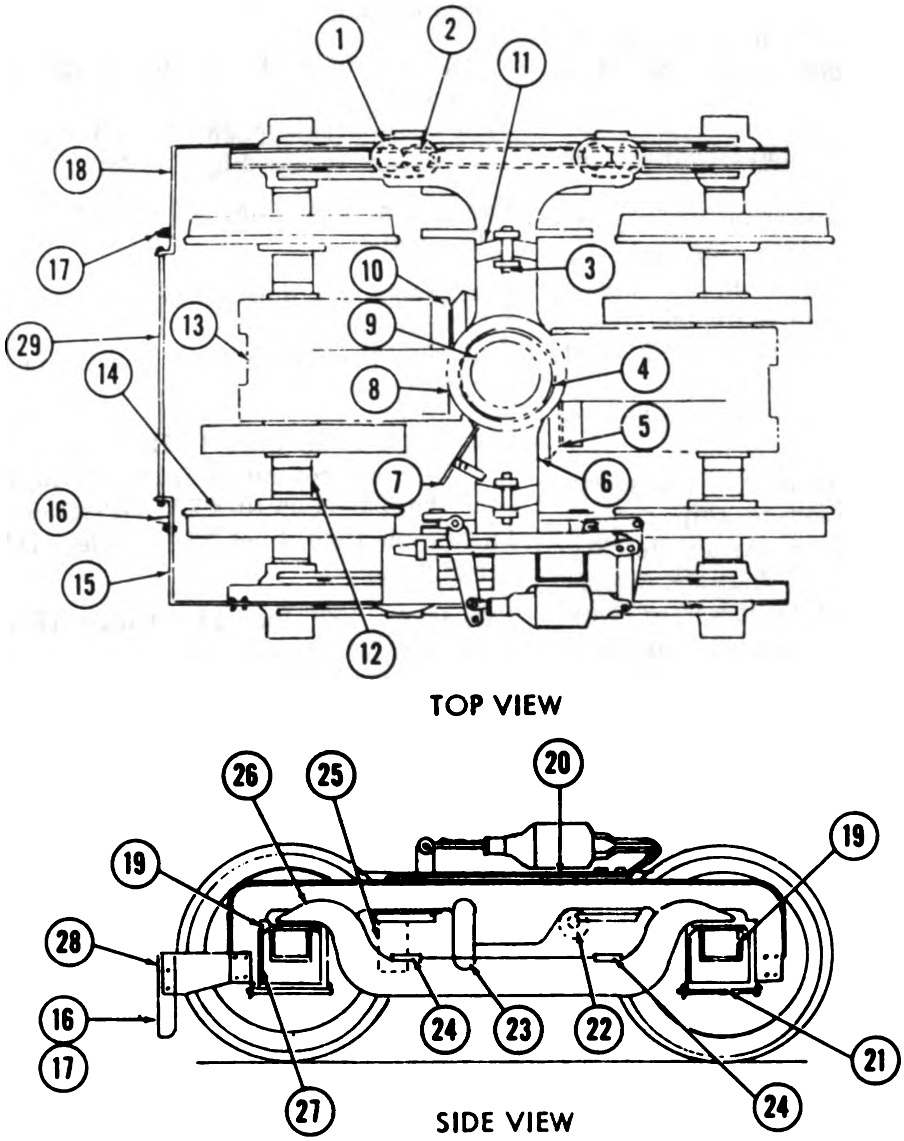


Figure 76①. Four-wheel truck, BLH, D/E locomotive 60-ton 500-hp, 56½ inch gage.

Add figure 76② after figure 76①.



1. Truck springs
2. Truck springs snubber
3. Truck stop pin
4. Wear sleeve
5. Motor bellows mounting flange
6. Bolster bellows mounting flange
7. Oilers
8. Center plate ring
9. Center plate sleeve
10. Air duct mounting flange
11. Side bearing wear plate
12. Axle
13. Traction motor
14. Wheel
15. Right-hand rail guard bracket
16. Right-hand rail guard
17. Left-hand rail guard
18. Left-hand rail guard bracket
19. Journal box
20. Wear plate
21. Pedestal binder
22. Bushing
23. Traction motor bellows
24. Equalizer spring seat
25. Motor truck suspension
26. Equalizer
27. Pedestal liner
28. Tie rod spacer
29. Rail guard tie rod bracket

Figure 76②. Four-wheel truck, blh, d/e locomotive 60-ton, 500-hp, 56½-inch gage.

Page 147. Paragraph 130*a*, line 7, change to read: (fig. 98).

Page 164. Paragraph 145*c*(2), lines 2-3, change to read: * * * on 44- and 45- ton (380 HP) and 65- and 80-ton * * *.

Paragraph 145*c* (7), delete and substitute the following:

(7) Inspect position and condition of journal bearings, wedges and lubricator pads. Be certain that the journal repack date conforms to commercial (CONUS) or national (overseas) railroad requirements. Provide additional lubrication to all journal boxes.

Page 165. Paragraph 145*c*(11), delete and substitute the following:

(11) Speed restrictions may be necessary. Prior to initiation of action to ship a locomotive in CONUS, the U. S. Army Mobility Equipment Command, ATTN: AMSME-MMM-R, St. Louis, Mo. 63120, will be contacted. This command will contact the railroads involved, and arrange shipping instructions to include applicable speed restrictions.

Page 172. Paragraph 151*t*(8) line 2, change brake to break.

Page 182. Paragraph 167*g* line 11, change ligibly to legibly.

Page 190. Paragraph 183, delete lines 15-23, It will * * * 188). Change to read: Pending revision and republication of DD Forms 863, 864 and 865, by U S Army Materiel Command, forms illustrated may be reproduced locally and used.

Paragraph 185, caption, delete (Not required for Army Installations.

Page 193. Paragraph 186*a*, line 3, add: (This form will be retitled to read: * * * Locomotives and Locomotive Cranes when revised).

Page 195. Paragraph 186*b* and *c*, delete * and two footnotes at bottom of page.

Pages 196, *197*, *198*, and 199, Figs. 91, and 92 this form will be retitled to read: * * * and Locomotive cranes when revised.

Page 202. Paragraph 186*e*(4) delete last sentence, Diesel * * * locomotives.

Paragraph 186*f*. add

f. DA Form 55 (-) Air Brake Test (To be developed).

Page 202. Paragraph 187*a*(1), line 1, delete quarterly, semiannual,

Paragraph 187*a*(3), line 1, delete quarterly, semiannual,

Paragraph 187*c*(4), line 6, change center to Command.

Page 203. Paragraph 188, lines 3-4, delete * * * which are required by TM 38-750, * * *.

Paragraph 188, line 18, Change Center to Command.

Paragraph 188, lines 19-27, delete Equipment * * * transferred.

Page 206. Paragraph 191*b*, line 12, delete (AR 750-5).

Paragraph 192*d*, lines 11-12, change to read: * * * are contained in technical manuals of the TM 55-2210-XXX-35P-series.

Paragraph 192*d*, lines 12-17, delete DA * * * and 2240.

Pargaraph 193, line 14, change (MWO) to read: (DAMWO).

Page 207. Paragraph 193, lines 2-3, change to read: * * * in DA Form 2407.

Page 226. Paragraph 205*f*, lines 4-7, delete * * * ampere hours. Change to read: *for example*, a 4-MS-420 battery has a capacity (at the 8-hour rate) of 420 amperes, or 525 amperes x 8 hours = 420 amperes.

Paragraph 205*h*, add:

CAUTION

U. S. Army ambulance, personnel, and other Medical Department cars are equipped with nickel-alkaline batteries. Under no circumstances will these batteries be serviced with the same tools and equipment used for the lead-acid batteries commonly used on diesel-electric locomotives.

Page 230. Paragraph 210*a* line 15, delete *c*, change to read: MIL-P-3321.

Page 231. Paragraph 212*a*, line 4, delete *c*, change to read: MIL-P-3321.

Paragraph 213*a*, line 2, delete *c*, change to read: MIL-P-3321.

Page 232. Paragraph 214*b*, line 4, delete *c*, change to read: MIL-P-3321.

Paragraph 215*a*, subparagraph *a* is superseded as follows:

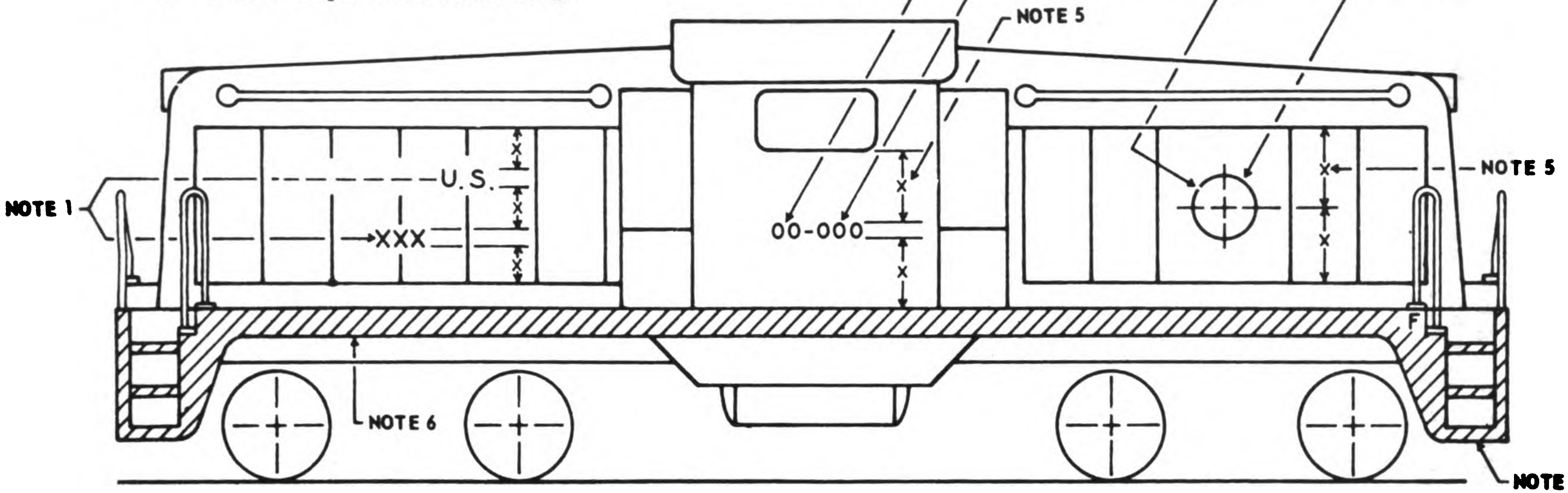
a. All letters, numbers, and insignia on locomotives will be applied with white gloss enamel.

Two coats of yellow enamel will be used for all safety markings. Bumpers and other surfaces as shown on the applicable figure will be painted with 4-inch diagonal stripes alternating colors of yellow and black. The stripes will be inclined at 45 degrees to the left and right of vertical to simulate an inverted V-pattern. Sufficient space must be allowed on bumpers for application of markings when specified. Peripheral stripes will run the full width of all steps and running boards.

Page 233. Figure 96, Change caption to read:

Typical letters * * *.

Page 236. Figure 99 is superseded as follows:



NOTE 1. AFTER "U.S." INSERT NAME OF COGNIZANT SERVICE – "ARMY", "NAVY", OR "AIR FORCE".

NOTE 2. CAB AND END SERVICE DESIGNATION AND NUMBERING SHALL BE AS FOLLOWS:

FOR ARMY	FOR NAVY	FOR AIR FORCE
00000	USN 65–00000	USAF 00000

NOTE 3. INSIGNIA SHALL BE USED ON AIR FORCE EQUIPMENT ONLY. IT SHALL CONFORM TO FIGURE 2.

NOTE 4. FOR AIR FORCE EQUIPMENT, REVERSE LOCATIONS OF INSIGNIA WITH THAT OF SERVICE DESIGNATION AND NUMBER.

NOTE 5. "X" INDICATES THAT MARKINGS ARE CENTERED AS SHOWN.

NOTE 6. SAFETY MARKINGS (4–INCH ALTERNATE BLACK AND YELLOW DIAGONAL STRIPES) SHALL BE APPLIED IN THE ZONE OF INTERIOR BUT SHALL NOT BE USED IN THEATERS OF OPERATION.

NOTE 7. MARKING SIZES SHALL BE AS FOLLOWS:

MARKING	HEIGHT–INCHES ARMY	NAVY	AIR FORCE
U.S. XXX	7	7	7
LOCOMOTIVE SERIAL NUMBER AND SERVICE DESIGNATION ON:			
CAB	7	7	7
FRONT	7	3	7
BACK	7	3	7
LETTER "F"	4	4	4
INSIGNIA			20 FOR EQUIPMENT OVER 25 TONS 18 FOR EQUIPMENT 25 TONS OR LESS

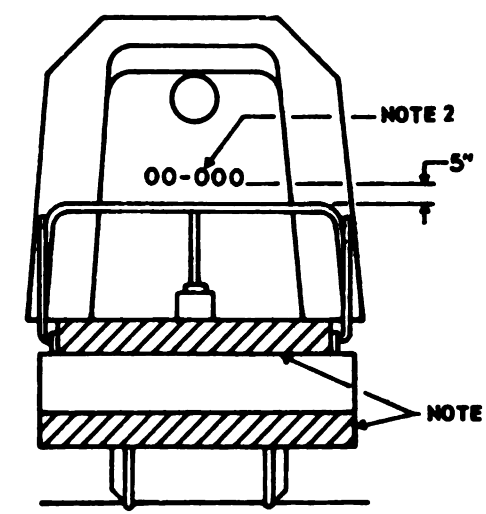
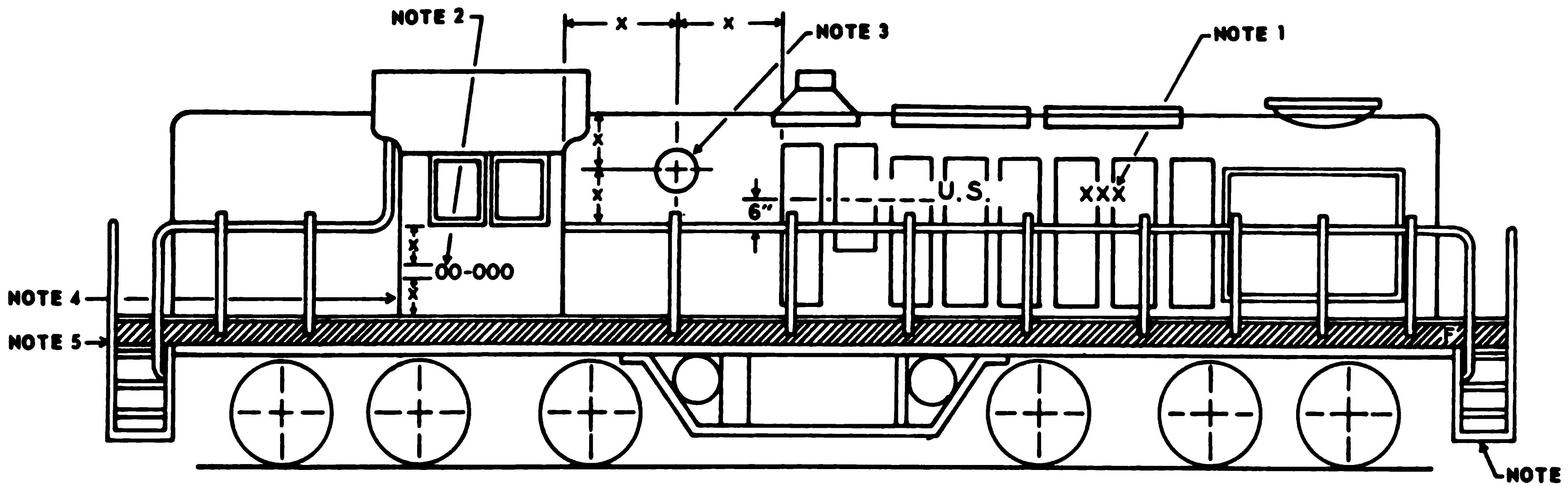


Figure 99. Markings for d/e locomotive with cab located in center for domestic and oversea service.

Figure 100 is superseded as follows:



NOTE 1. AFTER "U.S." INSERT NAME OF COGNIZANT SERVICE – "ARMY" "NAVY", OR "AIR FORCE".

NOTE 2. SERVICE DESIGNATION AND NUMBERING SHALL BE AS FOLLOWS:

FOR ARMY	FOR NAVY	FOR AIR FORCE
00000	USN 65–00000	USAF 00000

NOTE 3. INSIGNIA SHALL BE USED ON AIR FORCE EQUIPMENT ONLY. IT SHALL CONFORM TO FIGURE 2.

NOTE 4. "X" INDICATES THAT MARKINGS ARE CENTERED AS SHOWN.

NOTE 5. SAFETY MARKINGS SHALL BE APPLIED IN THE ZONE OF INTERIOR BUT SHALL NOT BE USED IN THEATERS OF OPERATIONS.

NOTE 6. MARKING SIZES SHALL BE AS FOLLOWS:

MARKING	HEIGHT–INCHES ARMY	NAVY	AIR FORCE
U.S. XXX	7	7	7
LOCOMOTIVE SERIAL NUMBER AND SERVICE DESIGNATION ON:			
CAB	7	7	7
FRONT	7	3	7
BACK	7	3	7
LETTER "F"	4	4	4
INSIGNIA			{20 FOR EQUIPMENT OVER 25 TONS {18 FOR EQUIPMENT 25 TONS OR LESS

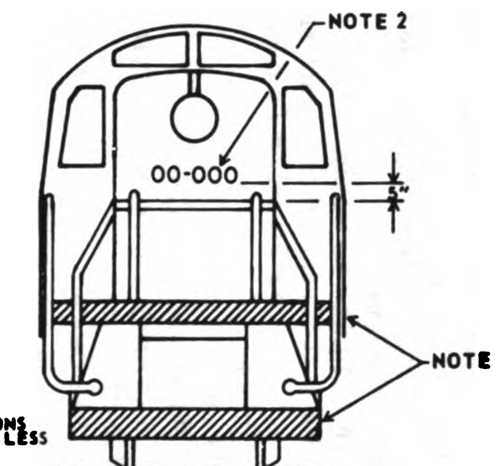


Figure 100. Markings for d/e locomotive with cab located to rear of center for domestic and oversea service.

Page 239. Paragraph 217*c*(2), lines 12-20, delete: These * * * 192*c*.

Page 269. Paragraph 249*b*, line 2, change to: * * * burning * * *.

Page 270. Appendix References, change to read:

1. Army Regulations
   AR 55-650 Military Railroads.
   AR 108-6 Department of the Army Motion Picture/Television Production.
2. DA Pamphlets
   DA Pam 310-5 Delete.
3. Field Manuals, Line 4, ADD:
   FM 55-20 Army Rail Transport Operations.
   FM 55-21 Delete.
   FM 55-22 Delete.

Paragraph 4, Technical Manuals, line 5, add TM 55-205, Inspection and Maintenance of U. S. Army-owned Foreign Rail Equipment.

Paragraph 4, line 16, TM 55-1268, Delete.

Paragraph 4, line 21, add TM 55-1273, Locomotive, Diesel-Electric, (56½-inch gage, 44- and 45-ton) 42-inch gage, 47-ton) 0-4-4-0, General Electric.

Page 271. Paragraph 4, lines 4-6, TM 55-1277, Delete.

Paragarph 4, line 7, add TM 55-1279, Locomotive, Diesel-Electric, 56½-inch gage, 44-ton, 0-4-4-0, 400-HP, Davenport-Besler.

Paragraph 4, line 10, add TM 55-1280, Locomotive, Diesel-Electric, 56½-inch gage, 80-ton, 0-4-4-0, Davenport-Besler Model 112-5708.

Paragraph 4, line 21, add TM 55-2038, Shop Maintenance, 2-cd, 2-b, and 2-cbd, Air Compressors.

Paragraph 4, line 22. add TM 55-2039, Shop Maintenance, 3-cd, 3-cbd, and 3cdc Air Compressors.

Paragraph 4, lines 20-21, TM 55-2210-216-35P, Delete.

Paragraph 4, line 23, add TM 55-4018-1, Cummins PT Fuel System.

Paragraph 4, line 24, change to read: Caterpillar * * * 12362-2.

Page 271, Paragraph 4, line 25, add Technical manuals, all TM's of the TM 55-2210-XXX-XXX series.

Paragraph 5, Lubrication orders, delete all LO's listed on pages 271-272 and change to read: All LO's of the LO 55-2210-XXX-20 series.

Page 272, Paragraph 6, Misc. Publications, line 8, change to read: MIL-P-3321.

Paragraph 6, line 14, add AAR Office Manual of Interchange Rules. AAR Field Manual of Interchange Rules. DOT Laws, Rules, and Instructions for Inspection and Testing of Locomotives Other Than Steam.
AAR Classification of Safety Appliance Defects. Code of Federal Regulations (CFR), Title 49, Transportation, Parts 191-999.

By Order of the Secretaries of the Army and the Air Force:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Official:
VERNE L. BOWERS,
Major General, United States Army,
The Adjutant General.

JOHN D. RYAN, *General, USAF*
Chief of Staff.

Official:
DWIGHT W. COVELL, *Colonel, USAF*
Director of Administration

Distribution:
To be distributed in accordance with DA Form 12-25 (qty rqr block No. 809) operator maintenance requirements for Rail Equipment, All.

CHANGE No. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *1 August 1968*

OPERATION AND MAINTENANCE OF DIESEL-ELECTRIC LOCOMOTIVES

TM 55-202, 25 October 1965, is changed as follows:

Page 180, paragraph 162, line 8. Change "12 months" to read 18 months.

Page 181, paragraph 164. Delete and substitute:

164. Cleaning

a. The filtering devices or dirt collectors located in the main reservoir supply line to the airbrake system must be cleaned, repaired, or replaced as often as conditions require to maintain them properly in a safe and suitable condition for service, and not less frequently than once each 6-montl. ›eriod.

b. Brake ‹ ̣linder relay valve portions, main reservoir safety valves, brake pipe vent valve portions, and feed and reducing valve portions in the airbrake system (including related dirt collectors and filters) must be cleaned, repaired, and tested as often as conditions require to maintain them properly in a safe and suitable condition for service, and not less frequently than once each 12-month period.

c. All other valves and valve portions in the airbrake system (including related dirt collectors and filters) must be cleaned, repaired, and tested as often as conditions require to maintain them properly in a safe and suitable condition for service, and not less frequently than once each 24-month period. This rule governs the following valves and valve portions in the airbrake system:

(1) Distributing or control valve (all operating portions).
(2) Automatic brake valve (all operating portions).
(3) Equalizing piston portion.
(4) Brake application valve (all operating portions).
(5) Independent brake valve.
(6) Rotair valve.
(7) Relayair valve for
  (*a*) Remote control of E-P valve.
  (*b*) Suppression of safety control.
  (*c*) Brake quick release.
  (*d*) Transfer valve function.
(8) Charging cutoff pilot valve.
(9) Reduction selector valve.
(10) Selector valve.
(11) Foot valve (safety control).
(12) Diaphragm cutoff valve.
(13) Magnet valve (for overspeed).
(14) Double check valve (to direct air to the relay valve from either the automatic or independent brake valve).
(15) Check valve (between Nos. 1 and 2 main reservoirs).
(16) Related dirt collectors or filters.
(17) Suppression valve (in conjunction with train control).
(18) Timing valve (pneumatic portion in conjunction with train control—not used on Government-owned locomotives).
(19) Any valve, however designated, which is used in a non-steam locomotive to perform the same or substantially the same function in the air brake system as that of any valve listed above, must likewise be cleaned, tested, and repaired in accordance with this paragraph.

d. The date of testing or cleaning, and the initials of the shop or station at which the work is done, ʰall be legibly stenciled in a conspicuous place on the parts, or placed on a card displayed under transparent cover in the cab of each locomotive unit.

Page 181, paragraph 167*c*. Delete and substitute:

c. Lost motion in drawbars and pins when used between units or trucks shall not exceed one-half inch at each pin, and shall be checked by tramming.

Page 182, paragraph 167*d*. Delete and substitute:

d. Lost motion in articulated connections when used between units or trucks shall not exceed one-half inch at each pin, and shall be checked by tramming.

Page 188, paragraph 177*b*. Delete and substitute:

b. Cable connections between units and jumpers that carry current having a potential of 600 volts or more shall be thoroughly cleaned, inspected, and tested as often as conditions require to maintain them in safe and suitable condition for service, but not less frequently than every 3 months, by immersing the cable portion in water and subjecting each conductor with another, and with the water to a difference in potential to not less than one and three-fourths times the normal working voltages for not less than 1 minute. Date and place of inspection and test shall be legibly marked on the jumper or cable or on a tag securely attached thereto.

Page 195, paragraph 186*d*. Delete and substitute:

d. DD Form 1336 (Monthly Inspection and Repair Report of Locomotives and Locomotive Cranes Other Than Steam). Not less than once every 30 days a report shall be made, DD Form 1336, covering each locomotive unit in use, which shall show the condition of the unit as determined by an inspection made in accordance with the law and applicable rules and regulations. The responsible activity may perform the inspection required by this rule within the 5 days next following the expiration of the 30-day period, if conditions beyond the control of the responsible officer render such additional time necessary; and in that event proper notation shall be made on the reverse of the report, DD Form 1336. This repart shall be made on a good grade of pale blue paper, size 6 x 9 inches, and subscribed and sworn to before an officer authorized to administer oaths, by the inspectors who made the inspection, and by the officer in charge (fig. 93). A duplicate copy of this report shall be filed in the office of the mechanical officer having charge of the locomotive and for locomotives used in interchange with CONUS commercial railroads within 10 days after each inspection of such locomotives one copy shall be transmitted to the United States District Inspector.

Page 202, paragraph 187*a* (4). Delete and substitute:

(4) Before the inspected locomotive is put into service a copy of the last inspection report shall be displayed under transparent cover in a conspicuous place in the cab of each unit. This copy must be a duplicate in all ways of the report filed with the transportation group railway headquarters, the United States Army Mobility Command, or in the case of locomotives used in interchange service, with the district inspector of the Department of Transportation. This copy need not be sworn to, and in the event it is destroyed or becomes lost or illegible it may be replaced by a conformed copy.

Page 203, paragraph 187*d*. Delete and substitute:

d. Out-of-Service Reports.

(1) When a locomotive is withheld from service for 30 or more consecutive days or was out of service when it would otherwise be due for inspection, an out-of-service report covering such locomotives shall be made on the reverse side of DA Form 1336, (fig. 93). The out-of-service time shall be totaled and recorded on the reverse of the form and the interval prescribed for any particular test or inspection required by U.S. Army regulations and directives or Federal Railroad Administration rules (locomotives in CONUS used in interchange service with commercial railroads are governed by Department of Transportation, Federal Railroad Administration regulations) may then be extended by the number of such consecutive out-of-service days recorded since the date of the last previous test or inspection, unless otherwise provided herein. The report shall be made on each date on which an inspection or test would have been

due except for the extension and shall show the name of the installation and/or activity, the place where made, the initials and number of the locomotive, the place where unit is out of service, and the reason for being out of service.

(2) The out-of-service report, for locomotives used in interchange service, shall be transmitted to the United States District Inspector in charge within 10 days after the 30-day inspection period for which it is to cover. One copy of the report will be retained in the office of the mechanical officer having charge of the locomotive. In other cases the responsible officer will retain the original copy. The copy need not be sworn to, but must be signed by the officer-in-charge of the locomotive.

(3) When an out-of-service report has been filed, an inspection must be made and new report prepared on DD Form 1336 before the locomotive is again returned to service (para 186*d*).

Page 205, paragraph 189. Add subparagraph *c*.

c. The time for making inspections and tests on units and boilers which are out of service for 30 or more consecutive days may be extended without application as hereinafter provided. Time out of service shall be properly accounted for by out-of-service reports and notations made on the back of each subsequent inspection report and cab card for time claimed out of service. Less than 30 days out of service shall not be counted toward extensions.

Page 234, paragraph 215*a*(3). Delete the first three lines "the words "Transportation Corps" will be placed as shown."

Add: The letter "F" (7-inch letter, fig. 96) shall be legibly shown on each side of every locomotive unit near the end, which for identification purposes, will be known as the front end.

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Official:

KENNETH G. WICKHAM,
Major General, United States Army,
The Adjutant General.

Distribution:

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Technical Manual
No. 55-202
Technical Order
No. 45A2-2-1-2

DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON, D. C., 25 October 1965

OPERATION AND MAINTENANCE OF DIESEL-ELECTRIC LOCOMOTIVES

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PART ONE
GENERAL
CHAPTER 1
INTRODUCTION

1. Purpose and Scope

a. This manual is published for the use of personnel engaged in the operation, inspection, and maintenance of diesel-electric locomotives. It may be used as a general reference for regulations, standards, and procedures governing such work. It describes the construction of a typical diesel-electric locomotive and its components, the procedures to be followed in routine and emergency locomotive operation, and the requirements for adequate inspection and maintenance of the locomotive. Because of the variety of makes and models of Government-owned diesel-electric locomotives, it is not practical to present specific details for all locomotives. At times it will be necessary to refer to Department of the Army operating and maintenance instruction manuals covering a specific locomotive for complete information. The following items are among those discussed in the various portions of the manual.

b. Construction of the locomotive and its components includes the principles of design and operation of generators, transmission equipment, diesel engines, fuel, lubricating and cooling systems, governors, superchargers, turbo chargers, air and oil filtration, compressors, accessories, airbrakes and brake rigging, and standard and multiple-gage trucks.

c. Operation covers normal locomotive movement in addition to inspections and precautions to be observed before and after operation to avoid damage, and elementary maintenance as it pertains to engine crew responsibilities.

d. Maintenance portions of this manual tell what to do. The discussion of facilities is a general guide on where the work should be done. Rules and report forms applying to maintenance work are also included. Appropriate intervals are suggested in some instances, but it is beyond the scope of this manual to attempt to set up maintenance schedules or give detailed discussion on how the work is to be done.

e. The material presented herein is applicable without modification to nuclear and nonnuclear warfare.

2. Changes and Revisions

Users of this manual are encouraged to submit recommended changes and comments to improve the manual. These should be keyed to the specific page, paragraph, and line of the text. Reasons should be provided for each comment or recommended change to insure understanding and complete evaluation. Comments and recommended changes should be forwarded direct to Commandent, U.S. Army Transportation School, ATTN: Director of Doctrine and Literature, Fort Eustis, Va. 23604.

3. Advantages of Diesel-Electric Locomotives

a. Diesel engines were long recognized as desirable prime movers or sources of power. Before it was practical to use them in railroad operations, engines were so large and heavy that they were used mainly in stationary powerplants. Refinements in design and other improvements resulted in the first experimental use of diesel engines on railroads in rail cars. Even in such small applications, it was soon apparent that the mechanical and hydraulic transmissions of that time were not sufficient to meet all service requirements. The electric drive was then developed. The operating characteristics of electric equipment (embracing various relationships of torque, current, voltage, and speed) proved to be an excellent solution to the problem. The application of diesel engines was then expanded from rail cars to switching service, and then to heavy through traffic in freight and passenger service. Diesel-electric locomotives were available for service a greater percentage of the time than steam locomotives. This was due to reduced servicing requirements. Major components are often repaired on the replacement basis, reducing the time a locomotive is out of service for repairs.

b. Greater flexibility in coupling units for various train assignments is possible by using multiple-unit controls, whereby one cab controls several units. This makes available a wide range of horsepower, plus a high degree of standardization of repair parts for maintenance shops. Electric traction, in general, has reached its present extensive application because of its superior operating characteristics; its economy in fuel and repairs; and its cleanliness, simplicity, and reliability. Steam turboelectric and gas turboelectric power has not reached a stage of development for locomotives comparable to that of diesel-electric systems, while railroad electrification, which is comparable in service, requires a costly wire system and correspondingly high traffic density to justify its use. More even weight distribution over the rails is accomplished by use of diesel-electric locomotives.

c. Modern diesel-electric locomotives are an assembly of many component parts. Details vary considerably depending on the make and model, but all types are generally similar. The automatic operation of much of the equipment is designed for ease of control of the locomotive as a unit. The operation of a diesel-electric locomotive is very simple. The diesel engine produces mechanical power which the generator converts to electric power to drive the traction motors geared to the axles. To vary the output and speed of the locomotive, the operator (engineman) has only to move the throttle which controls both powerplants. Moving the throttle lever upward from the first position permits more fuel to the diesel engines which speed up and deliver more power to the generators and, thus, to the traction motors.

CHAPTER 2

DIESEL ENGINE PRINCIPLES

4. General

a. *Description.* A diesel engine is an internal combustion fuel oil burning engine employing compression ignition. The engine, frequently referred to as a prime mover, converts heat energy into mechanical energy. An internal combustion engine is one which derives its power from the buring of a charge of fuel within a confined space called a cylinder. (An external combustion engine is operated by the expansion of gases which have received energy from fuel burned in a separate chamber, as in a steam engine.) Compression ignition occurs when the fuel is ignited solely by the heat of compression. This is caused by the fuel coming in contact with highly compressed, and hence highly heated, air in cylinders.

b. *Advantages.* The advantages of various types of prime movers, and even of various types of diesel engines, vary with their application; but diesel engines as a group have certain advantages which should be known by those working with them.

(1) Fuel economy is the principal advantage of the diesel engine. This is due to the high compression ratio and the proportionately higher expansion ratio and thermal efficiency than that found in other internal combustion engines. The high percestage of British thermal units (Btu's) that are converted to useful work also exceeds that of steam engines.

(2) The torque of a diesel engine is fairly constant throughout its speed range and, therefore, the engine pulls well at low speeds.

(3) The fire risk is low because the fuel is not as volatile as gasoline.

(4) The exhaust gas is not as dangerous as that of gasoline engines (although poor combustion causes high concentration of carbon monoxide fumes).

(5) Compression ignition eliminates the need for an ignition system.

(6) The engine is highly reliable under a variety of weather conditions.

c. *Classification.*

(1) Diesel engines are classified by the following principal operating characteristics:

(a) *Operating cycles.* Two-stroke cycle or four-stroke cycle (para 10).

(b) *Cylinder arrangement.* Chiefly in-line or V-type.

(c) *Piston action.* Single-acting, opposed piston.

(d) *Speeds.* Trend is from medium to high speed engines (particularly on locomotives).

(e) *Method of fuel injection.* Predominantly mechanical injection types are used in locomotives.

(2) Diesel-electric locomotives are classified according to the type of service they are designed to perform.

(a) *Switchers.*

(b) *Road switchers* (freight, passenger, and yard service).

(c) *Passenger.* (None of these in the military fleet).

5. Principles of Operation

a. *Heat Energy and Mechanical Energy.* The transformation of heat energy to mechanical energy by the engine is based on a fundamental law of physics which states that gas will expand upon application of heat. When the gas is confined with no outlet for expansion, the pressure of the gas will increase when heat is applied. This pressure acts against the head of a piston and causes the piston to move away from the combustion chamber.

b. *Reciprocating Motion to Rotary Motion.* The downward movement of the piston is transformed into rotary motion through a connecting rod and crankshaft.

The cylinder is a hollow tube closed at the upper end by a cylinder head. The piston moves inside the cylinder. The connecting rod is straight and its upper end is attached to the bottom of the piston whose motion is reciprocating, or up and down, whereas motion of the drive shaft is rotary. The necessary transformation is accomplished by the crankshaft, which is mounted on bearings at both ends so that it can revolve freely. On the crankshaft, there are offset parts known as the "crank" or "throw" to which the lower end of the connecting rod is fastened. As the piston is forced down by the expanding gas, the connecting rod moves down also, but it must follow the circular path described by the throw of the crankshaft. Thus, the reciprocating motion of the piston is transformed to rotary motion by the crankshaft.

c. *Factors Necessary for Proper Functioning of Diesel Engine.* Four factors are necessary for proper combustion in a diesel engine — air, fuel, compression, and ignition. Any discussion of engines must be based on these factors and the methods for delivering fuel or timing in the combustion chamber. The principal difference between a diesel engine and a gasoline engine is in the method of admitting and igniting fuel. Pure air is compressed to a high temperature before any fuel is delivered in a diesel engine, which differs from the air-fuel mixture delivered by carburetors in gasoline engines. Fuel oil is then injected into the cylinder of the diesel in a finely divided spray and ignited by the hot air. Fuel is consumed by burning rather than by explosion, and injection and burning continue over an appreciable portion of the stroke. A relatively constant pressure is thereby maintained during the entire power stroke of the piston. This characteristic of the diesel engine classifies it as a constant-pressure engine.

6. Combustion Principles

In the first diesel engines, fuel oil was injected into the cylinder by a simple pressure pump. The result was poor since the pump would not deliver the oil at high enough pressure to atomize the oil as it entered the cylinder through the spray nozzle. Since the pressure pump was unsatisfactory, an air blast was introduced which sprayed the oil somewhat in the fashion of a perfume atomizer. This air, at 900 pounds pressure, was supplied by a two- or three-stage compressor. The air injection diesel has been superseded by the mechanical injection or solid injection diesel. The change has been due to the high cost of the compressor (about 20 percent of the entire engine cost), operating difficulties with the compressor, and the better efficiency of the solid injection engine. The ability of any solid injection diesel to operate satisfactorily depends upon the delivery of a finely atomized charge of fuel, without leakage or afterdribble, and a distribution which brings all particles of fuel into contact with sufficient oxygen for complete combustion. Without a reasonable degree of combustion efficiency, the power developed for each gallon of fuel would be low, thereby eliminating the economic advantage possessed by the theoretical diesel cycle. If the entire charge of fuel injected into the engine cylinder is not completely burned, the unburned portion will settle on the cylinder wall and piston leaving a sticky mass of carbon. This carbon will fill the space between a piston ring and its groove, finally binding the ring so that the ring no longer seals the piston against blowby. Other portions of the carbon settle on the exhaust valve seat and cause the valve to leak. This reduces compression to a point where the air temperature does not reach a high enough value during compression to ignite the next fuel charge.

7. Atomization

a. Oxygen in the chamber contacts only those carbon and hydrogen atoms that are on the surface of a fuel oil particle. The oxygen cannot penetrate into the interior of a fuel oil drop. To obtain the largest surface, the oil must be divided into the greatest possible number of fine particles. To insure a spray which is equal to, or better than, the atomizations obtainable with a perfume atomizer, the spray valve must be properly designed. There must be proper correlation between the fuel oil pressure and the diameter of the orifice. Even if the fuel particles are properly broken up, they must be completely diffused through the air charge. This may be accomplished either by a nozzle that spreads the fuel in a wide cone spray pattern or by some arrangement whereby the air is diffused through the fuel charge. For diffusion of the fuel charge, the usual spray valve is supplied with several openings in the tip. The fuel issues through the holes and forms an equal number of cones of atomized fuel which effectually fill the combustion space of the engine cylinder. With medium and large bore engine cylinders, the multi-hole orifice gives an ideal spray formation. When the size of the engine cylinder decreases (high speed engines are, as a class, of small bore), the amount of fuel injected into the engine cylinder is very small. The diameter of each of the spray valve openings must then be exceedingly small.

b. After the spray enters and is diffused into the cylinder, a three-stage combustion process follows:

(1) The fuel particles must be heated to a temperature high enough to permit self-ignition upon meeting the oxygen. This heating is necessary even if the fuel remains in the liquid state. Since the fuel actually vaporizes before ignition, it must be heated to the firing temperature, or a range from about 700°-900° Fahrenheit. Vaporization starts as soon as the first droplet of fuel enters the cylinder and continues until combustion occurs.

(2) The second step in the combustion process is ignition of the fuel charge. Ignition occurs shortly after the first fuel particle enters the cylinder. The time interval is the "ignition lag" and it varies with the kind of fuel, the compression pressure, and other engine characteristics. Ignition may start in any portion of the fuel spray. The first flame may occur at a point removed from the spray nozzle or may occur simultaneously at several places. In a well designed engine, ignition occurs before the entire fuel charge enters the cylinder and burns.

(3) The third step in the combustion process follows, with the fuel burning as fast as it enters the cylinder.

8. Combustion Knock

If the initial ignition is delayed so long that the entire mass of fuel has entered the cylinder and has become vapor, the primary ignition may be followed by a rapid combustion (an explosion) of the entire fuel mass. This explosion may set up a pressure wave which, traveling at the speed of sound, strikes the metal walls and thereby produces a sharp knock called "combustion knock." It is then highly desirable to arrange the design so that the first part of the fuel charge is ignited before the entire fuel charge enters the cylinder. The flame of the first particles then insures a continuous ignition and combustion of the remainder of the fuel as fast as the fuel enters the cylinder. To accomplish this, there are various designs of combustion chambers, all intended to prevent combustion knock, but most designs fail in their purpose. Combustion that takes place after injection has stopped is termed "afterburning." The rate of burning during this period is slow and results in little power increase. During this afterburning period, the combustion chamber contains a mixture of nitrogen, oxygen, carbon dioxide, steam, vaporized fuel, and products of partial combustion. The percentage of inert gases is high because of the combustion that has been completed. As a result, the mixing of the active gases and their subsequent combustion takes place slowly, extending to as late as 80 degrees of crank travel after top center. This late burning has a low expansion ratio and decreases the overall cycle efficiency of the engine, although the final combustion efficiency may be high. Difficulty in obtaining a mixture of fuel and air and of securing efficient combustion increases as engine speed increases. A four-cycle diesel at 300 revolutions per minute (rpm) injects and burns the fuel charge in 30 degrees of crank travel. Such an engine covers 1,800 degrees of crank travel per second, so the 30 degrees of injection and combustion occur in approximately 0.017 second. A high speed diesel turning at 1,800 rpm will use the same 30 degrees of crank travel, but the actual time interval is about 0.003 second.

9. Methods of Mixing Air With Fuel

a. General. The methods of moving air into the diesel engine cylinder so that it flows across the fuel stream varies with different engines. Methods common to the engines found in locomotives of the military fleet are described below.

b. Entrance Swirl. Air flowing into the engine cylinder may follow a circular path, a whirling motion that will continue during the compression stroke. When fuel is sprayed into the cylinder, the air circulating in the combustion space passes through the fuel spray. This insures a thorough mixture of air and fuel.

c. Piston Swirl. If the piston has a concave crown, the air between the cylinder head and the high outer surface of the piston crown is forced into the concave section when the piston approaches the end of its stroke. The air mixes with the fuel sprayed toward the center of the piston.

d. Turbulence Chamber. In some diesel engines, the Caterpillar for example, the fuel spray is injected into the turbulence chamber and meets the entire mass of air which has been given velocity by the piston motion, and rotates in the turbulence chamber at a high speed. The turbulence chamber is either in the cylinder head or in the upper portion of the cylinder casting. The postion of the spray valve in the combustion chamber is of greatest importance. If the fuel spray is not directed toward the throat connecting the chamber with the cylinder, combustion will not be complete and the engine will not pull its rated load. The fuel spray must pass across the airstream. There is one operating difficulty, however; if the engine has been stopped for some time the turbulence chamber becomes cold. The air warmed in the cylinder by compression rushes into the turbulence chamber and loses its heat by the cooling action of the cold metal of the throat. It is necessary to provide some device to add heat to the air. This device may be a coil heated by electricity from the starting battery.

e. Precombustion Chamber. A precombustion chamber is a feature of several high speed diesels. When the piston completes its compression stroke, about 35 percent of the air charge is forced into the precombustion chamber. The air forced into the chamber is not enough to unite completely with the fuel charge when the fuel sprays into the chamber. As a result, carbon monoxide gas is formed and some of the fuel vaporizes. Pressure rise, due to the partial combustion, causes carbon monoxide gas and vaproized fuel to blow into the engine cylinder where the gaseous mass mixes with hot air and combustion is completed. One advantage of the precombustion system is that fuel may be injected early enough to heat up and vaporize without danger of serious preignition. The limited amount of air in the precumbustion chamber holds the pressure rise to a reasonably low value. A disadvantage of the precombustion chamber is difficulty in starting because of the relative slowness of engine warmup.

10. Operating Cycles

a. General. To produce power through an interval of time, an engine must accomplish a definite series of operations and perform them over and over again. This series is known as a cycle in which suction, compression, ignition, expansion, and exhaust take place in the order listed. If the engine requires four strokes of the piston and two revolutions of the crankshaft to complete a cycle, it is known as a four-cycle engine (1, fig. 1), while an engine completing the cycle in two strokes of the piston and one revolution of the crankshaft is known as a two-stroke cycle engine (2, fig. 1). Diesel engines used to power locomotives in the military fleet of American Locomotive Company (ALCO), Caterpillar, or Cummings manufacture are four-cycle engines, while those manufactured by the Electro-Motive Division of the General Motors Corporation (EMD) are two-cycle engines.

b. Four-Stroke Cycle Suction Stroke. This suction stroke begins with the piston at top dead center. As the piston moves downward, a charge of fresh air is drawn into the cylinder through the inlet valve which is held open by its cam. The air passage is closed when the piston reaches the bottom of its stroke. The crankshaft has made half of a revolution during this stroke.

c. Four-Stroke Cycle Compression Stroke. The piston reaches the bottom of its stroke and the inlet valve is closed by its spring when the high point of the cam rotates from under the push rod. The bottom dead center has been passed and the piston is being forced upward toward the cylinder head. The inlet and exhaust valves are closed and the upward travel of the piston compresses the air in the cylinder. When the end of the compression stroke is reached, a charge of oil is injected through the spray valve in the cylinder head. The oil ignites spontaneously as soon as it mixes with the air in the cylinder, for the piston has compressed the air to about 500 pounds per square inch, and this high compression raises the temperature of the air to about 900° F., which is high enough to ignite the oil without a spark. The crankshaft has made another half turn during this stroke.

d. Four-Stroke Cycle Expansion Stroke. As soon as the crank moves past top dead center, the pressure created by the burning of the fuel forces the piston downwards which causes the crank to rotate, delivering power to the crankshaft. The oil continues to spray into the cylinder while the piston moves a short distance on the expansion stroke. The gases continue to exert force on the piston until it reaches bottom dead center. At this time, the exhaust cam opens the exhaust valve. The crankshaft has made another half turn during this stroke.

e. Four-Stroke Cycle Exhaust Stroke. As soon as the exhaust valve opens, much of the burned gas rushes out of the cylinder. The exhaust valve continues in the open position during the next upstroke of the piston, which permits complete removal of the exhaust gases. The crankshaft has made another half turn, completing two full revolutions during the four steps of the complete cycle, which is repeated again as long as the engine is running.

f. Two-Stroke Cycle Compression Stroke. The events of compression, injection, and expansion take place in the same order as they do in a four-stroke cycle. The upstroke of the piston compresses the air. Injection of the fuel oil occurs when the piston nears the top of the stroke. The hot gases expand against the piston forcing it downward on the power stroke.

g. Two-Stroke Cycle Power Stroke. When the piston nears the bottom of the power or expansion stroke, the exhaust valve in the top of the cylinder opens. The hot burned gases rush past the valve. As the piston moves farther downward, the air intake air ports in the cylinder wall near the lower end are uncovered. Intake and exhaust take place at the same time. Fresh air enters the lower end of the cylinder forcing the remaining burned gases out of the exhaust valves at the top of the cylinder and filling it with fresh air. The exhaust valves then close and the engine is ready to start another cycle. The intake of fresh air and the exhaust of burned gases take place at the same time.

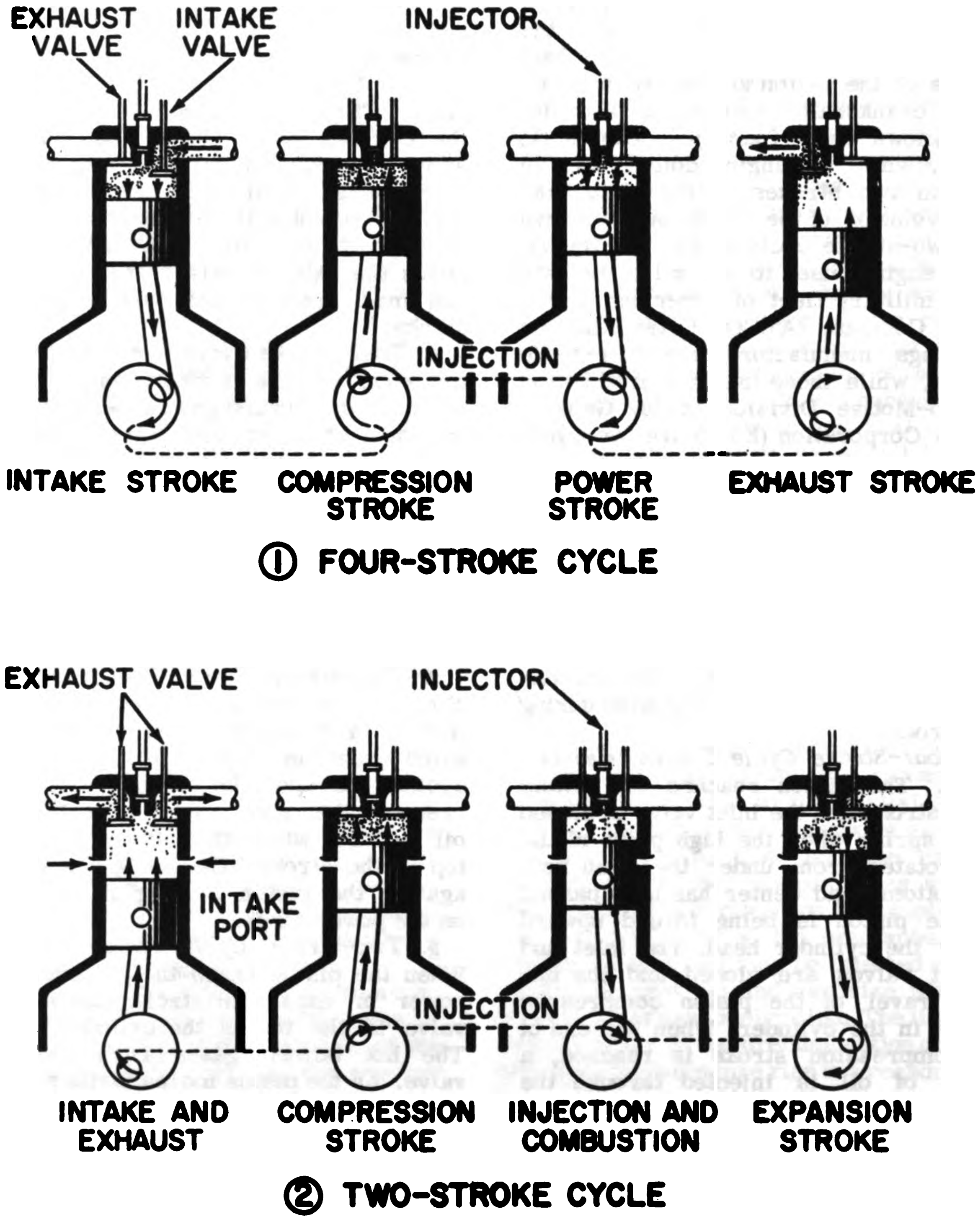


Figure 1. Cycle of events in engine cylinder.

11. Fuel Injection

a. *Fuel Atomization and Penetration.* Fuel oil is forced into the combustion area under extremely high pressure, 1,200 psi to as high as 3,500 psi, depending upon the design of the engine. This pressure is required to assure proper atomization and mixing of fuel and air in the combustion area. It must be remembered that the compression pressure is approximately 500 psi; therefore, the injection pressure must be considerably higher. The higher the pressure, the better atomization and mixing of air and fuel. Turbulence (para 9*a* and *b*) will assure an even burning of fuel and give the desired even downward pressure on the piston.

b. *Function of Injection System.* The function of an injection system is to meter the fuel accurately. It delivers equal amounts of fuel to all cylinders at a pressure high enough to insure atomization and controls the start, rate, and duration of injection. The injectors are directly connected with the engine governor; this assures maintaining power requirements with increases or decreases in the load.

PART TWO

DIESEL ENGINE

CHAPTER 3

RAILWAY DIESEL ENGINE

12. Power Requirements

Power ratings per locomotive unit in general use vary from about 300 horsepower in light switching service to 5,000 horsepower in heavy road service. The engines which supply this power (figs. 2 and 3) must supply power for all auxiliary equipment on the locomotive. Fans, blowers, pumps, compressors, heaters, lights, and similar equipment may increase the total power requirement by as much as 10 percent above that required for moving the train. Two-stroke cycle or four-stroke cycle engines of in-line, V-line, or opposed-piston cylinder arrangements are used. The lack of a stationary foundation and the limitations in allowable width and height had to be taken into account in designing the engine for railroad use. The engine speed is varied to accommodate the output of the powerplant to changes in trailing tonnage, train speed, and grades. Many railways operate where significant changes in altitude and temperature occur in a comparatively short time. The power output decreases as the altitude or temperature increases because the amount of air drawn into the engine decreases. This causes the fuel to burn slower. Decreased air intake is due to expansion of air when heated, or to low pressure of high altitudes. Many combinations of engine power, gear ratio, and speeds are available in individual locomotives; however, a multiple-unit control has been developed which enables one operator to control several similar power units on separate locomotives coupled together to act as a single locomotive (paras 3*b*, 86, and 147).

13. Power Unit

A complete engine generator set is called a power unit. Some locomotives have two power units on one underframe. Limited space on railway equipment is a great factor in the design of a power unit. Each power unit requires a fuel pump, water pump, oil pump, radiator fans, and blowers which are directly related to the engine. Auxilary equipment such as an air compressor and auxiliary generator is also necessary. These auxiliaries are powered by the diesel engine. They supply the air-brake system, pneumatic controls, and the low voltage light and power circuit. Separate engine starting equipment is generally eliminated by using the generator as a cranking motor. The construction of the main generator employs an additional field coil. This converts the generator into a motor, when connected to a power source such as a lead acid battery, thereby supplying power and a means of cranking the main diesel engine.

14. Construction

a. *General.* Typical section views of an engine appear in figures 4 and 5. The brake horsepower of an engine is the actual power measured at the end of the crankshaft by a dynamometer or Prony brake. Indicated horsepower is the formula computation of the total power developed within the cylinders. They differ by the power absorbed by the mechanical losses within the engine. The horsepower ouput of an engine is based on three factors — the pressure on the piston, the cylinder displacement which is the product of the piston area and stroke, and the number of power strokes in a given time. This is expressed as a formula—

$$HP = \frac{P \times L \times A \times N}{33{,}000}$$

P is the mean effective pressure in pounds per square inch; L is the length of the piston stroke in feet; A is the cylinder

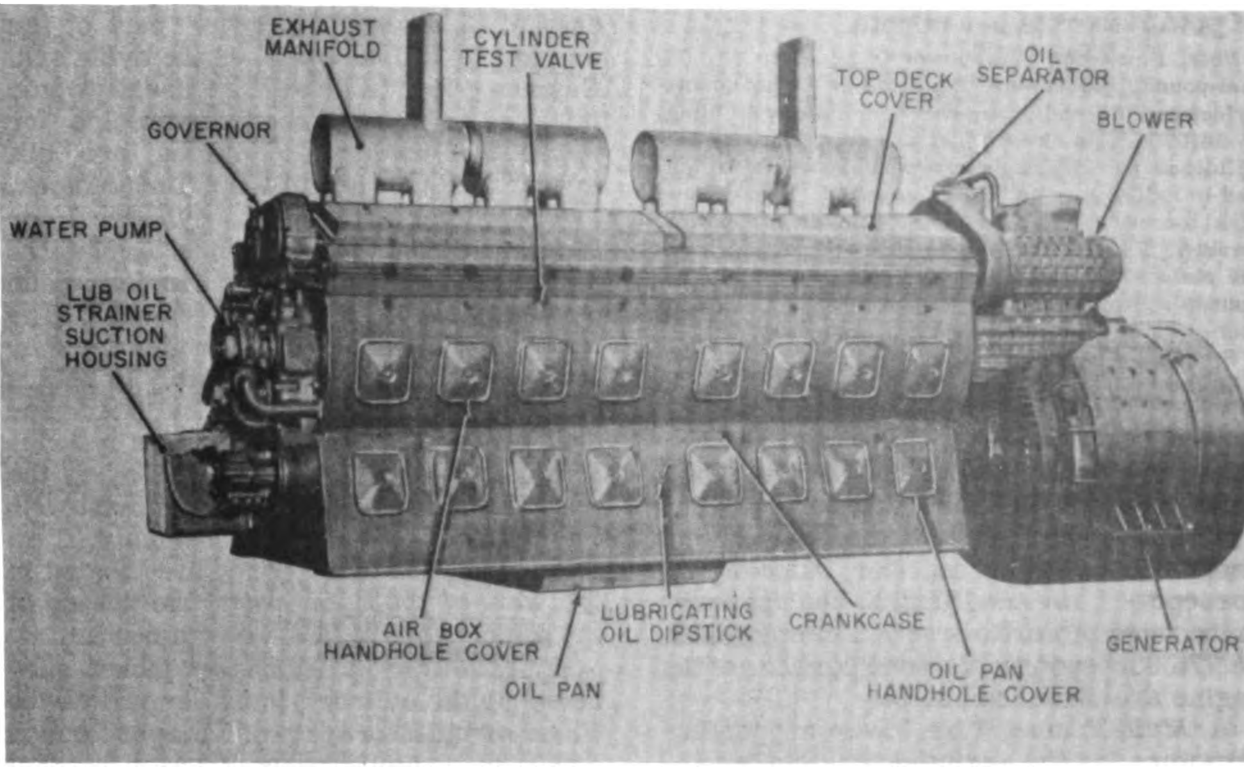


Figure 2. V-type diesel engine, side view (EMD-567 model).

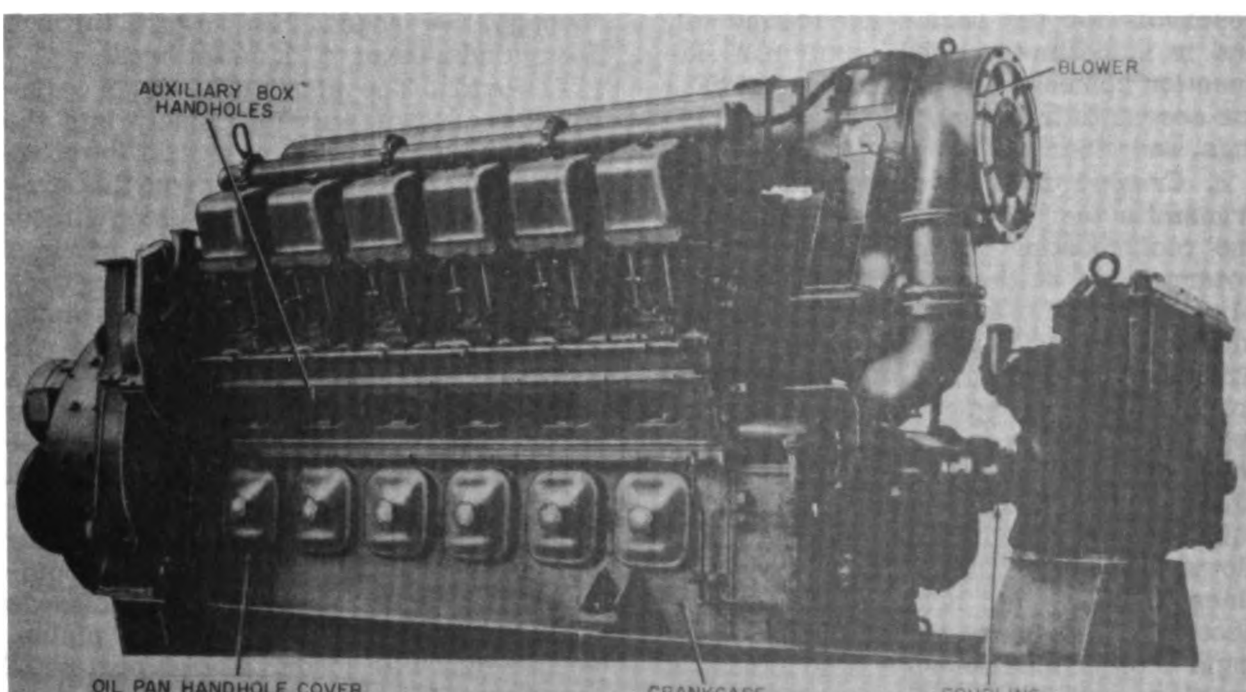


Figure 3. V-type diesel engine, front three-quarter view (ALCO-244 model).

area in square inches, and N is the number of power strokes per minute.

Note. Since one horsepower is equal to 33,000 foot-pounds per minute, P x L x A x N must result in foot-pounds, and horsepower is derived by dividing by 33,000. N is the number of cylinders times revolutions per minute in a two-stroke cycle engine and is half this value in a four-stroke cycle engine because only half the strokes are power strokes. N x L gives the total feet through which the pistons are working, and P x A gives the total pounds at work. A typical engine specification of a four-stroke cycle, six-cylinder engine—

Pressure	= 94 pounds	P = 94 pounds
Stroke	= 15.6 inches	L = 1.3 feet
Bore	= 13 inches	A = 132.7 square inches
Speed	= 625 rpm	N = 1,875

Using the formula with these figures results in about 921 indicated horsepower. Friction within the engine reduces this to about 850 brake horsepower. Allowing 75 horsepower for auxiliaries, the approximate rated power to traction motor would be 775 horsepower. Various portions of the engine are discussed below.

b. Main Frame. The lower supporting structure for the engine consists of a bedplate (fig. 6) which is mounted on the locomotive frame. This structure serves as a housing for the crankshaft and as a reservoir for the engine lubricating oil, and is sometimes called an oil pan. Inspection openings are provided in the base for access to the crankcase, oil pan, bearings, and other parts.

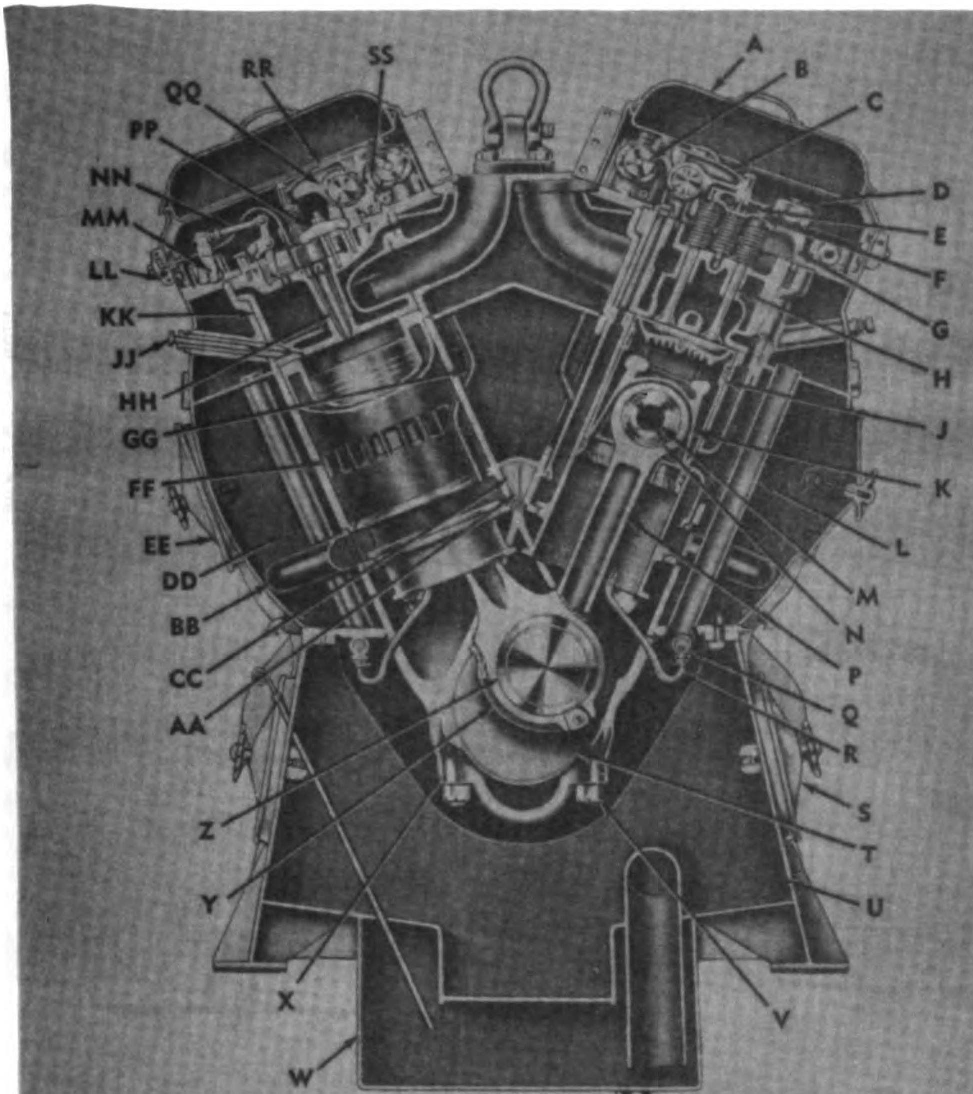
c. Crankshaft. The crankshaft (fig. 7) transmits the useful power developed by the reciprocating action of pistons to the rotary drive at the external engine coupling. Main bearings support the crankshaft between each pair of cranks. Cranks are counterbalanced to offset centrifugal force and are designed for a specific firing order in the cylinders to insure an even distribution of forces through the shaft. The bearings are usually pressure lubricated through drilled passages. Oil flows from a header through individual lines to each main bearing, then to connecting rod bearings and piston pin bearings. Proper clearances and alinement of bearings and crankshaft are very important. The manufacturer's instructions for checking these parts should be followed.

d. Cylinder Blocks. The cylinder block (fig. 8) is the main structural part of the engine. It forms the upper part of the crankcase and also houses the cylinders. Engines differ in details, but usually water jackets and headers, or manifolds for water and lubricating systems, are built into or are attached to the cylinder block.

e. Cylinder Liners. The cylinder liner is made of cast iron with an integral water jacket formed by a cored annular space between the inner and outer walls. The liner is secured to the cylinder head by studs and nuts and the assembly is held in place in the engine by the cylinder head crab studs. A pilot stud locates the cylinder liner in proper angular relation to the cylinder head and assures alinement with the piston cooling pipe assembly. The scavenging air inlet ports are located in the wall of the liner just above the top of the piston when it is at bottom center.

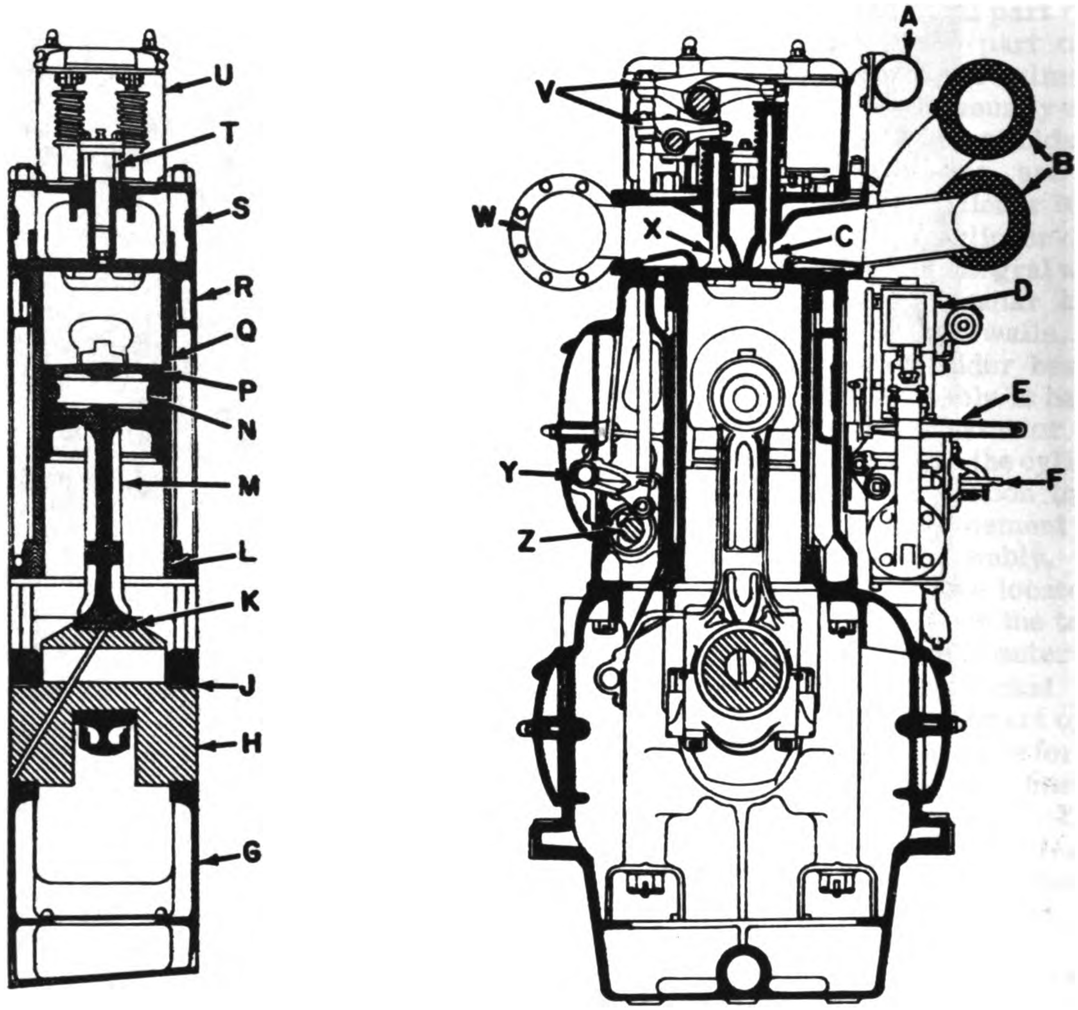
f. Water Jacket. A water jacket surrounding the cylinder liners is part of the water circulating system. It may be formed by a cored annular space between integral inner and outer walls, or by a liner fitted to the frame according to individual design. Water circulates from an inlet header through the jacket, then upward through the cylinder head to an outlet header.

g. Piston. The piston (fig. 9) is cylindrically shaped and fits closely into the cylinder liner. Piston rings seal the combustion chamber so energy from the burning fuel has full effect on the piston without loss from leakage. The number of rings on each piston varies with the engine's design. The rings near the top of the piston are called compression rings and are essential to effective combustion. The rings below the compression rings are called oil rings and are provided to distribute and wipe off excess lubricating oil along the cylinder liner. Oil must lubricate the entire liner without carbonizing or restricting the free action of the compression rings. The rings are usually made of softer metal than the liner and piston, so that they will absorb a large portion of the wear. Lubricating oil serves as a cooling agent by circulating under pressure through drilled passages leading from the connecting rod through the piston pin



A—CYLINDER-HEAD COVER
B—CAMSHAFT
C—EXHAUST VALVE ROCKER ARM
D—CYLINDER-HEAD CRAB STUD
E—VALVE BRIDGE
F—HYDRAULIC LASH ADJUSTER
G—CYLINDER-HEAD CRAB
H—EXHAUST VALVE
J—PISTON
K—PISTON CARRIER
L—OIL DRAIN TUBE
M—PISTON PIN
N—CONNECTING ROD BUSHING
P—BLADE CONNECTING ROD
Q—PISTON COOLING OIL MANIFOLD
R—PISTON COOLING OIL PIPE
S—OIL PAN HANDHOLE COVER
T—CRANKSHAFT
U—OIL PAN
V—MAIN BEARING STUD
W—OIL PAN SUMP
X—MAIN BEARING CAP
Y—FORK CONNECTING ROD BASKET
Z—CONNECTING ROD BEARING
AA—CRANKSHAFT OIL SUPPLY PASSAGE
BB—WATER MANIFOLD
CC—LUBRICATING OIL MANIFOLD
DD—AIR BOX
EE—AIR BOX HANDHOLE COVER
FF—CYLINDER LINER
GG—WATER DRAINPIPE
HH—INJECTOR PIPE
JJ—CYLINDER TEST VALVE
KK—CYLINDER HEAD
LL—FUEL OIL MANIFOLD
MM—INJECTOR LAYSHAFT
NN—INJECTOR ADJUSTING LINK
PP—INJECTOR CRAB
QQ—INJECTOR ROCKER ARM
RR—LUBRICATING OIL LINE
SS—OVERSPEED TRIP ROCKER ARM PAWL

Figure 4. Cross section of V-type diesel engine (EMD-567 model).



A	WATER OUTLET-MANIFOLD	N	PISTON PIN
B	EXHAUST MANIFOLD	P	PISTON
C	EXHAUST VALVE	Q	CYLINDER LINER
D	GOVERNOR	R	CYLINDER BLOCK
E	GOVERNOR CONTROL	S	CYLINDER HEAD
F	OVERSPEED TRIP	T	INJECTION NOZZLE
G	BASE	U	ROCKER BOX
H	CRANKSHAFT	V	VALVE ROCKERS
J	MAIN BEARING	W	AIR INTAKE MANIFOLD
K	ROD BEARING	X	AIR VALVE
L	LINER SEAL RINGS	Y	PUSH ROD LIFTER
M	CONNECTING ROD	Z	CAMSHAFT

Figure 5. Cross section view of in-line engine.

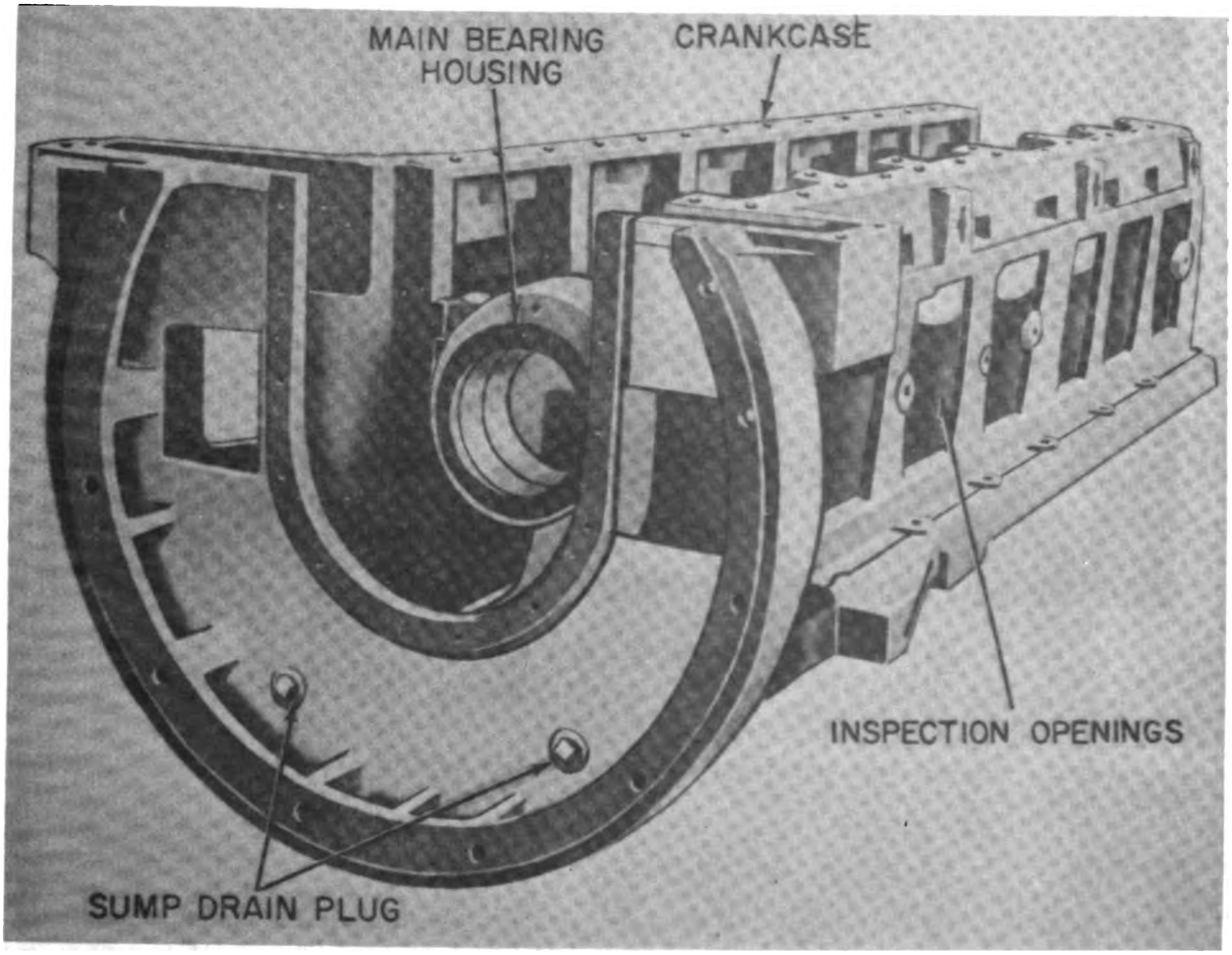


Figure 6. Engine main frame.

bushing crown and eventually discharging by gravity to the sump. Generally, pistons are made of light material, such as aluminum or cast iron alloy to reduce weight.

h. Connecting Rod. A connecting rod is mounted between the piston and the crankshaft to convert the up and down motion of the piston to rotary motion of the crankshaft (fig. 9). It is usually made of drop-forged, high-strength alloy steel, because it is subject to forces in all directions. Combined vertical and sideway forces tend to make a twisting force, which reverses direction frequently and abruptly. The bearing at the crankshaft end is called the connecting rod bearing. The bearing at the piston end is called the piston pin bearing. These bearings must be fitted accurately.

i. Cylinder Heads and Valves. Individual cylinder heads (fig. 10) are fastened to each cylinder in V-type or vertical inline engines. There are no cylinder heads on opposed-piston engines. The head is cast with drilled water passages, which line up with those in the liner and the water outlet header or manifold. On four-stroke cycle engines, each head is provided with intake and exhaust valves, a fuel injector opening, and occasionally an indicator valve opening. There are no intake valves on two-stroke cycle engines because the air ports are in the liner. Rocker arms are mounted on the cylinder head to operate the valves. The rocker arms are actuated by the camshaft through push rods and have adjusting screws and locknuts to adjust the valve tappet clearances and, in some models, the injectors.

j. Camshaft and Drive. The camshaft

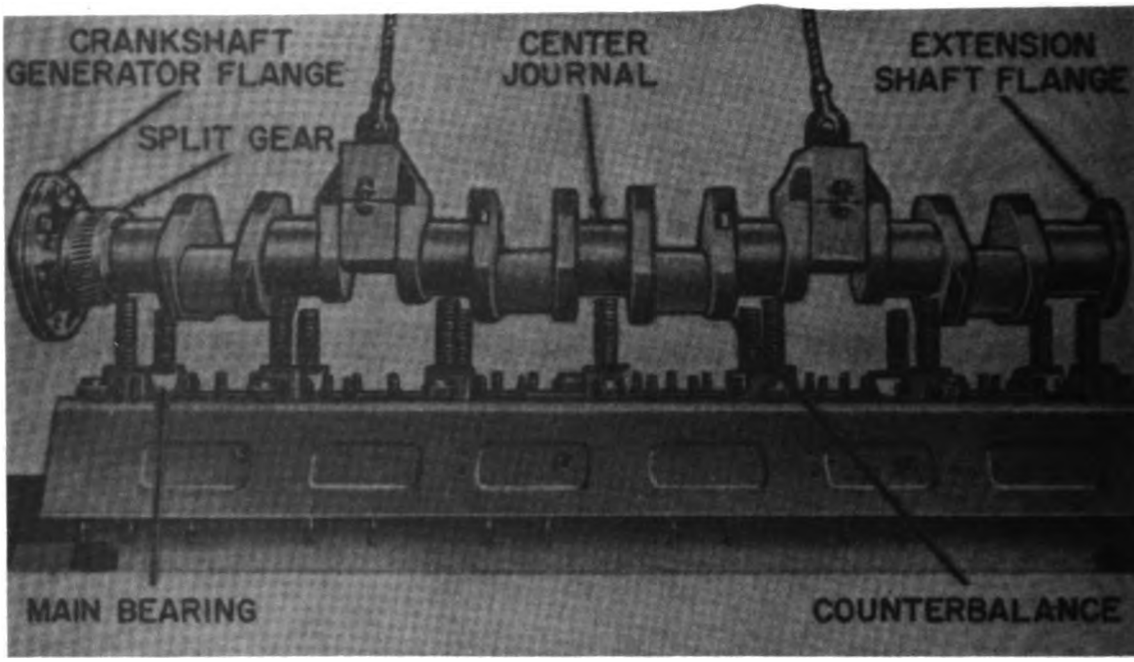


Figure 7. Crankshaft.

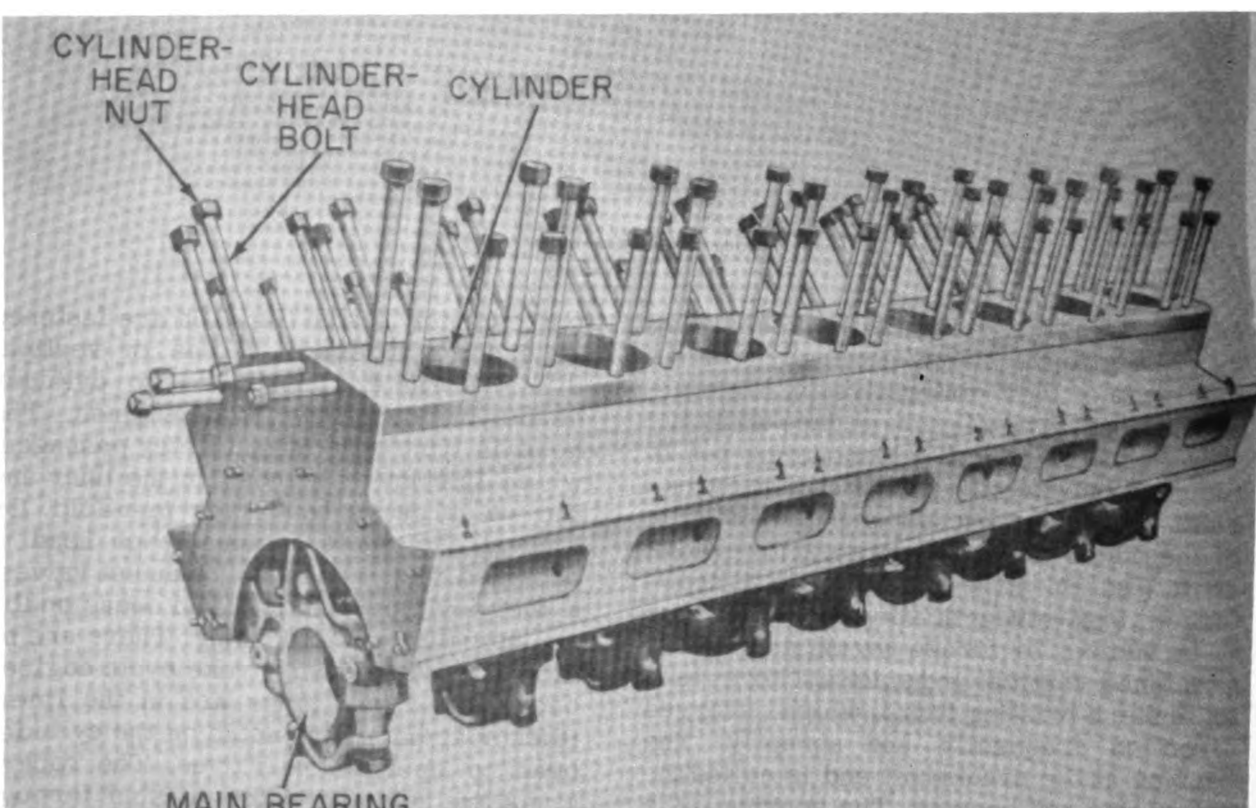


Figure 8. Cylinder block.

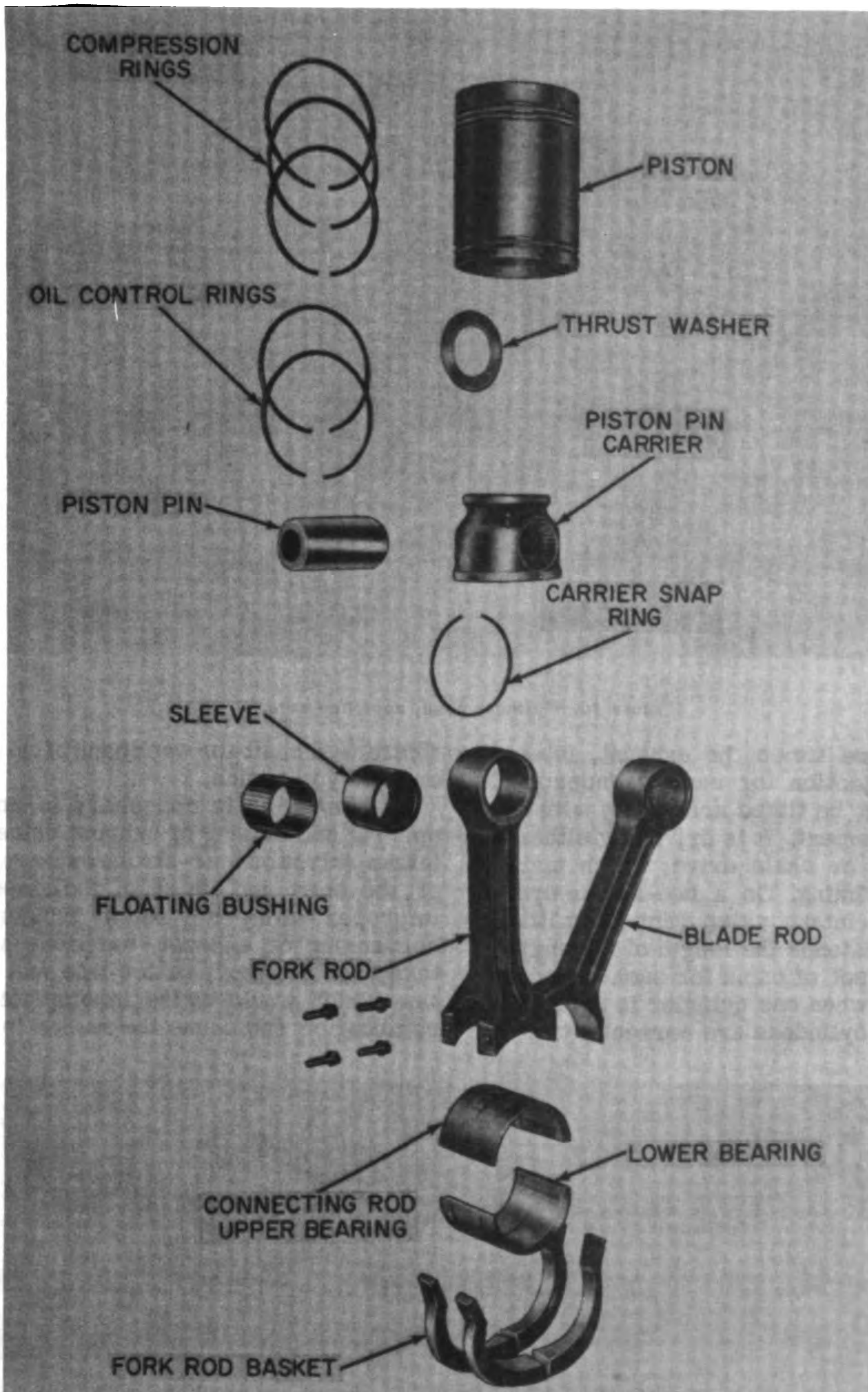


Figure 9. Piston and connecting rod assembly, exploded view.

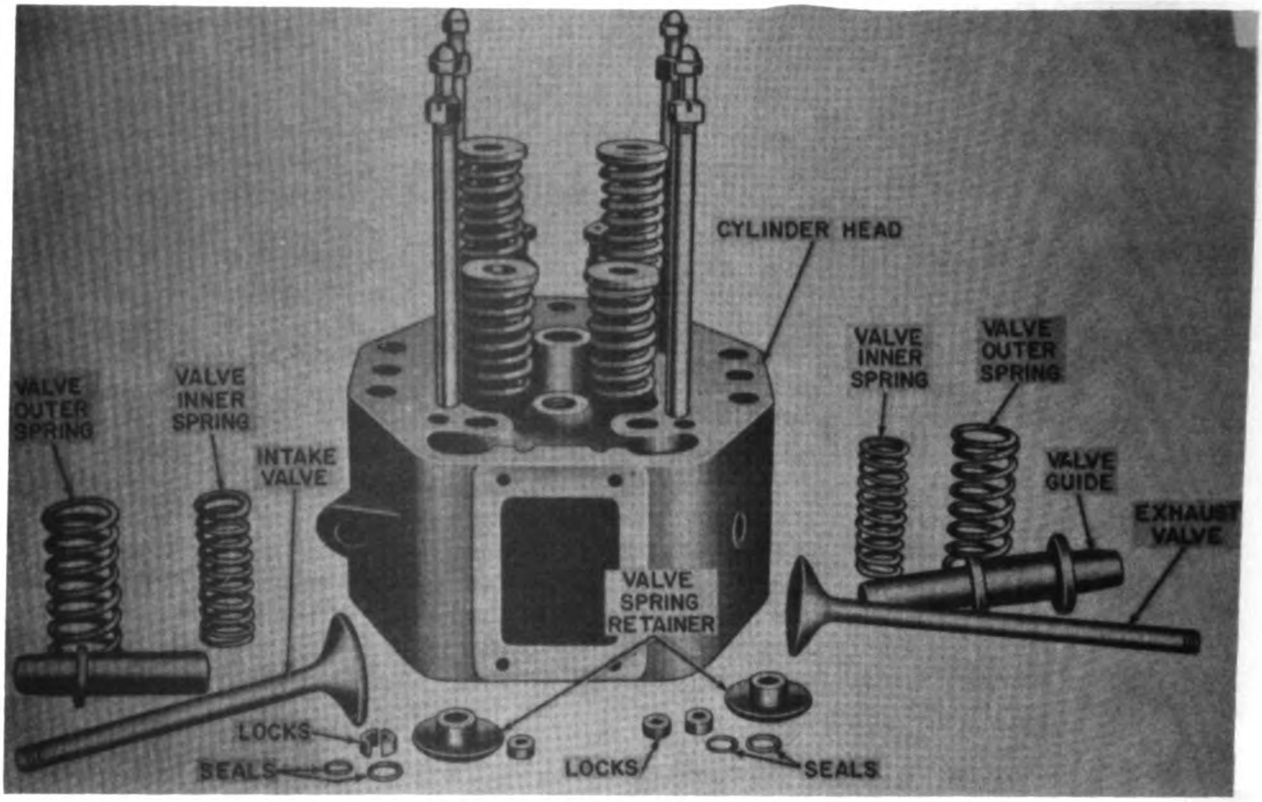


Figure 10. Cylinder head, exploded view.

regulates and times the exhaust, intake, and fuel injection for each cylinder (fig. 11). It must be timed accurately with the piston movement. It is driven by either a gear train or chain drive, which maintains this timing. On a two-stroke cycle engine, the intake valve cam is omitted. The shaft extends the length of the engine and has a set of cams for each cylinder; therefore, when one cylinder is correctly timed, all cylinders are correctly timed. There is a shaft for each bank of cylinders on a V-type engine.

k. Timing. It is necessary to time the opening and closing of exhaust valves (and intake valves on four-stroke cycle engines) at the start and finish of fuel injection. Improper timing may result in incomplete scavenging or exhaust, too little air intake, and too early or too late fuel injection which would cause incompleted fuel combustion and cause the engine to knock

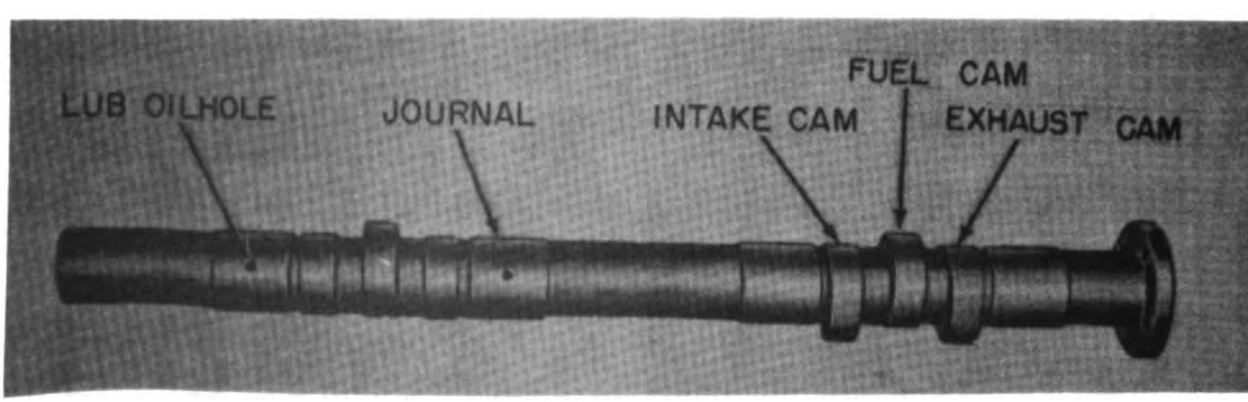


Figure 11. Camshaft.

or smoke. The action of the three cams depicted on the camshaft in figure 11 is shown for each of the three functions in the timing diagram (fig. 12). The point at which intake, exhaust, and injection take place is shown in degrees before top dead center (tdc) and bottom dead center (bdc). Adjustment of timing is seldom necessary except when major repairs or replacements are made to the fuel injection pumps, timing gears or chains, and camshaft or crankshaft.

l. Harmonic Balancer. Heavy vibrations occur if the frequency of a pulsating torque, as produced by the pistons, equals the natural frequency of vibration of the crankshaft. This is called the critical speed of an engine. The slightest deviation from critical speed will cause any such vibration to stop. A momentary change in the throttle position would produce the necessary change in speed. The harmonic balancer is used on 12- and 16-cylinder engines and is located on the front end of the crankshaft. It consists of two couplings, laminated springs, pins, and a spring housing. The function of the balancer is to dampen torsional vibration in the crankshaft.

m. Overspeed Trip. Diesel engines in locomotive service are provided with an overspeed trip mechanism which automatically brings the engine to a stop if engine speed exceeds a safe limit. The mechanism is tripped by centrifugal force at a speed usually about 10 percent above normal maximum speed. Under certain conditions, for instance a sudden loss of load (if a protective relay such as a wheel slip or ground relay is functioning), the governor may not be able to limit the engine to its maximum speed. The overspeed trip may function through electrical connections to solenoid-operated governors (para 36*c*), or through direct mechanical connection to the fuel control shaft on the engine.

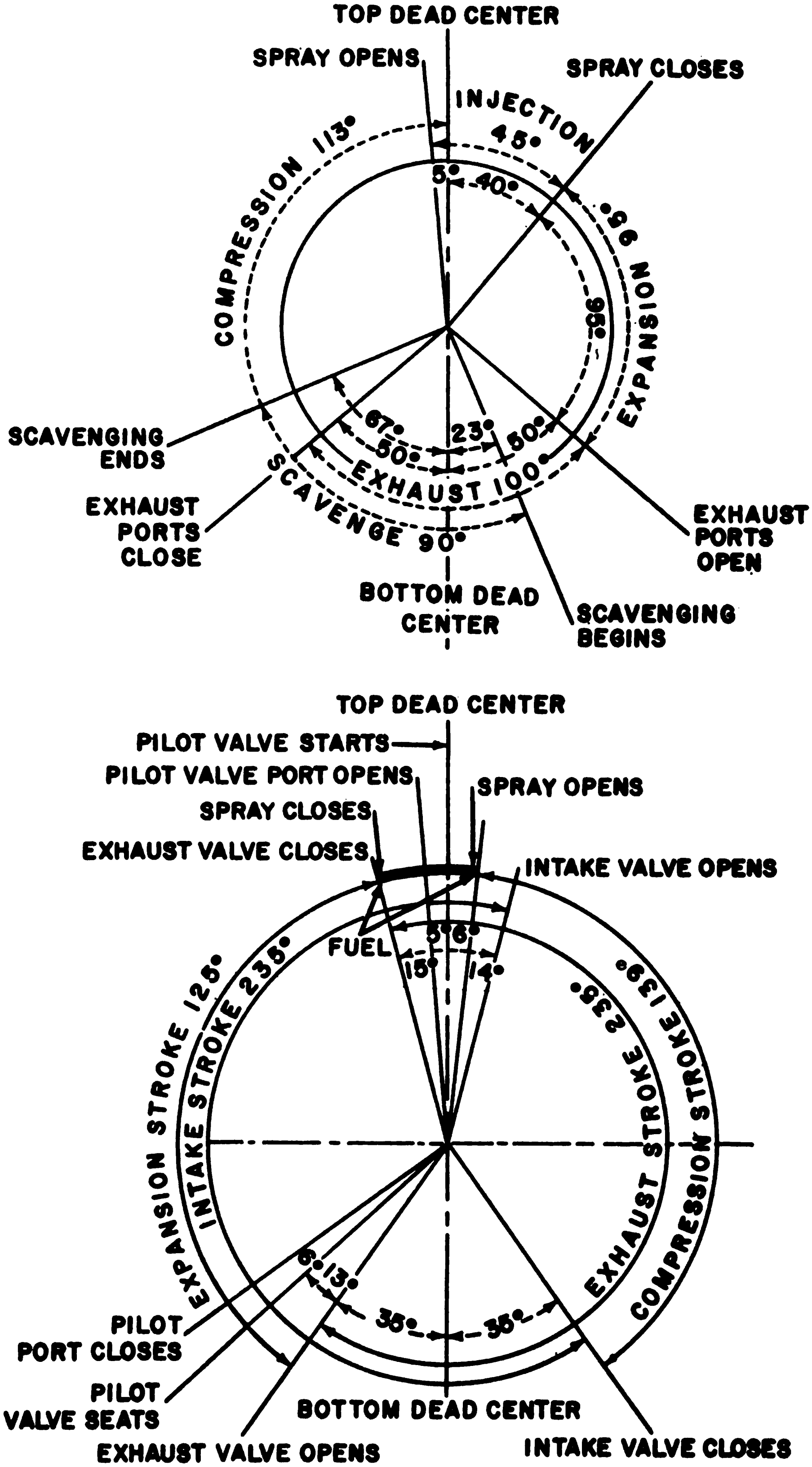


Figure 18. Camshaft timing diagrams.

CHAPTER 4
FUEL SUPPLY SYSTEM

15. General

Fuel is pumped from a fuel tank through strainer filters and related fixtures to a fuel oil manifold and header, then discharged under pressure to injection equipment at each cylinder (fig. 13). The pump is usually driven by an electric motor and is designated as a supply pump, fuel transfer pump, or booster pump. It should always be clearly distinguished from the fuel injection pumps. Relief valves are provided to protect the fuel pump and motor against excessive overload, and to keep excess oil in the fuel oil header from returning to the tank. A pressure gage in the cab tells whether adequate fuel oil pressure is being maintained in the supply line. The fuel tank is usually suspended beneath the underframe between trucks and can be filled from either side. Air comes through openings protected by a flame arrester. A fuel gage is provided near the fill pipe to show fuel level. Some locomotives also have a fuel gage in the cab. The fuel tank has a drain plug for cleaning purposes and a condensation drain valve. Drain plugs in filter housings or suction lines should be opened only when the engine is stopped, so the pump does not draw air and lose its prime. It is essential that sludge, water, and air be kept out of the system.

16. Fuel Oil Requirements

a. *General.* Specific fuel oils are used to obtain high power at a low rate of consumption and minimize corrosion or other causes of excessive maintenance. High heat content, as expressed in Btu's, is a major requirement. A standard fuel is usually provided for all locomotives in a given area and the crew will seldom find it necessary to make a selection. Cleanliness, viscosity, and ignition quality as expressed in cetane ratings are the most important properties of diesel fuel.

b. *Cleanliness.* Diesel fuel must be clean; otherwise fuel pump and injector difficulties will occur. Fuel acts also as a cooling agent for the pump and injector parts. Diesel fuel is heavier and more viscous than gasoline and will hold dirt in suspension for longer periods of time. Every precaution must be taken to keep dirt out of the fuel system or to eliminate it before it reaches the pumps. Water in diesel fuel will cause uneven operation and corrode the fuel system. Any corrosion or erosion of the accurately machined surfaces in the injection equipment will cause it to become inoperative.

c. *Viscosity.* Viscosity is the resistance offered by a fluid to change in shape or motion. The higher the viscosity, the greater the resistance to flow. When oil is hot, it will flow more rapidly than when it is cold. Oil should be thin (low viscosity) in cold weather and heavy (high viscosity) in hot weather. The viscosity of a diesel fuel must be sufficiently low to flow freely at the lowest temperatures encountered. It must also be high enough to properly lubricate the closely fitted pump and injector plungers. There must be sufficient viscosity to prevent leakage at the pump plungers and dribbling at the injectors. The viscosity determines the size of the fuel spray droplets which, in turn, govern the atomization and penetration qualities of the spray. Viscosity, as measured by a viscosimeter, is indicated by the number of seconds required for a given volume of liquid at a predetermined temperature to flow through an orifice.

d. *Cetane Ratings.* Cetane ratings are the measure of the ignition quality of the fuel oil. These ratings are established by laboratory tests which compare the combustion, pressure, and ignition lag of oil with a test fuel of varying percentage of cetane. Pure cetane is graded 100. Better quality fuels have high cetane ratings. Manufacturers' recommendations on cetane ratings of fuel should be followed. Use of fuel with too high a cetane rating

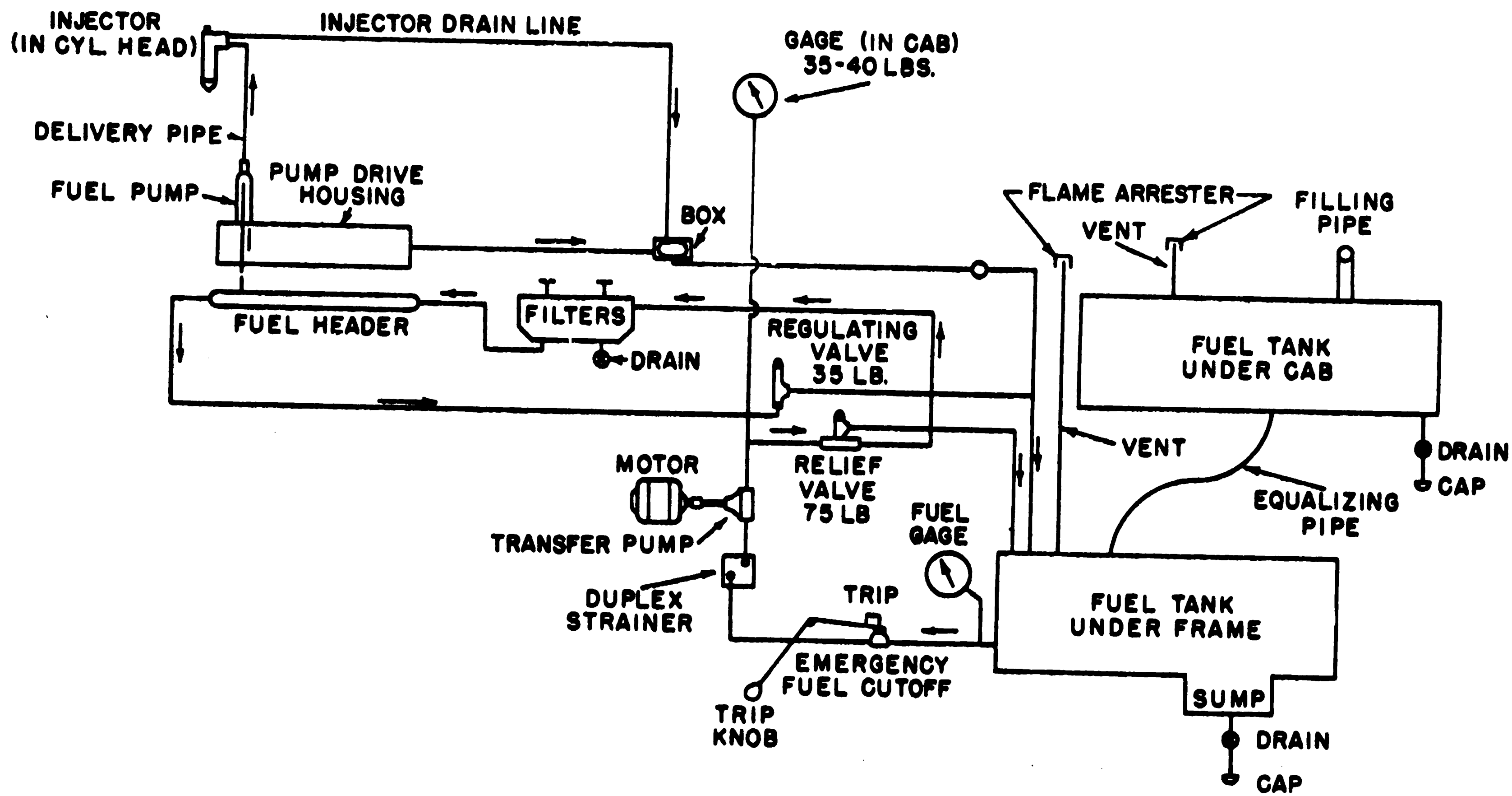


Figure 13. Diagram of fuel oil system.

usually causes preignition. A determination of cetane number is an involved laboratory procedure.

e. *Miscellaneous Requirements*. Fuel oil should burn completely without leaving carbon residue; it should not clog the system or cause corrosion due to the presence of sulphur. The flashpoint and pour point should occur at suitable temperatures. *Never* fill the fuel tank near an open flame.

17. Fuel Oil Purification

In order to deliver clean fuel to the engine, constant effort must be made to prevent contamination at wayside supply stations and on the locomotive. Each time fuel oil is moved from one container to another, it should be run through filters and strainers. The more filtering and straining fuel oil receives, the less the the contamination from dirt and foreign particles. Natural settling is an effective method of cleaning. Storage tanks have a drain cock and tap through which water and sediment can be drained or flushed. To prevent accumulation of water, keep tanks as full as possible to eliminate condensation from moisture-laden air. Any evidence of water at wayside storage facilities requires prompt inspection and correction. Fuel should be delivered from the tank to the locomotive directly through a permanent pump installation. The use of cans, funnels, and drums should be avoided. After the fuel is delivered to the locomotive tank, filters and strainers in the fuel system further filter the fuel as described in paragraph 18.

18. Fuel Oil Filters

a. Thorough and careful filtration of fuel oil is especially necessary to keep diesel engines efficient. Diesel fuels are more viscous than gasoline. They contain more gums and more abrasive particles which may cause premature wear of injection equipment. The abrasives consist of materials which are difficult to eliminate during the refining process; others may enter the fuel tank through careless refueling. Whatever the source, it is imperative that the engine system be protected from these abrasives.

b. Most diesel engine designs include two or more filters in the fuel supply systems to protect the closely fitted parts of pumps and nozzles. The primary (coarse) filter is usually located between the supply tank and the fuel supply pump. The main (fine) filter is between the fuel supply pump and the injection pump. Additional filtering elements are frequently installed between the injection pump and the nozzle. A duplex fuel oil filter is shown in figure 14. A close watch must be made of the fuel pressure gage; if a pressure drop occurs, it is an indication that a filter change is needed.

c. Diesel fuel oil filters are referred to as full-flow filters, because all the fuel must pass through the filters before reaching the injection pumps. Filters must be inspected regularly and cleaned or replaced if maximum efficiency is to be maintained. All metal disk filters and some cloth bag-type filter elements are cleanable. Most cloth or fabric elements must be replaced when they become dirty. Diesel oil filters usually incorporate an air vent to release air which might accumulate in the filter during operation and a drain plug in the bottom for removing sediment.

d. Metal filters are used as primary filters because the fine particles that may pass through them are not as injurious to the supply pump as they would be to the injection pump. A cleaning knife is often provided to scrape deposits off the filtering disks (fig. 14). The solids fall to the bottom of the filter housing where they can be removed through the drain plughole. The ball relief valve in the filter cover enables the oil to bypass the filter element if the disks become clogged.

e. Fabric filters, because of their greater filtering qualities, are usually used as main filters to protect the fuel injection pump. A bag-type filter is desirable because it can be cleaned. The filter is made of an evenly woven, lintless, acid-resisting textile material. The entire surface of the bag is available for filtering purposes. The fuel to be filtered flows from the filter inlet at the top through a

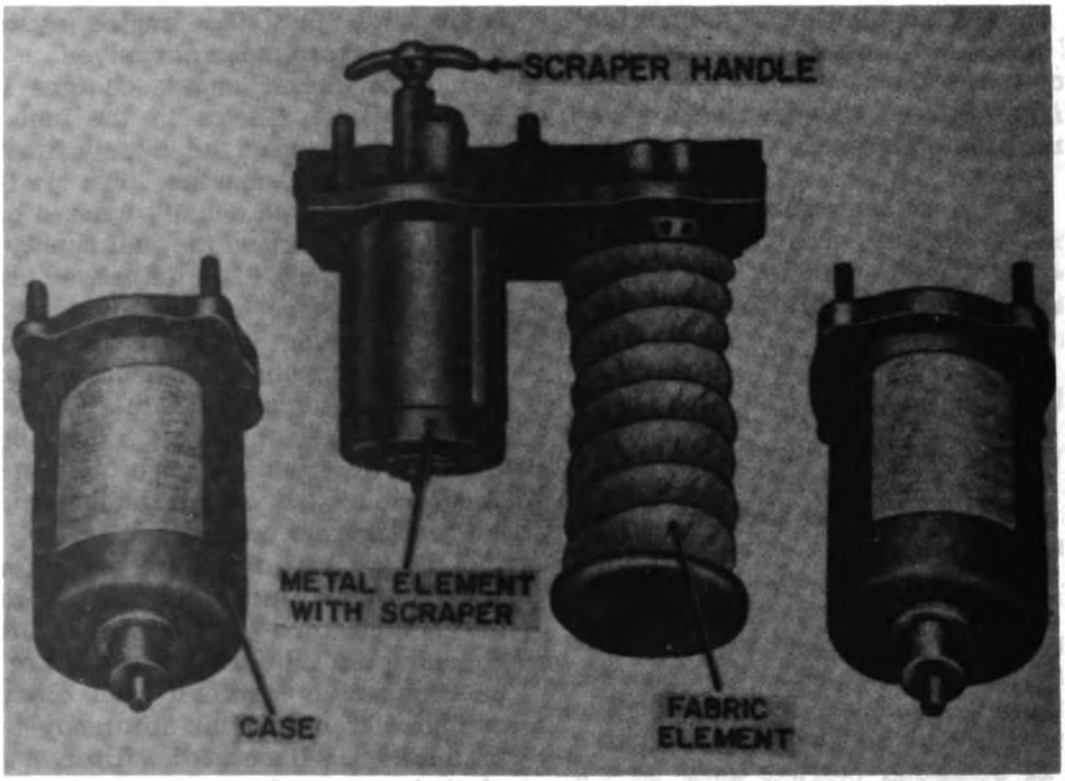


Figure 14. Fuel oil filter.

spool and out the ports to the inside to the bag. The dirt, solids, abrasives, carbons, etc., are caught in the bag, and the clean fuel passes outward and to the filter outlet. The bag can be turned inside out to expel the dirt and may be washed and reinstalled.

19. Fuel Oil Supply Pump

A motor-driven positive displacement pump (fig. 15) is used to draw fuel oil from the tank and pump it to the fuel oil header so that the injection pumps are supplied at all times. Injection pumps do not have enough suction ability of their own to draw the oil. Cummins fuel pumps combine fuel injection pump and a suction pump in one unit and therefore do not require a separate suction pump. The fuel oil is discharged from the pump at a pressure of about 35 to 40 pounds per square inch (psi). A relief valve on the pressure side, set at about 75 psi, protects the pump in case a blocked fuel line overloads the pump. Fuel delivered by the pump is then metered and timed (para 11) by an injection pump system or a unit injection system. Unit injectors combine the injection pump and nozzle in one housing.

20. Fuel Injection Pump

Each cylinder in multiple-unit systems has an individual injection pump (fig 16) which meters fuel and delivers it under high pressure to the spray nozzles leading into the combustion chambers. The pumps are operated by a cam. The plunger stroke remains constant at all loads. The plunger is turned axially by a fuel control rack connected to the governor. The angular position of the fuel pump plunger with respect to the barrel ports determines the quantity of fuel injected per stroke. The actual metering is done by a helical groove cut into the plunger which alternately opens and closes a port in the barrel (fig. 17). The port on the left is an inlet port and the port on the right is a bypass port. A vertical passage extends from the top of the helical groove to the top face of the plunger. In

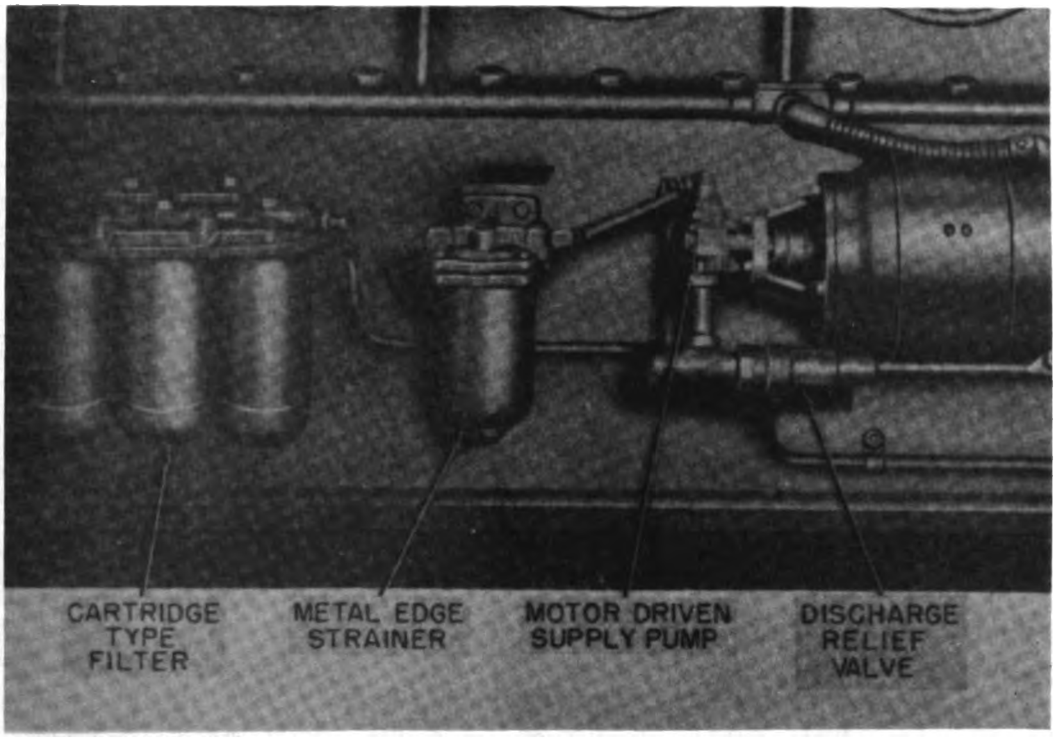


Figure 16. Fuel oil supply pump.

the no-fuel position, the plunger is turned so the vertical groove connects the space immediately above the plunger with the bypass port throughout the entire stroke, and the pump exerts no pressure on the line to the injector. At the point of maximum fuel delivery, the plunger is turned axially so it completes almost a full stroke before the helix uncovers the bypass port to release pressure. The plunger forces oil to the injector nozzle as it moves. At any position between no-fuel and maximum fuel delivery, the plunger assumes a corresponding axial position; the helix uncovers the bypass port at intermediate portions of the stroke and a proportionate amount of fuel is forced to the injector nozzle before the pressure is released.

21. Fuel Injector Nozzle

The injector nozzle directs the fuel into the combustion chamber in a definite pattern designed to obtain the best mixture for combustion. It contains a nozzle valve which is lap fitted to the nozzle body to form a mated assembly. These parts must be kept paired at all times and interchange must be carefully avoided when any repair work is done. The valve is opened when fuel is delivered under sufficient pressure to lift the valve against spring pressure. When it is open, fuel oil is delivered through the nozzle orifices to the combustion chamber. The injector shown in figure 18 is a unit injection pump and nozzle combined, which includes a helical metering arrangement similar to the one described in paragraph 20 and performs the same function as the injection pump and separate nozzle. A simple injector nozzle, for use with separate injection pumps, is similar but less involved in design and operation. Some injectors have built-in filters to protect the working parts. The fuel provides adequate lubrication of the moving parts.

22. Emergency Fuel Cutoff Valve

The emergency fuel cutoff valve furnishes a means of cutting off the flow of fuel from the tank to the diesel engine in case of emergency. The type used on ALCO locomotives is illustrated in figure 19. This valve is located in the suction line

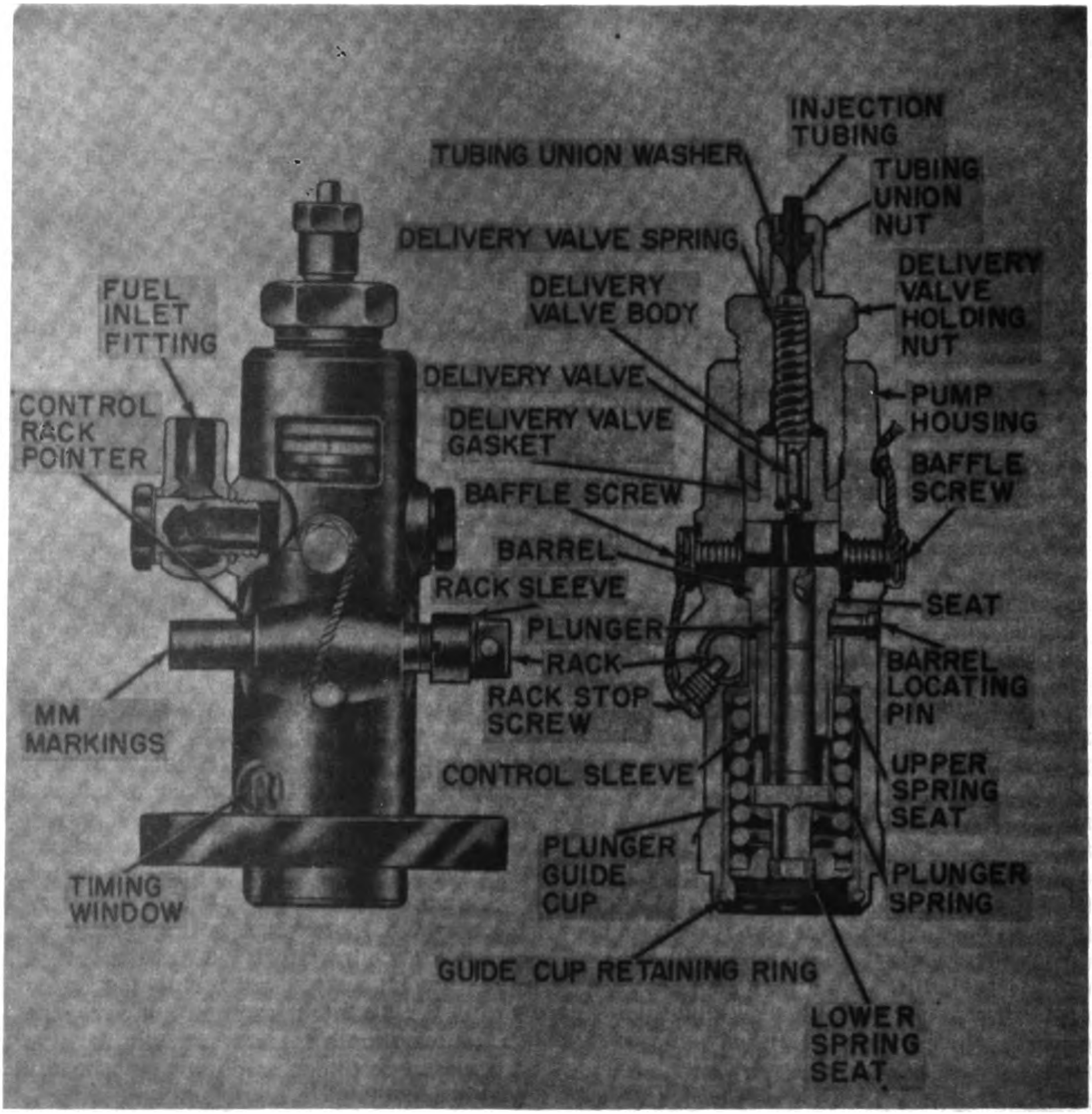


Figure 16. Fuel injection pump.

near the booster pump in the contactor compartment. It can be closed from three points on the locomotive by pulling the red knob at the engineman's position or at either side of the locomotive above the center of the rear truck. When the valve is tripped (closed), the fuel pressure gage should indicate zero pounds pressure. It is reset manually by pulling up on the valve stem and resetting the crutch which holds the valve open.

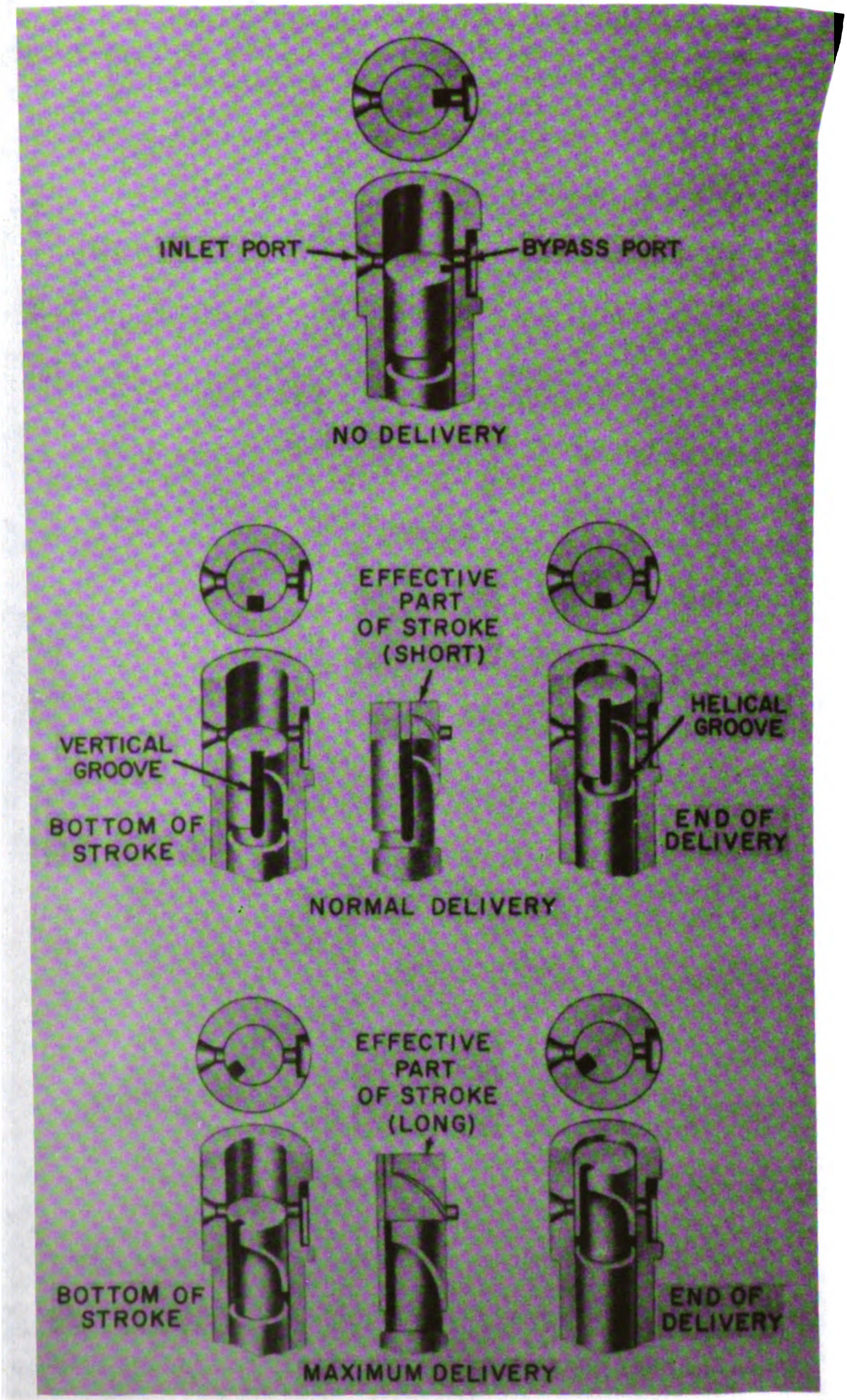


Figure 17. Injection pump plunger passages.

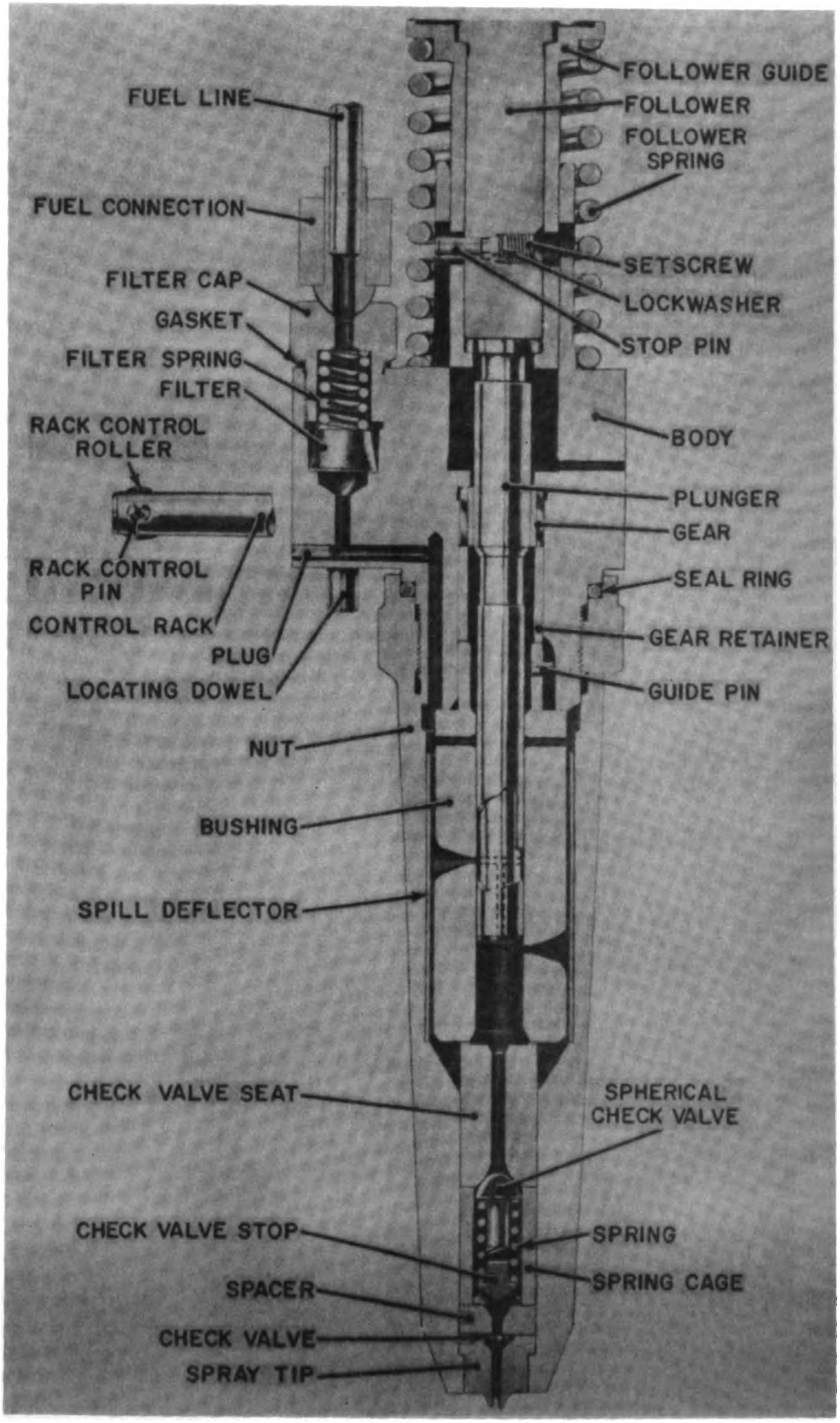


Figure 18. Unit injector.

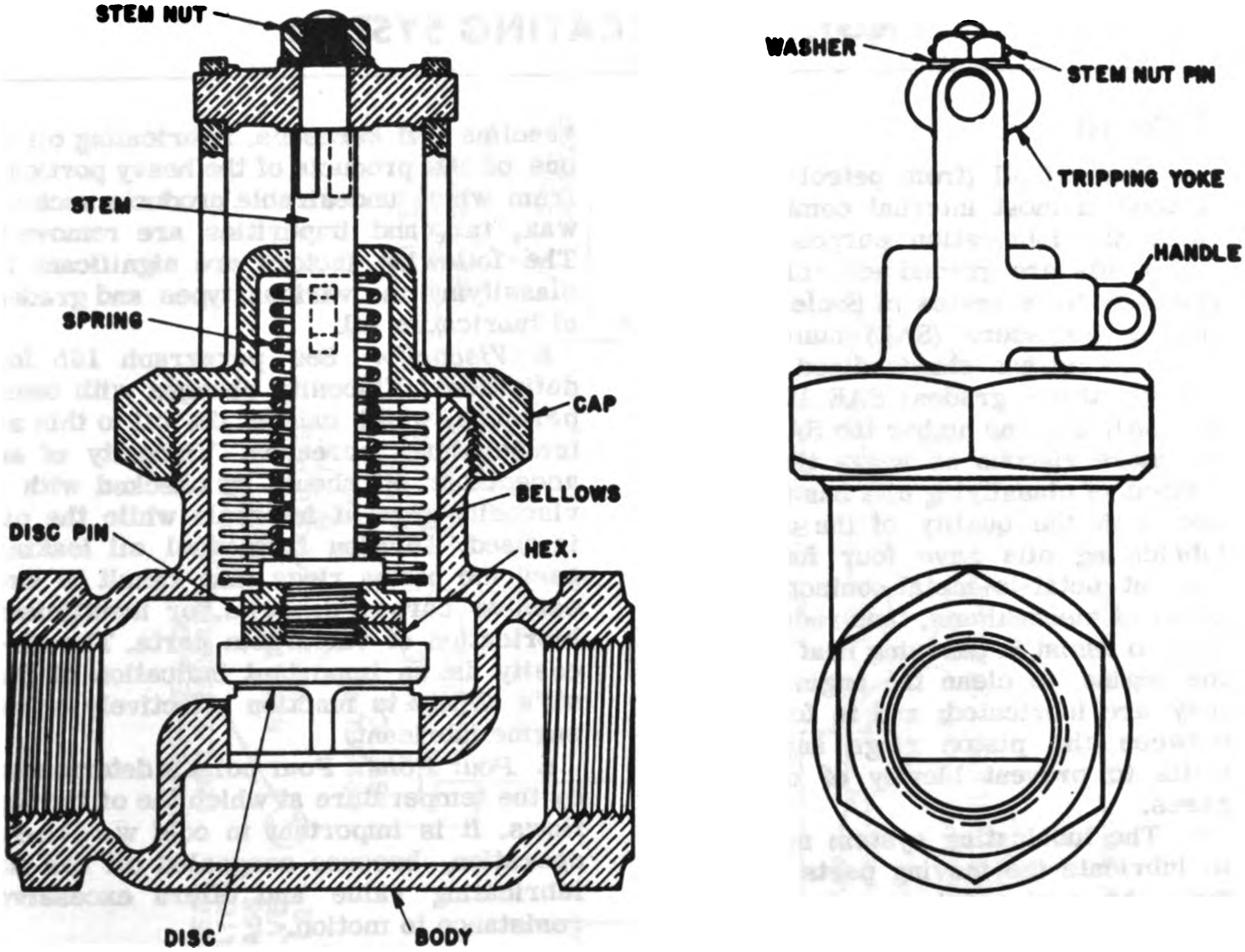


Figure 19. Emergency fuel cutoff valve.

CHAPTER 5
ENGINE LUBRICATING SYSTEM

3. General

a. Mineral oil (from petroleum bases) is used in most internal combustion engines for lubrication purposes. Lubricating oils are graded according to their viscosity by a series of Society of Automotive Engineers (SAE) numbers. The U. S. Army has standardized its engine oils on three grades: SAE 10, SAE 30, and SAE 50. The higher the SAE number, the more viscous or heavy the oil. This method of classifying oils has no connection with the quality of the oil. Engine lubricating oils have four functions: to prevent metal-to-metal contact in moving parts of mechanisms, thus reducing friction; to assist in carrying heat away from the engine; to clean the engine parts as they are lubricated; and to form a seal between the piston rings and cylinder walls to prevent blowby of combustion gases.

b. The lubricating system supplies oil to lubricate the moving parts of the engine. An engine-driven pump draws oil from the engine base and circulates it through a series of filters, strainers, etc., to the engine lubricating oil header (fig. 20). Lubrication of individual assemblies is described under separate headings in paragraph 14. A bayonet gage is provided in the base of the engine to check the oil level. A filling hole or pipe is generally provided near this gage for the addition of makeup oil. Handholes in the engine base should not be opened when the engine is running. Relief valves, or pressure regulating valves, are installed at appropriate places in the piping to protect the pump, oil cooler, or similar accessories. The settings of these valves vary with the normal oil pressure in the various parts of different systems.

24. Properties of Lubricating Oil

a. *General.* Crude oil is distilled to obtain lighter volatile products such as gasoline and kerosene. Lubricating oil is one of the products of the heavy portions from which undesirable products such as wax, tar, and impurities are removed. The following factors are significant in classifying the various types and grades of lubricating oil.

b. *Viscosity.* See paragraph 16*b* for definitions. Viscosity changes with temperature, which causes the oil to thin as temperature increases. Viscosity of an acceptable oil should be checked with a viscosity gage at intervals while the oil is used. Dilution from fuel oil leaking past the piston rings may result in excessive carbon deposits, or insufficient lubrication of vulnerable parts. The viscosity is an important indication of the oil's ability to function effectively as an engine lubricant.

c. *Pour Point.* Pour point is determined by the temperature at which the oil barely flows. It is important in cold weather operation, because congealed oil has no lubricating value and offers excessive resistance to motion.

d. *Flashpoint.* Flashpoint is that temperature at which oil vapor above the oil will ignite when exposed to flame. Although flashpoint gives some indication of the oil's volatility, it has little to do with the oil's lubricating value. It is used primarily to determine the safety factor in storing oil.

e. *Carbon Residue.* Carbon deposits are formed by the residue left after volatile matter in the oil has evaporated. They should be kept at a minimum, because accumulation of carbon causes leaky, sticky valves and rings and may score the cylinder liners.

f. *Oxidation.* Every effort is made when the oil is refined to remove materials which have a tendency to oxidize. Deposits from oxidization are objectionable for the same reason as given in *e* above. The lubricant must resist oxidation when subjected to the flame of combustion.

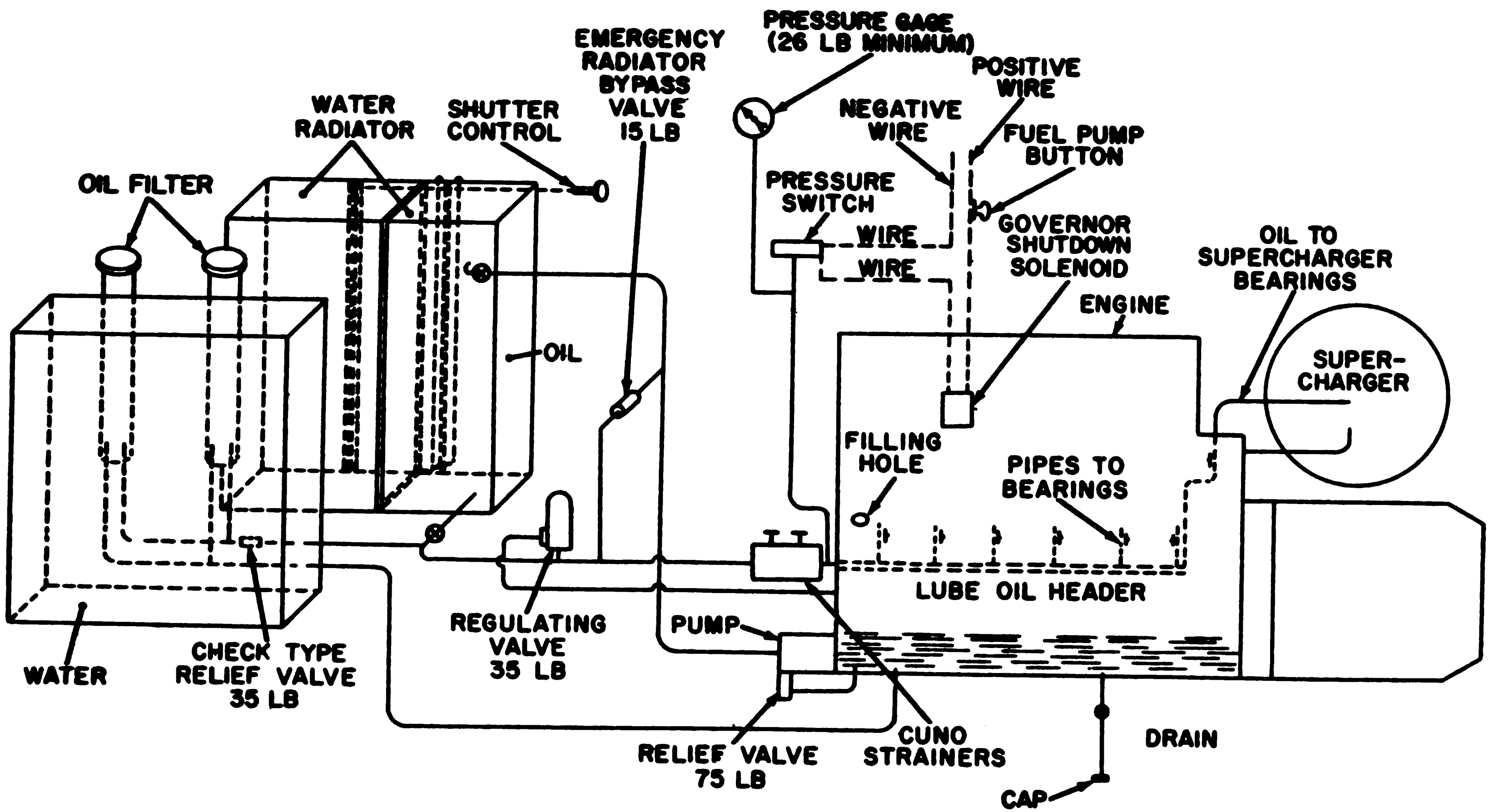


Figure 20. Diagram of typical engine lubricating system.

g. Emulsion. Oil in the crankcase of an engine becomes emulsified when mixed with water. This condition comes about through exhaust gases (which always contain some water) reaching the crankcase, leaking head gaskets, damaged cylinder blocks, excessive condensation, etc. Oil should be checked frequently and drained at regular intervals.

h. Sulphur. Excessive sulphur may cause chemical reactions which promote corrosion and increase friction resistance of wearing parts.

25. Purification of Oil

a. General. Oil does not wear out but it becomes contaminated soon after it is used within an engine. However, the lubrication properties are still effective if the impurities are removed. This is often done by gravity settling and passing oil through filter beds, or by centrifuging the oil in a rotary separator whose operation is based on the relative specific gravity of the oil and impurities. Proper maintenance can assist in preventing contamination. The engine interior, cylinder heads, air boxes, and crankcases should be cleaned when oil is changed if these locations are readily accessible. When oil is changed without first remedying the fault of contamination that is responsible for the poor condition of the oil, the same results can be expected to recur immediately after the change. The condition of the oil and its contents are indicative of many troubles; by testing samples removed from the system, remedial measures may be taken when the results of the test are revealed. When all the items of tests made at frequent intervals have been fully correlated, the record should show the extent of the fuel dilution, soot, water; wear of cylinder sleeve, liners, and other parts; and oxidation of oil.

b. Filters and Strainers. Dirt is a very damaging element in an engine. Cleanliness of the oil has a direct bearing on the life and service of an engine. Even when oil is supplied under ideal conditions, carbon deposits, sludge, tar, and gum may form and should be removed by filters or strainers (para 18*b*).

(1) *Filters.* Filters consist of a casing containing removable elements or cartridges (fig. 21). The elements are generally a metal cage packed with waste or similar loose fibrous material. The elements should be renewed often enough to keep the oil clean. The interior of the casing is cleaned at the same time. Elements of a type which can be repacked are returned to the shop for new packing. These elements can be repacked by maintenance personnel.

(2) *Strainers.* Strainers consist of various arrangements of metal straining elements. A scraping element in contact with the straining element is provided for the frequent removal of accumulated deposits. A handle extends through the casing and should be turned regularly for this purpose (turn in one direction only when so specified). The foreign matter that is scraped off drops to the bottom of the case. Strainers are removed for cleaning when oil is changed or at other suitable intervals. Specific directions for dismantling and replacement as well as suitable cleaning solutions appear in the various manufacturers' bulletins. Strainers may give a good indication of the condition of main or connecting rod bearings, since they trap the metallic particles worn from the bearings before they reach the pump.

26. Lubricating Oil Pump

Lubricating oil pumps are driven by the engine by means of a gear train. Some oil systems have two pumps, one for a scavenging system and the other for engine pressure lubrication. The ALCO pump is typical of those in general use. This pump consists of a pumping element of the helical gear type housed in a bronze casing assembly made in two sections. The casing sections are joined together in metal-to-metal fits and the parts are held in assembly by studs and ream bolts. The

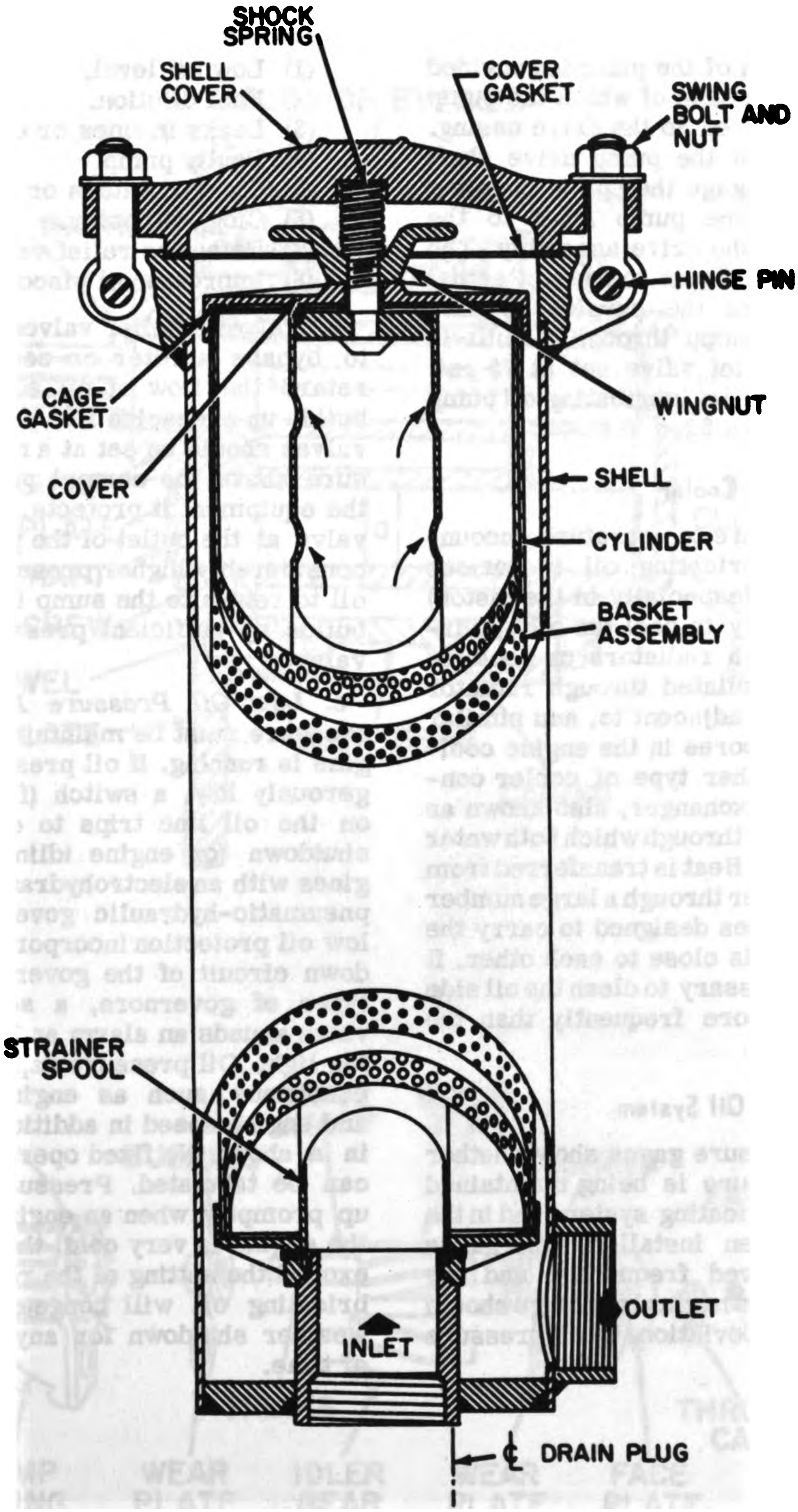


Figure 21. Lubricating oil filter.

uppermost section of the pump is provided with a flange by means of which the pump assembly is secured to the drive casing. The upper end of the pump drive shaft is machined to engage the spline coupling which connects the pump shaft to the vertical shaft of the drive assembly. The pump has a capacity in excess of actual requirements, and the surplus is discharged to the sump through a built-in spring-loaded relief valve set at 75 psi. Component parts of a lubricating oil pump are shown in figure 22.

27. Lubricating Oil Cooler

The high engine temperature encountered by the lubricating oil in various engine passages (especially in the piston) make it necessary to cool the oil by circulating it through radiators or coolers. Oil may be circulated through radiator cores which are adjacent to, and similar to, the radiator cores in the engine cooling system. Another type of cooler consists of a heat exchanger, also known as a lube oil cooler, through which both water and oil circulate. Heat is transferred from the oil to the water through a large number of thin-walled tubes designed to carry the flow of these fluids close to each other. It is generally necessary to clean the oil side of the cooler more frequently than the water side.

28. Accessories in Oil System

a. Gages. Pressure gages show whether normal oil pressure is being maintained in the engine lubricating system and in the turbocharger when installed. The gages should be observed frequently, and any deviation from the normal readings should be investigated. Deviations in oil pressure may be due to:

(1) Low oil level.
(2) Fuel dilution.
(3) Leaks in lines or connections.
(4) Faulty pump.
(5) Clogged filters or strainers.
(6) Clogged cooler.
(7) Defective relief valves.
(8) Improper oil viscosity.

b. Valves. Relief valves are provided to bypass a filter or cooler if deposits retard the flow of oil so that the pump builds up excessive line pressure. Bypass valves should be set at a reasonable pressure above the normal pressure drop in the equipment it protects. A system relief valve at the outlet of the pump is set at a considerably higher pressure and permits oil to return to the sump if restricted flow builds up sufficient pressure to trip this valve.

c. Low Oil Pressure Protection. Oil pressure must be maintained when the engine is running. If oil pressure drops dangerously low, a switch (fig. 23) mounted on the oil line trips to close an engine shutdown (or engine idling) circuit. Engines with an electrohydraulic governor or pneumatic-hydraulic governor have the low oil protection incorporated in the shutdown circuit of the governor. With other types of governors, a separate magnet valve sounds an alarm and shows a warning light. Oil pressure depends on several conditions such as engine temperature and engine speed in addition to those listed in *a* above. No fixed operating pressures can be tabulated. Pressure should build up promptly when an engine is started. If the engine is very cold, the pressure may exceed the setting of the relief valve. Lubricating oil will congeal during a cold weather shutdown for any lengthy period of time.

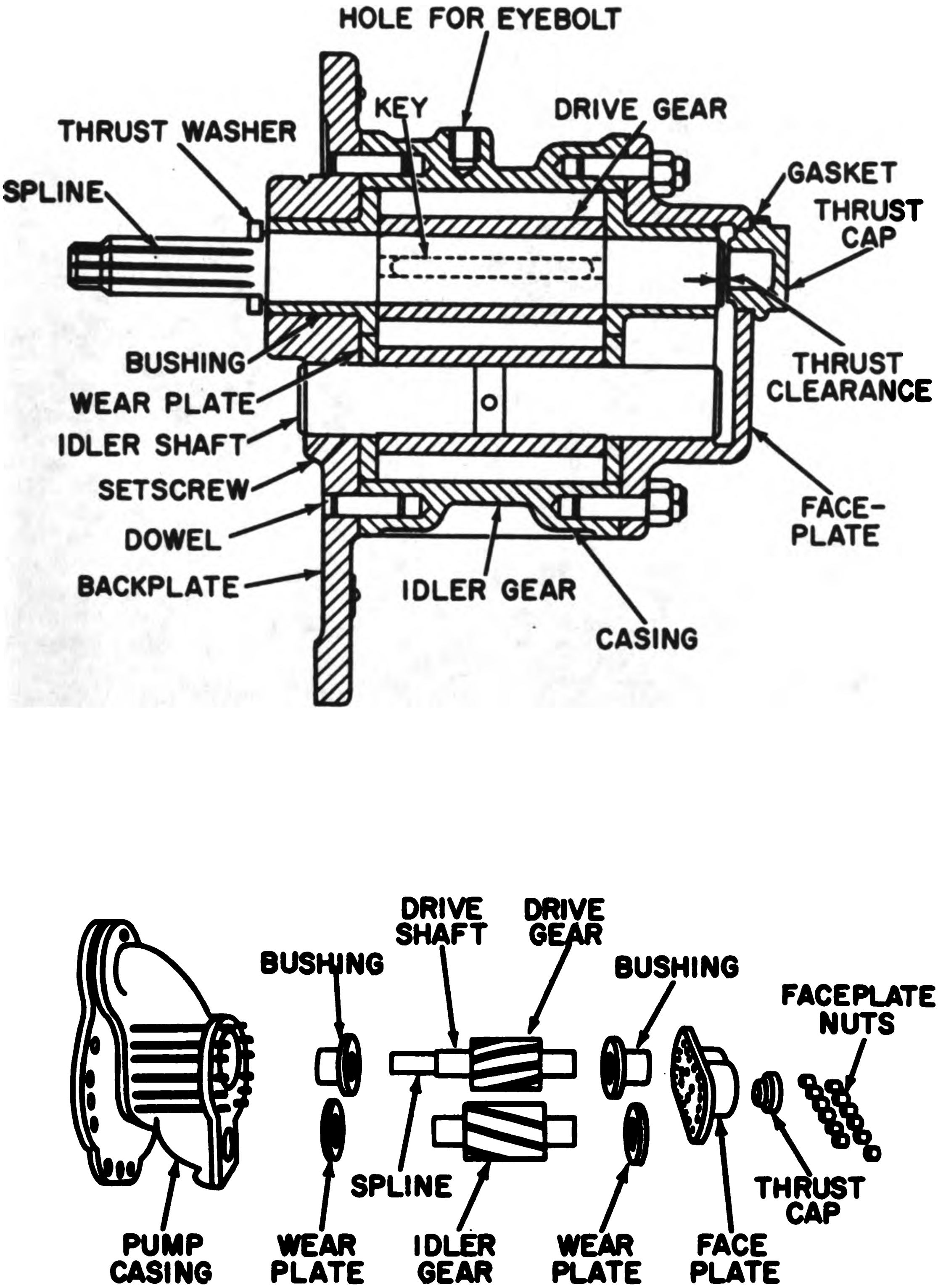


Figure 22. Lubricating oil pump.

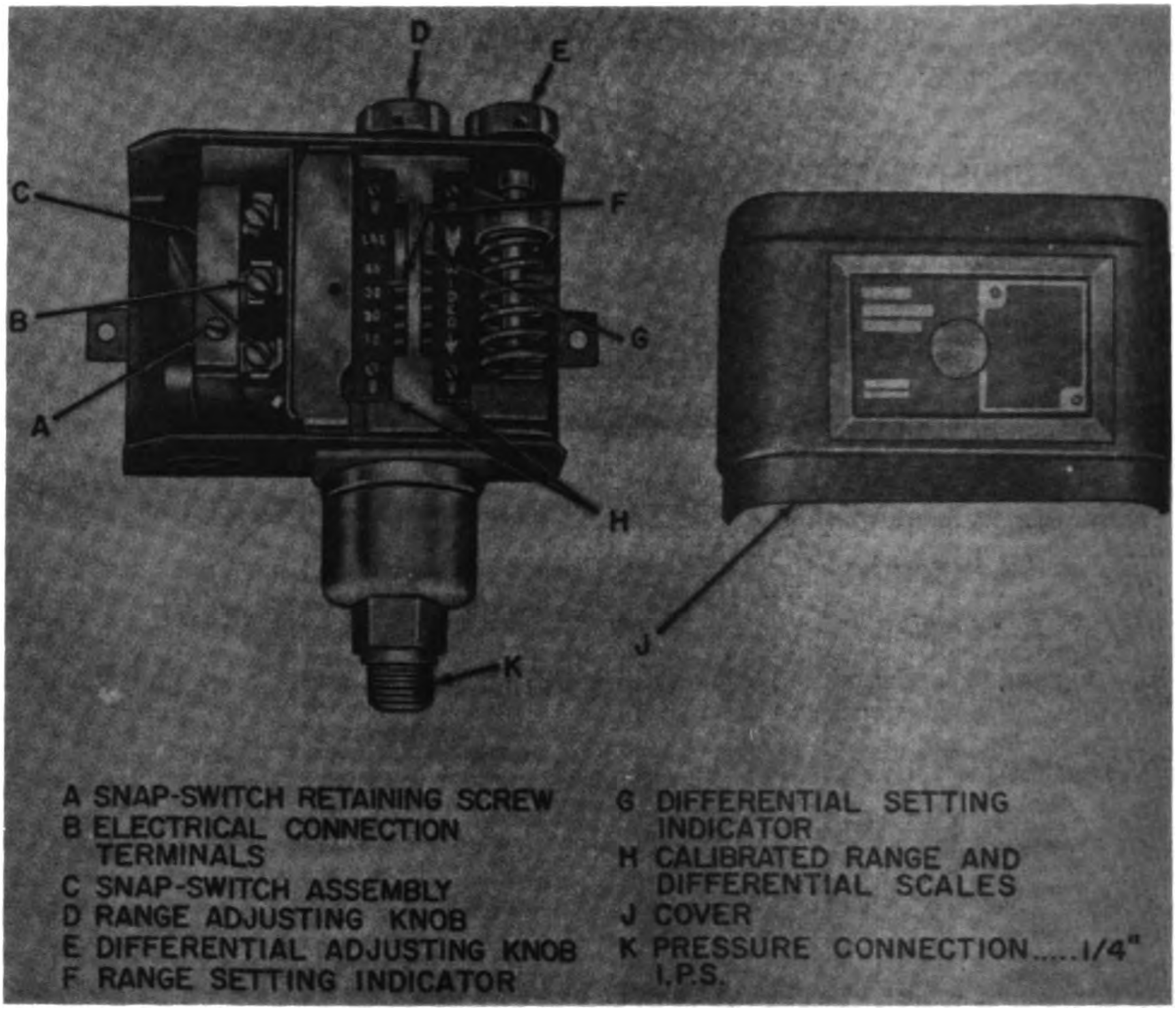


Figure 23. Low oil pressure switch.

CHAPTER 6
ENGINE COOLING WATER SYSTEM

29. General

The care and servicing of the cooling system is an important maintenance matter. The cooling system is designed to carry away and disperse the excess heat generated in the engine. It usually consists of a water circulating pump, radiator, expansion tank, a heat exchanger, lube oil cooler, fans, shutters, various gages, valves and filling, venting, and drain connections (fig. 24). Waterlines of the turbocharger and cab heaters are also connected to the system. The pump is usually mounted on and driven by the engine. The fans may be mechanically driven or motor driven. The amount of air forced through the radiator varies with the speed of the fans, the number of fans running, and the setting of the shutters (varying with the particular model).

30. Water Pump

A water circulating pump of the centrifugal type (fig. 25) consists chiefly of an impeller and housing, drive shaft and housing, bearings, and seal assemblies. It is characteristic of some pumps to permit a small amount of water to drip through the packing gland. This water serves to lubricate the packing and prevent bearing seizure. If there is a drop of water every few seconds, the nut should not be tightened any further. Excessive leakage at the packing can be caused by a worn shaft bushing, which can be recognized by a continual chattering of the shaft.

31. Radiators and Shutters

Radiators generally consist of two core units located on each side of the locomotive just below the roof or on each front side. A core consists of several bolted sections with a water header for piping connections. Tubes of thin rectangular cross sections are held by continuous fins extending across the core assembly. Copper fins and seamless tubes are silver-soldered and the tube ends are brazed to the tube sheets to form a rigid assembly. Air drawn through grills beside the radiators is exhausted upward through the roof. The radiator and fan openings in the roof and sides are usually covered by shutters. Shutters are sometimes omitted in tropical service or insulated for very tight closing in very cold regions. Shutters may be opened or closed automatically by connecting them to a temperature control system or they may be set manually.

32. Temperature Control

a. The efficiency of the diesel engine depends a great deal on maintaining an even water temperature in the cooling system. The thermostat controls coolant temperature into the engine while the temperature gage in the cab tells the operator how hot the engine water is as it leaves the engine (approximately 10 degrees difference at full load). If the engine is too cool, fuel combustion is retarded. If the engine is too hot, there will be a breakdown of lubricating oil and possible serious damage to the engine. If an automatic temperature control system is not installed, the operator should set the shutters manually to restrict the flow of air when water temperature is too low, or to open the shutters when water temperature is too high. If temperature is regulated automatically, thermostatic controls open and close the shutters and change the speed of the fans when they are motor driven. Automatic systems can be regulated manually if the thermostatic controls fail.

b. The designs of control systems vary widely. A complete automatic system consists of a temperature control operating a shutter control valve, a pneumatically operated shutter, contactors in the fan motor circuits, and an alarm and protective device. The electrical portion of the

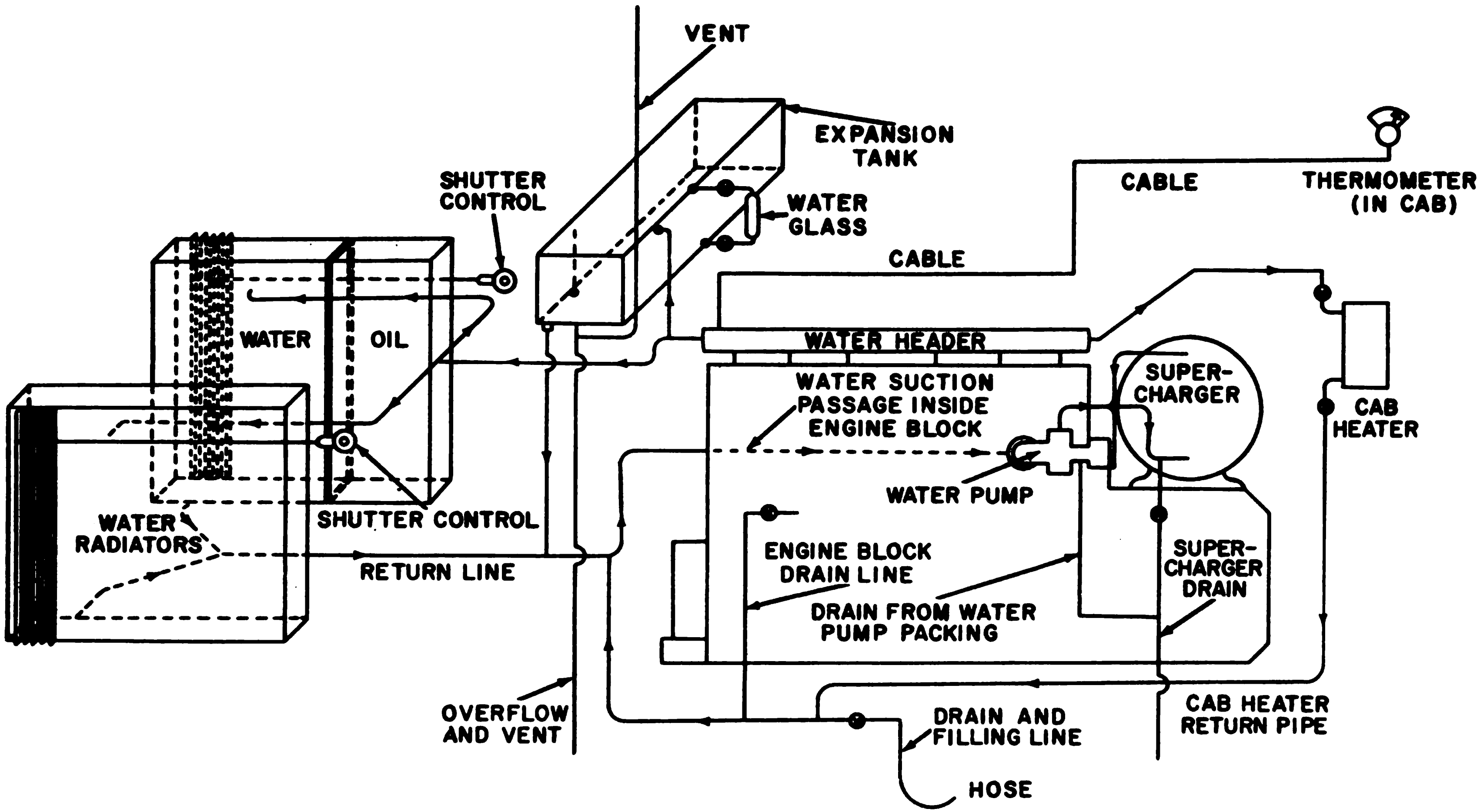


Figure 24. Water cooling system diagram.

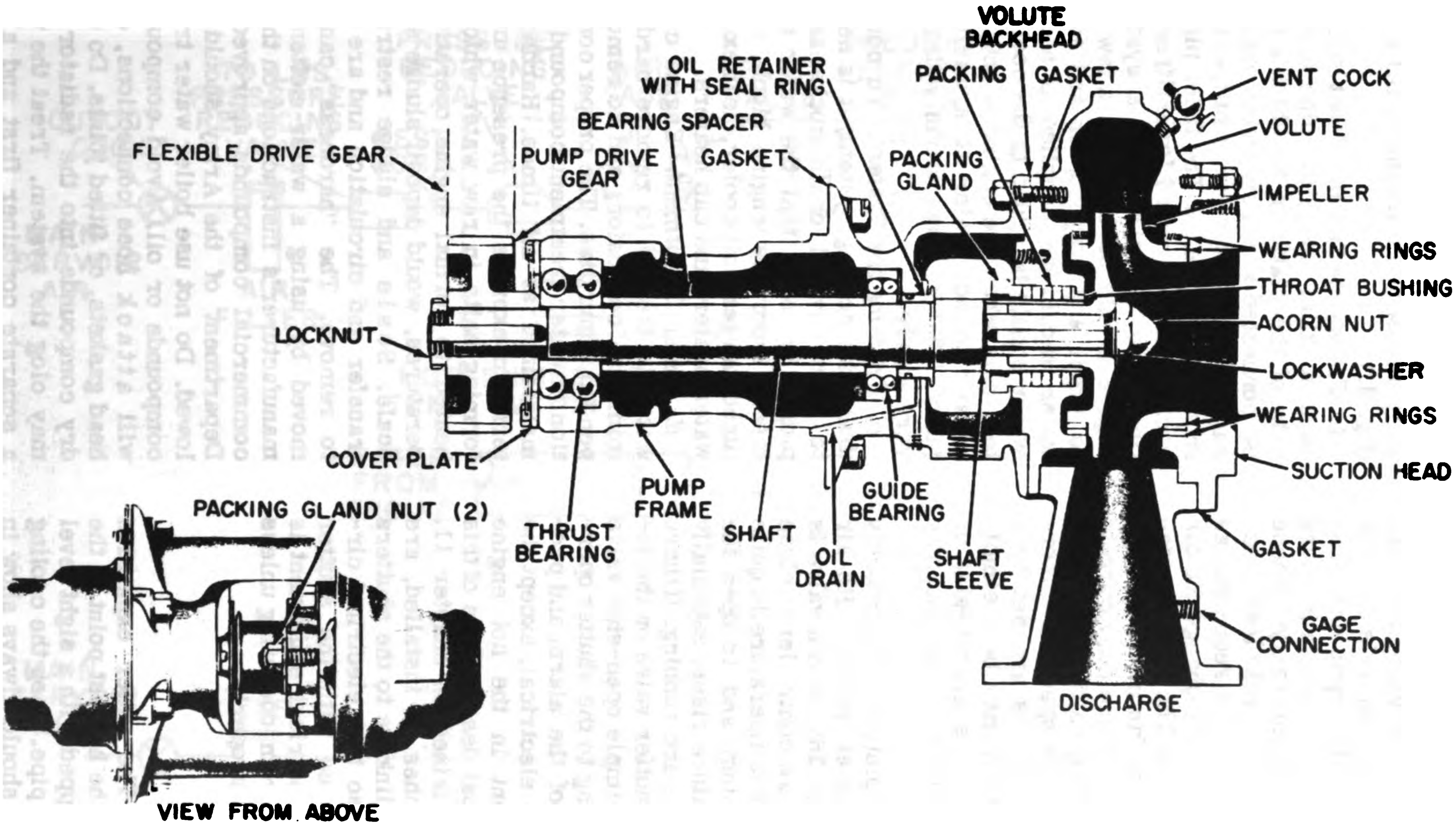


Figure 25. Centrifugal water pump.

system is described in the electrical section (para 90). Air for the pneumatic portion is supplied from the main air reservoir through reducing valves (fig. 26). A thermostatic air valve installed in the engine waterline controls the flow of air to other pneumatic equipment. The temperature controller as shown in figure 26 is a group of pneumatic relays. These relays can be set to open and close electrical switches in a definite sequence, as variations in temperature change the air pressure on the relays. The switches determine the setting of fan motor contactors, or of resistance in the eddy current clutch field, according to design. These settings determine the speed of motor-driven fans. The shutters are set by a shutter operator which may be a simple enclosed air piston or a grad-u-stat or grad-u-motor which has regulatory features.

c. A simple air piston will probably have a shutter magnet valve in its air line (not shown in fig. 26). Such a valve is set by the temperature controller to close the shutters if water temperature is quite low (fans not running) and to open the shutters as temperature rises, especially anytime that the fans are running. If there is a manually set shutter valve on the locomotive, it is a simple open-shut valve in the air line leading to the shutter operator. All portions of the alarm and protective features are electrical, except the temperature element in the hot engine switch. The electrical descriptions of this equipment are contained in chapter 11. Shutter limit switches, if installed, are set by mechanical linkage to the shutters and are arranged so that electrical circuits are interlocked with the shutter position. Certain electrical equipment is thereby prevented from operating unless the shutters are set properly.

33. Water Supply

a. Water Level. The water expansion tank is located at the highest point in the system and is equipped with a sight level glass and overflow pipe. Keep the cooling system full. Water should always show in the sight glass. If leaks in the water system are suspected, the engineman must endeavor to locate them while the engine is warm and report such leaks on the daily inspection worksheet, DD Form 862 (fig. 81).

b. Filling the System. Most locomotives have a filler overflow pipe under each side of the platform to which a hose can be connected to supply water under pressure. When the system is full, water flows from the other side. The filler pipe on the roof is generally used for antifreeze solutions only. After refilling a system, the engine should be operated a few minutes to expel any trapped air and additional water should be supplied if necessary. Water should be added to the cooling system only when the engine is cool. If necessary to add water to a warm engine (above 120° F.), use warm water or add very slowly.

c. Draining the System. To completely drain the cooling system, it is necessary to open several drain cocks and drain plugs. Be sure that the water can flow freely from the engine block, radiator, turbocharger, oil cooler, heat exchanger, water heater, and cab heaters.

d. Water Treatment. Engine cooling water is treated to remove hardness, to minimize corrosion, and to remove suspended impurities. The proper concentration of water treatment compound must be maintained at all times. Hardness is a term to express the presence of scale-forming salts in raw water which, when heated to normal engine operating temperatures, would deposit sludge and form scale. Scale and sludge restrict heat transfer and circulation and are difficult to remove. The "hardness" can be removed by using a water softener. The manufacturer's instructions on the use of commercial compounds approved by the Department of the Army should be followed. Do not use boiler water treatment compounds or oil. Avoid compounds that will attack hose connections, cylinder head gaskets, or fitted joints. Do not pour dry compounds into the radiator as they may clog the system. Treat the water in a separate container first and allow any

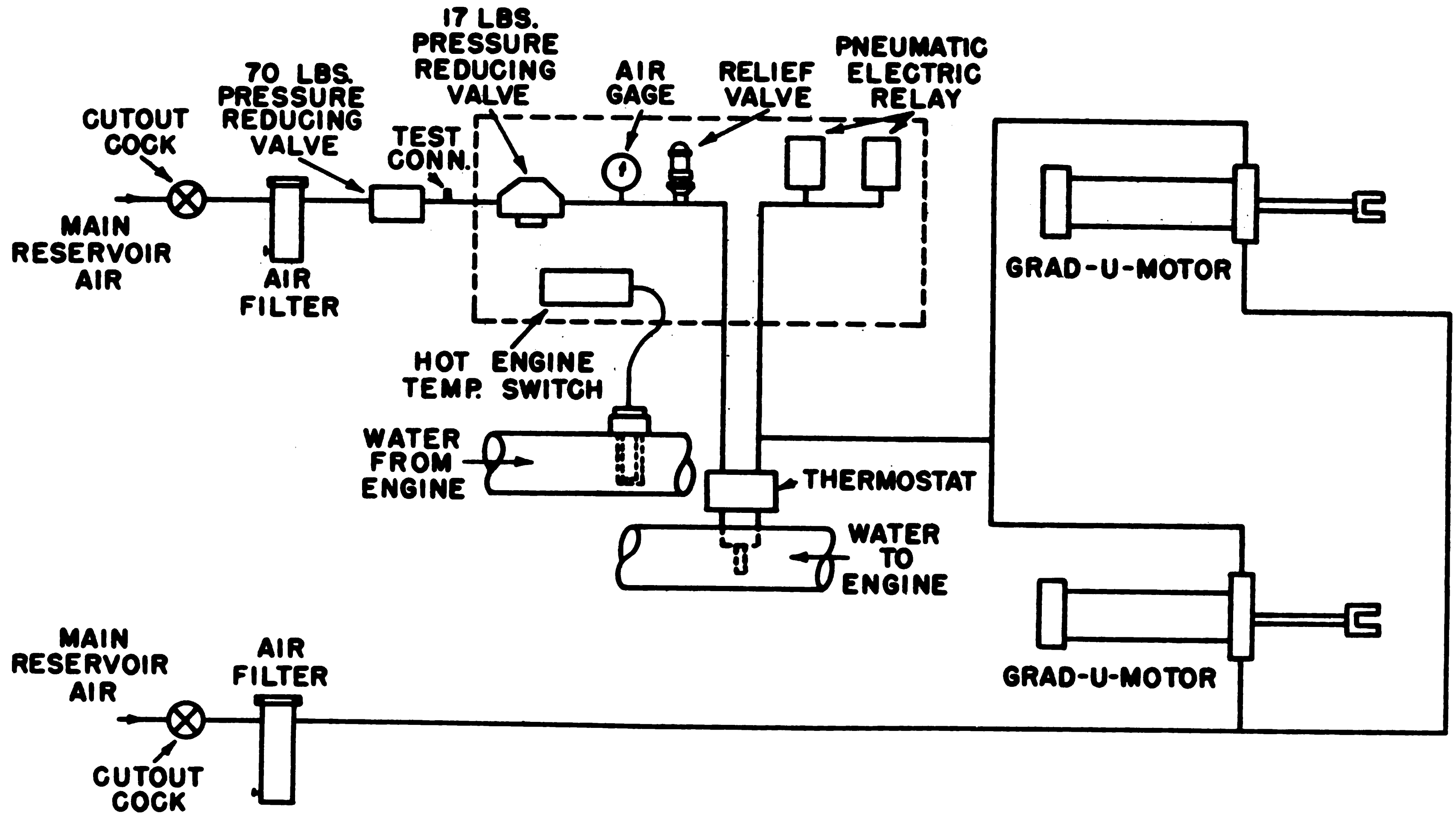


Figure 26. Schematic temperature control diagram.

solids to settle before drawing solution off for the engine. Improper or ineffective treatment will result in clogged radiators and water jackets or corroded cylinder liners.

Caution: Treatment compounds should not be allowed to come in contact with the human body. Strong alkali may cause skin eruptions. Wash off promptly if accidentally spilled on the person.

34. Cold Weather Precautions

During layover periods in freezing weather, the engine cooling water should be heated, drained, or antifreeze added to it. Steam from an external source can be admitted through the filler pipe (or a special steam admission line when so equipped) or the water can be heated by separate oil or electric water heaters. Check the amount of water treatment in the water after heating with steam, because the solution will be weakened. Running the engine at idling speed during reasonable periods of layover is an acceptable method of preventing frozen water systems. Antifreeze solutions should be used only when approved by competent authority and then with allowable mixtures of inhibitors.

CHAPTER 7
GOVERNOR

35. General

The purpose of the governor is to regulate the speed of the engine in accordance with the various throttle settings. As the throttle is moved through its various positions, the governor adjusts to and maintains the engine speed in each position regardless of load. The governor also provides emergency engine shutdown protection. Engine Speed in a diesel engine is regulated by the amount of fuel injected, which is controlled by the operation of the fuel injection pumps. The engine is able to deliver power in proportion to the amount of fuel introduced into the cylinders. When the load decreases, the fuel injected is more than sufficient to deliver the needed power, and the engine will speed up until the governor acts to reduce the fuel injection. When the load increases, there is a tendency for the engine to slow down until the governor permits an increase in fuel injection. The sensitivity of the governor is determined by the amount of speed change the governor is required to make to take corrective action. A governor that is too sensitive will hunt, which carries the governor beyond the proper position. This will result in an alternate excess and deficiency in fuel injection as the governor seeks the exact position for the existing load. Stability is attained by a compensating system which prevents hunting and minimizes speed changes after the load changes. Two views of governors appear in figures 27 and 28.

36. Types of Governors

a. Governors are usually controlled from the throttle by an electropneumatic, electrohydraulic, or pneumatic-hydraulic mechanism. Some locomotives, especially small industrial locomotives which are not equipped for multiple-unit operation, have a direct mechanical linkage between the throttle and the governor control shaft. Governors on all these installations have four essential portions which are similar, namely—the oil supply, the speed control column, the power piston, and a compensating mechanism. Figure 29 is a cross section of a typical hydraulic governor and is shown schematically.

(1) The oil supply is a self-contained system consisting of a storage tank, rotary gear pump, ball check valves, and pressure equalizer piston. The oil comprises the hydraulic medium of the governor and it also acts as a lubricant for the moving parts.

(2) The speed control column consists of ball head flyweights and a related pilot valve plunger whose position is determined by the rotating flyweights. The plunger controls the supply of oil which actuates the power piston.

(3) The power piston supplies the force to move the injector control racks (through injector linkage), thereby determining the amount of fuel injected into the cylinders.

(4) The compensating mechanism prevents the engine from racing or hunting by stopping the movement of the power piston after it has traveled a sufficient amount to bring the speed to normal for the specific throttle setting.

b. Speed control connections from electropneumatic and electrohydraulic governors extend from solenoids within the governor through a cable and conduit to an electric throttle. From pneumatic-type governors an air line is connected to an actuator which responds to throttle settings. In each case, the action of a conventional flyball assembly, as in *a*(2) above, is regulated by the changed compression of the speeder spring as the solenoids, or the actuator shafts, respond to throttle settings. The throttle does not at any time move the fuel control rack directly.

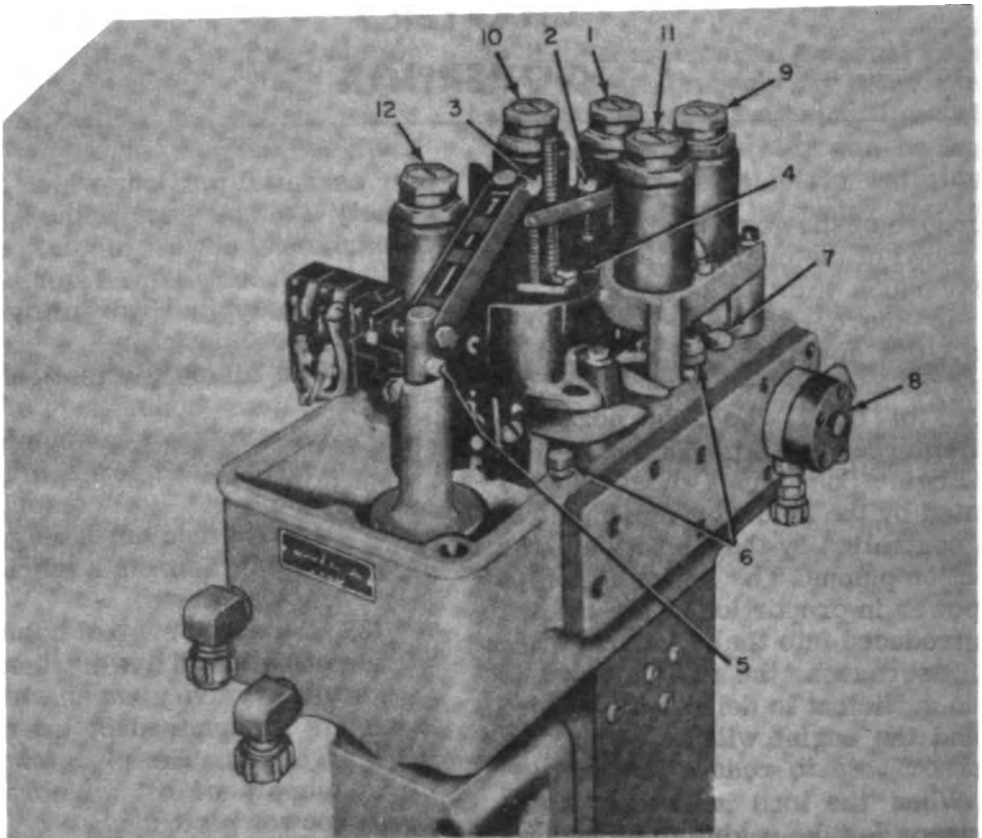


Figure 27. Electrohydraulic governor.

c. Engine stop control is built into electrically controlled governors by a solenoid whose pull, when energized, is opposite to that of the other solenoids. When this is the only solenoid that is energized, the fuel control shaft is automatically moved to a position that shuts off the fuel supply. This particular solenoid, in conjunction with the other solenoids in the governor, makes possible a large combination of speed settings as the throttle is advanced, and functions as a shutdown solenoid only when it alone is energized in the STOP position of the throttle. Governors are also equipped with a manual shutdown plunger which may be pushed by hand to stop the engine.

d. Oil pressure shutdown is built into the governor in some instances to protect against failure in maintaining oil pressure. An oil line from the engine lubricating system to the shutdown mechanism of the governor normally transmits engine lubricating oil pressure to the governor, which is then free to respond to the throttle in a normal manner. If the engine oil pressure is too low, a shutdown piston in the governor moves the power piston and fuel control shaft to shut off fuel and stop the engine.

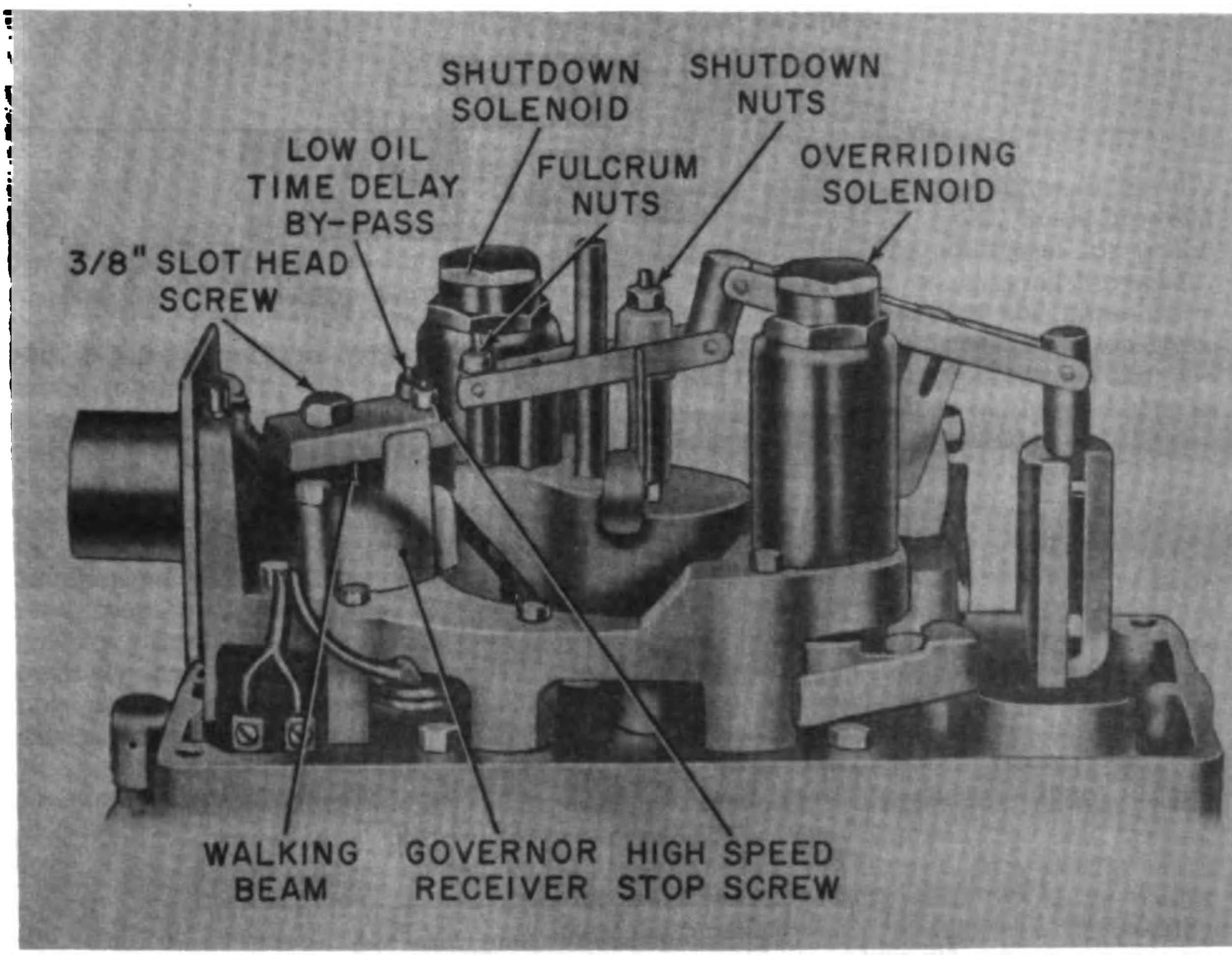


Figure 28. Pneumatic-hydraulic governor.

37. Operation

Governor linkages have many adjustments which should be studied in specific governor bulletins when detailed information is required. Oil should show in the upper sight glass at all times. The oil supplied to the governor must be of the proper weight and possess nonfoaming qualities. Care must be taken when adding oil to prevent the entrance of dirt or other foreign matter.

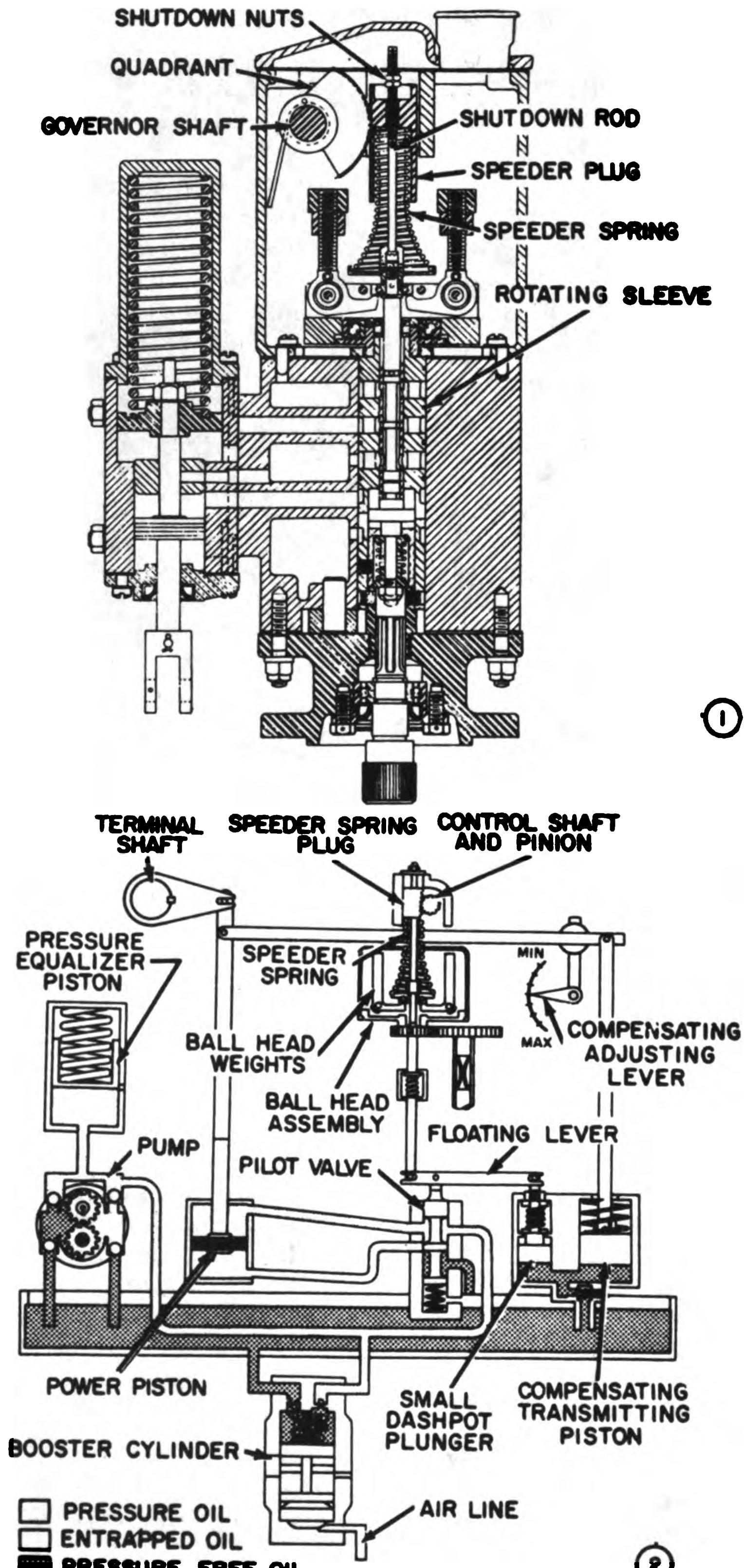


Figure 29. Cross section view of governor.

CHAPTER 8
ENGINE AIR INTAKE

38. General

A diesel engine must have an adequate supply of air in order to burn the fuel completely. A full charge of fresh air is drawn into each cylinder during each cycle. If air enters the cylinders at atmospheric pressure, the engine is described as normally aspirated or nonsupercharged. If air is supplied at a pressure greater than atmospheric pressure and maintained until compression begins, the engine is said to be supercharged. This pressure increase varies from 2 to 14 pounds. By forcing more air into the cylinder, a correspondingly greater amount of fuel can be burned and an engine of a given size can do more work.

39. Air Intake Filters

A diesel engine must have clean air for efficient operation. Dust is an abrasive and will cause excessive wear of liners, rings, and other parts. Air that enters the engine air intake system passes through air filters to remove dust and dirt. Although there are many types of air filters, they are generally made of finely shredded metal or fine wire screening which is kept coated with a film of oil to collect the dust. Filters do their work effectively only as long as they can pass clean air freely to the engine. They must be carefully cleaned and oiled at regular intervals as described in maintenance portions of this manual.

40. Types of Superchargers

Superchargers may be positive-displacement blowers or centrifugal blowers. They may be mechanically driven by the engine, or they may be turbine driven by the energy from the exhaust gases of the engine. The latter type is called a turbocharger. The speed of a turbocharger varies with the quantity of exhaust gas, which results in a maximum delivery of air when the engine is heavily loaded and needs it most. Some blowers are used to provide additional air to the engine for forced scavenging purposes. Such a blower operates the same as a blower used for supercharging. However, at the time the compression stroke begins, the air pressure in the cylinder is back to atmospheric pressure.

41. Construction of Blowers and Turbochargers

a. A blower consisting of a pair of two- or three-lobed rotors revolving in a closely fitted housing supplies a large volume of air at low pressure (figs. 30 and 31). The housing may be attached to the engine box or it may deliver air through a manifold. Large blowers of this type are normally gear driven by the engine; small ones may be belt driven. Each rotor is pressed on a tubular steel shaft. The engine ends of these shafts form journals which turn in bearing blocks at the blower end plate. At the other end, flanged hubs with a serrated bore are pressed on serrated shafts to provide rugged structural relationship of rotors and gears. These hubs serve as bearing journals. All bearings are pressure lubricated through drilled passages in the blower end plates. The rotor gears are lubricated by maintaining a reservoir of oil which permits the teeth to dip into oil as they turn. Oil seals are fitted in the end plates to prevent leakage.

b. The turbocharger consists of a centrifugal blower driven by an exhaust gas turbine (figs. 32 and 33). Both blower and turbine are mounted on a common rotor shaft and separated by a water-cooled diaphragm. The exhaust gases are conveyed through multiple manifolds to the turbocharger casing at the end of the engine. After passing through the turbine, they are discharged to the atmosphere.

(1) The blower casing is divided at the centerline of the shaft into

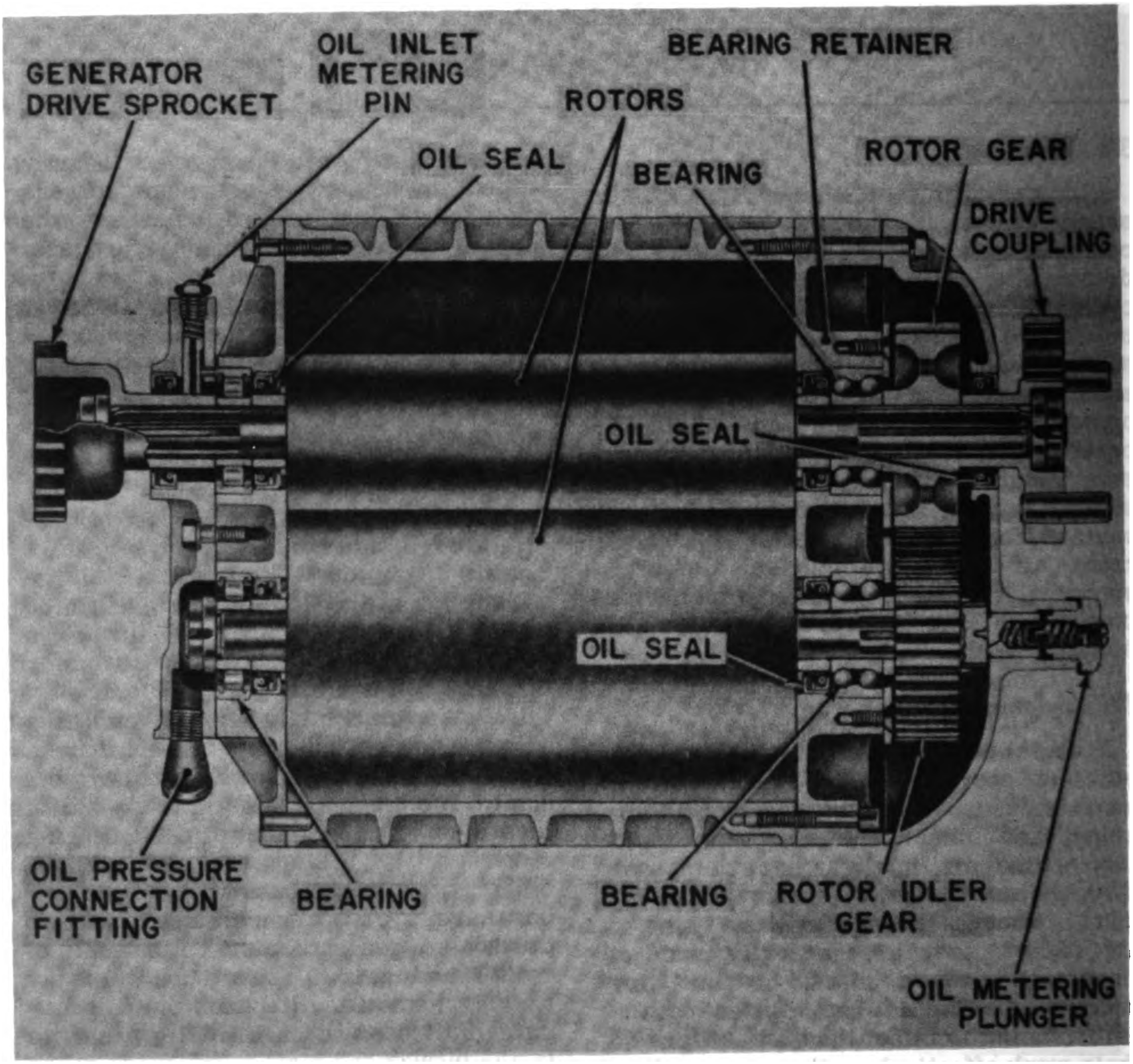


Figure 30. Cross section of blower.

upper and lower halves. The casing is securely bolted to the other parts of the turbocharger housing. One of the two rotor shaft bearings is carried in a housing mounted in the blower casing. The impeller is housed in a suitably shaped space in the blower casing and the outer rim of the impeller is surrounded by the stationary bladed diffuser. Axially converging entrance passages surround the bearing housing. The air flows from these passages into the impeller and is discharged from the impeller to the diffuser. The blades in the diffuser are shaped to decrease the velocity of the air and at the same time increase its pressure. The air discharged radially from the diffuser is collected in a spiral chamber and delivered to the air manifold of the engine through a connecting pipe. Some engines are fitted with cover plates for the turbocharger

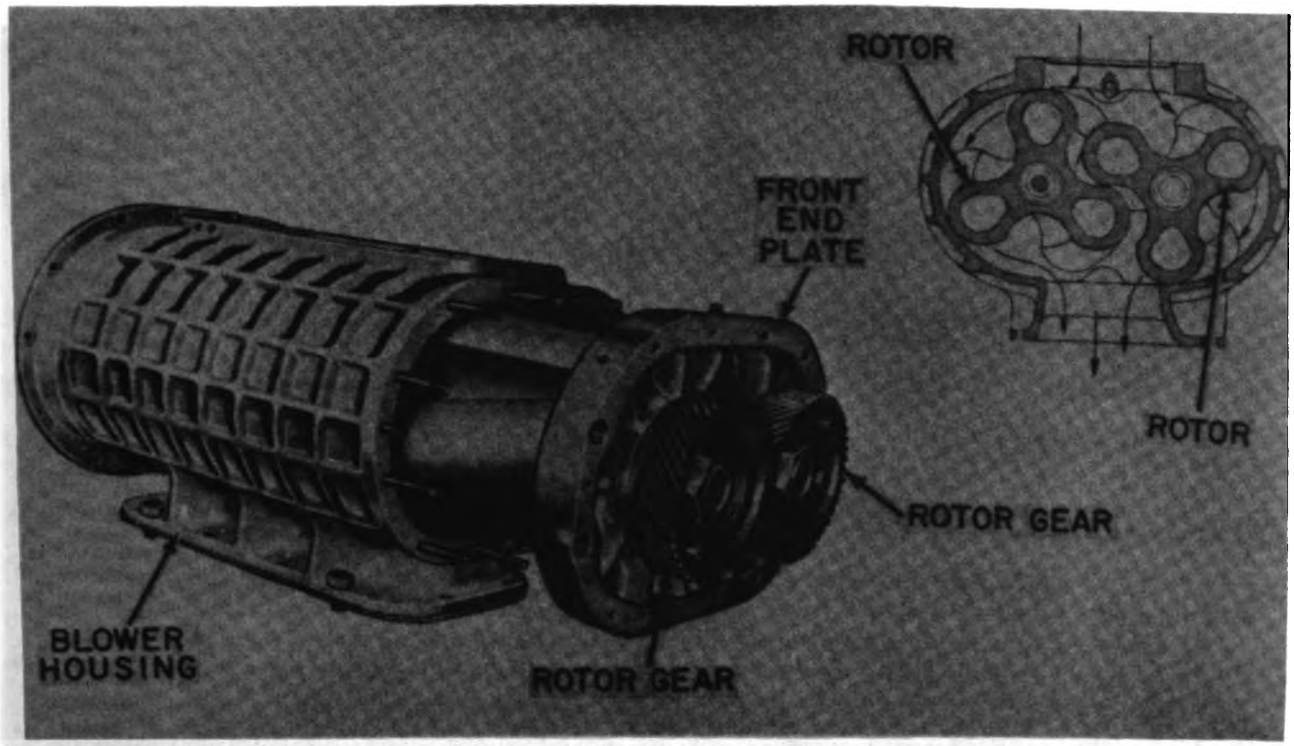


Figure 31. Blower.

air intake filters in order to block off the outside air when, in colder weather (below 40° F.) it is advantageous to use the warmer engine-room air.

(2) The central portion of the turbocharger is made up of two castings with the dividing line on the horizontal shaft centerline. The lower half has an integrally cast foot for mounting the entire assembly on its foundation. A large opening in the upper half provides the connection to the exhaust stack. On the exhaust side, a nozzle ring is mounted on the exhaust casing which serves to direct the exhaust gases against the turbine blades at the proper angle. The turbine blades rotate within the rim of the nozzle ring. Gas from the nozzle ring flows across the blades and leaves the blades in an axial direction. The collection and discharge chamber, which is part of this central portion, is provided with water-cooled walls throughout.

(3) The turbine consists of a forged-steel, one-piece shaft mounted in bearings at each end. The air impeller, described in (1) above, is fitted near one end of the shaft. The turbine rotor is a large integral flange near the other end of the shaft in which the turbine blades are fitted and locked. A lashing wire passes through a hole in each blade and is silver soldered in place. The wire is made in several lengths so that groups of 3, 4, or 5 blades are independent of adjacent groups. The turbine nozzle ring is divided at the horizontal centerline and has a flange on the exhaust inlet casing side which fits into a counterbore in the intermediate casing. There is a small clearance between this flange and the exhaust casing. There are two separate nozzles in this assembly which are independently connected to the upper and lower exhaust manifolds and extend into the passages in the exhaust inlet casing. In each of the

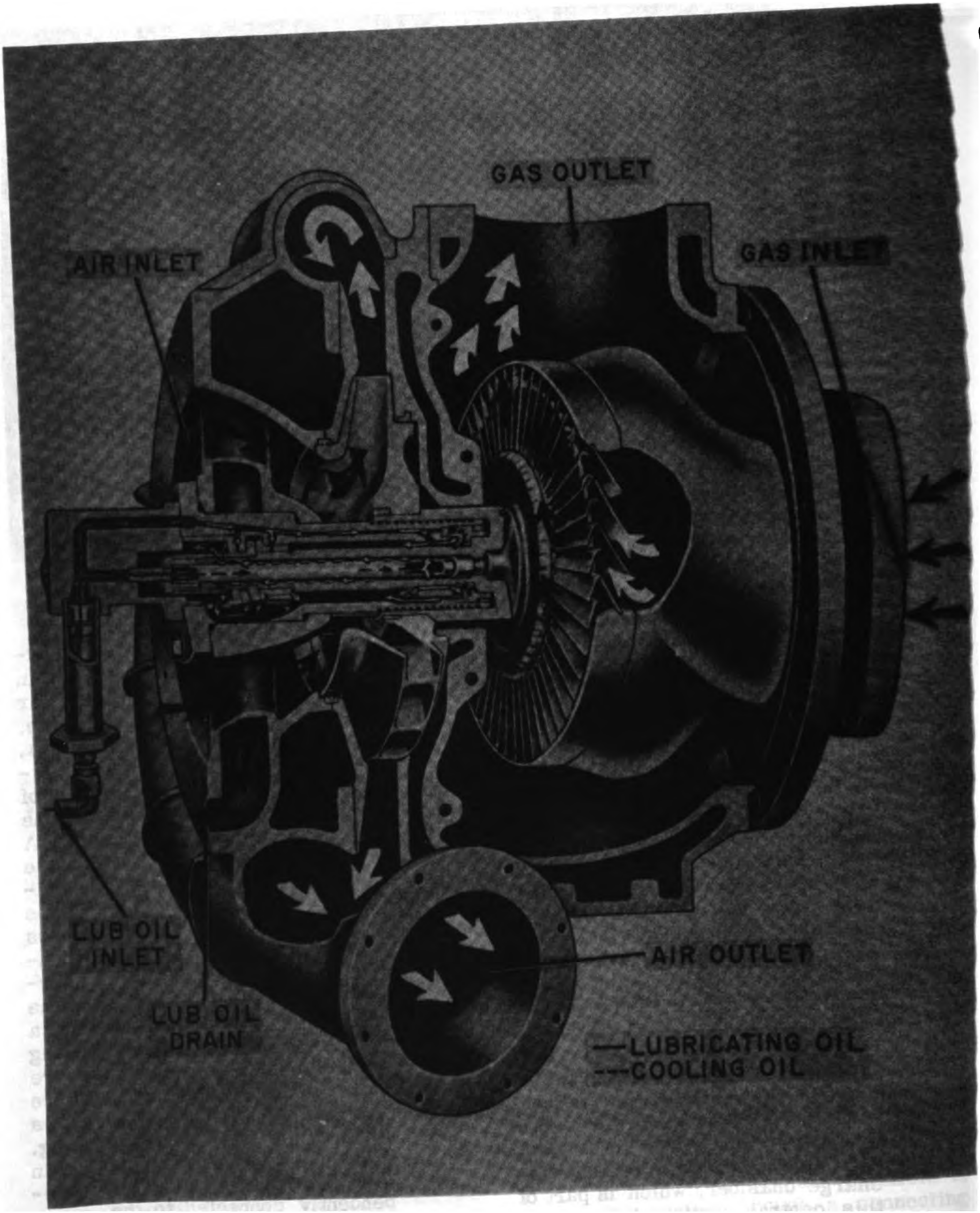
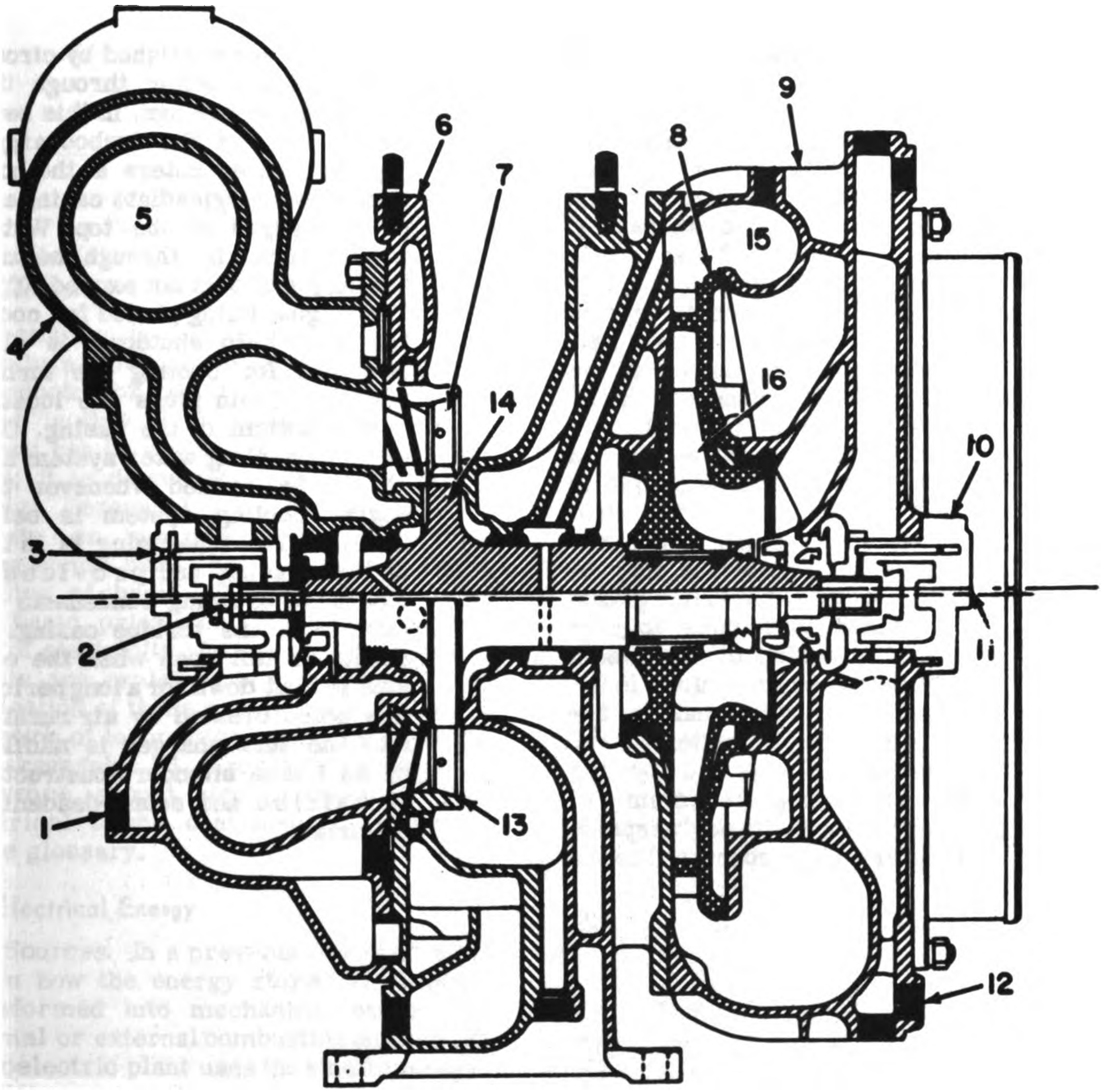


Figure 32. Turbocharger.



1 LUB OIL OUTLET
2 TURBINE END BEARING
3 LUB OIL INLET
4 EXHAUST INLET CASING
5 EXHAUST INLET
6 INTERMEDIATE CASING
7 TURBINE
8 BLOWER DIFFUSER
9 BLOWER CASING
10 BLOWER END BEARING
11 LUB OIL INLET
12 LUB OIL OUTLET
13 TURBINE NOZZLE RING
14 ROTOR SHAFT
15 AIR OUTLET
16 BLOWER IMPELLER

Figure 33. Cross section view of turbocharger.

nozzle ports, there are eight cast-in-steel vanes.

(4) The exhaust inlet casing is provided with suitable passages for conducting the exhaust gases from the manifolds to the nozzle ring. It is made of cast iron and is water jacketed. In assembly, the casing halves are bolted together at the horizontal centerline and also to the intermediate casing. The exhaust end shaft bearing is carried in a housing mounted in this casing. The rotor is carried at both ends by sleeve bearings. The bearing at the turbine end is a combined supporting and thrust bearing for fixing the axial position of the shaft. The bearing at the blower end is arranged to allow free expansion of the shaft by heat. The journals are hardened steel sleeves which may be readily replaced. Labyrinth glands are provided throughout to prevent contamination by the gases. End bearings are machined in the form of a bushing, making replacement a simple matter.

(5) Lubrication is supplied by the engine lubricating oil system. Oil pressure varies with engine speed. A pressure gage connected to the turbocharger oil line is installed in the cab and should be observed periodically as a check on normal operation.

(6) Cooling is accomplished by circulating engine water through the turbocharger casings. In this sectional view of the turbocharger (fig. 33), water enters at the bottom of the intermediate casing and is discharged at the top. Water temperature rise through the turbocharger should not exceed 30° F. The engine idling period for cooling prior to shutdown is also essential for cooling the turbocharger. Drain plugs are located at the bottom of the casing. One is in the cooling water system and should be opened whenever the engine cooling system is being drained. The other plug is in the turbine casing and provides a means of draining condensate or rain from the turbine casing. It should be left open when the engine is shut down for a long period. The noise created by air rushing into the turbocharger is muffled by an intake silencer constructed of baffles and sound-deadening material.

PART THREE

ELECTRICAL SYSTEM

CHAPTER 9

ELECTRICAL FUNDAMENTALS

Section I. ELEMENTARY ELECTRICITY

42. General

Electricity is a form of energy. It is actually a movement of electrons through a conductor or, as it is most commonly called "a flow of current." This flow of current can be utilized to perform various tasks; it is discussed in following paragraphs. Personnel who are required to operate or maintain diesel-electric locomotives must have a good understanding of basic electrical principles. The basic principles which govern the flow of electricity and its related magnetic effects are explained in this section. The application of these principles in the construction of locomotive equipment appears in paragraphs 55 through 65. Frequent reference should also be made to the electrical terms contained in section II of the glossary.

43. Electrical Energy

a. Sources. In a previous chapter it was shown how the energy stored in fuels is transformed into mechanical energy by internal or external combustion engines. A hydroelectric plant uses the kinetic energy of falling water. Modern power systems are chiefly concerned with the conversion of such mechanical energy to electrical energy. Electricity may be obtained by chemical action, as in a dry cell, but the quantity is small. Electricity from a storage battery is not entirely chemical in origin since the battery is charged by power from mechanically driven generators. The type of mechanical energy chosen to drive a generator depends largely upon the engine or prime mover. Such factors as fuels, economic operation, and space limitations must be considered. In the diesel-electric locomotive, as the name implies, electrical energy is produced by a generator driven from the diesel engine.

b. Uses of Electrical Energy. Electrical energy may be used to supply heat, as in welding equipment, domestic cooking, and hot water heaters. It may be used to supply light, to operate communication equipment, to energize magnets for small relays and control apparatus, in electrolytic processes such as the manufacture of aluminum, and for many other purposes. But, the most familiar use of large quantities of electric power is to drive machinery by means of motors.

44. Electrical Circuits

a. General. The ease with which electrical energy can be distributed in large or small quantities over long or short distances is one of the advantages of electrical systems. Since energy can seldom be harnessed at its source and mechanical transmissions are limited in size, extent, and flexibility, the transfer of electrical energy finds many applications. To visualize the transfer or distribution of anything, it is necessary to know what is moved, over what path it is moved, and what moves it. Then, further questions naturally arise concerning how much is moved, how big a path is required, and what forces are involved.

b. Comparisons. A few simple comparisons with familiar items having a close resemblance to electricity will assist the reader. The big difficulty is that electricity cannot be seen or gathered and the speed at which the energy travels baffles the imagination. The mystery may be largely removed by recognizing the similarity between a hydraulic system and an electric system. Remember, electricity is defined as a form of energy. An elementary transfer of energy can be demonstrated by applying enough energy longitudinally a the end of a stick of wood to move it. Th other end moves at once and any work done at the far end is equal to the work done at the near end less the work done on the stick itself. This basic fact applies to the system illustrated in figure 34. The path of the water system (pipe) is obvious and compares to the wires of an electrical system. The path, or group of interconnected paths, through which energy is transmitted in an electrical system, is called a circuit. The energy supplied by the pump and absorbed by the water turbine compares with the energy supplied by the generator (or any other electrical source) and absorbed by the motor (or any other electrical use). It is evident that water moves in the hydraulic system but, like the stick mentioned previously, it does not move fast although the effect is quickly noticed throughout the system. In an electrical circuit, it has been demonstrated that electrons, or charged particles, move slowly (silver plating is a relatively slow process). However, the effect of the movement is quickly noticeable throughout the circuit. The arrangement of particles in the path (the conductor) is different when current is flowing than when no current is flowing. Scientists have described it as a haphazard versus an orderly arrangement of molecules. A military man might describe it as "at ease" versus "attention." The effect of a call to attention is quickly noticed throughout the ranks, although call-off progresses less rapidly.

c. Factors. Any attempt to describe the hydraulic circuit in figure 34 would have to be based on data giving the strength, size, and capacity of the system. The factors are reflected in working pressure, resistance to flow, and quantity transferred. Similar factors describe the electrical circuit.

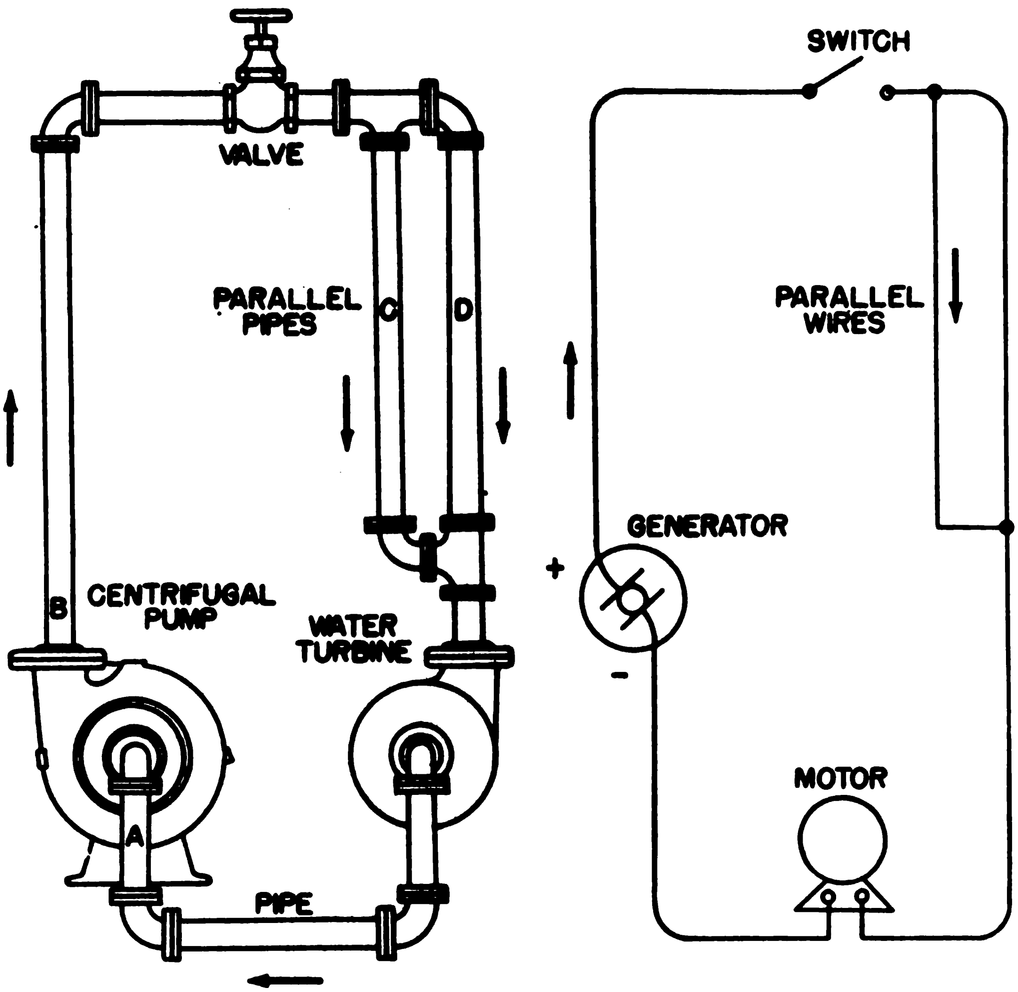
(1) The pressure supplied by the pump varies with its speed, size, and design. As the pressure increases, an increased amount of energy can be transferred within certain limits. If too much pressure is applied, the pipe is overloaded and bursts. The proper size of pipe must, therefore, be used for the particular pump to be used.

(2) Resistance of the flow of liquid varies with the size of the pipe. Even though an increased pressure will increase the flow within the pipe, the working range of each size has limits beyond which another size of pipe should be used.

(3) Quantity, or rate of flow, varies with both pressure and resistance (or size of pipe). It is measured in gallons per minute, or cubic feet per second, or some similar combination of volume and velocity, and any variation in either factor varies the amount of work, in a like manner.

d. Units of Measure. The above factors of pressure, resistance, and quantity in a hydraulic circuit act in like manner in an electrical circuit where they are called volts, ohms, and amperes, respectively. Scientists spent much time studying elementary electricity before they arrived at definite methods of measuring these factors. It will suffice here to say that all basic elements of energy and work in other systems exist and are measured in a like manner in electrical systems. This fact is of great significance when studying magnetic forces and electrical machinery later in this manual, because electrical energy is converted to mechanical energy by a combination of electrical and magnetic circuits.

e. Basic characteristics of electrical circuits frequently require the use and measurement of resistances of a millionth of an ohm, or a million ohms. Heavy cables and much power apparatus have little resistance, which is measured in millionths of an ohm. For convenience, a unit called the microhm is used to denote small resistances. Very high resistances are used in some electrical circuits, such as radio, and, for convenience, a unit called



HYDRAULIC POWER

FLOW THROUGH PIPES

FLOW LIMITED BY SIZE OF PIPES, TORQUE OF TURBINE
CIRCUIT IS OPENED OR CLOSED BY VALVE

ELECTRIC POWER

FLOW THROUGH WIRES

FLOW LIMITED BY SIZE OF WIRE, TORQUE OF MOTOR
CIRCUIT IS OPENED OR CLOSED BY SWITCH

Figure 34. Similarity between hydraulic and electric systems.

the megohm is used to denote 1,000,000 ohms. The series of commonly used prefixes denoting large and small units of current, resistance, voltage, etc., are—

Mego—denotes -------- 1,000,000
Kilo—denotes ----------- 1,000
Centi—denotes ----------- 1/100
Milli—denotes ----------1/1,000
Micro—denotes ------ 1/1,000,000

45. Current

An ampere is the rate (or intensity) of flow of electric current. The magnetic field set up by a current flowing in a wire at right angles to another magnetic field (as at the end of a magnet) will create a force giving the wire a side thrust. The relationship between current and force is definite, but difficult to measure accurately. The measure agreed upon after many years of experiment is that an ampere is that flow of unvarying current which will deposit a specific weight of silver from a standard silver nitrate solution under standard prescribed conditions in one second. Standards of instrumentation are based on such basic facts but the chief importance of the ampere to the power electrician lies in the measure of power. When an electromotive force causes current to flow in any portion of a simple series circuit, the same current flows through all portions of the circuit. In a parallel circuit of several branches, the sum of the current in all branches equals the total current supplied by the electromotive force (emf).

46. Resistance

Some materials carry electric current easily, while other materials offer much more resistance to the flow of current. Those which carry current easily are called conductors. All conductors offer some resistance to the flow of electricity similar to the resistance of friction which restricts the flow of fluid in a pipe system. The resistance depends on the material of which the conductor is made, the length of conductor, its size or cross section area, and several minor factors such as temperature. To measure the resistance, an electrical unit known as an ohm is used. An ohm is a unit of resistance which allows one ampere of current to flow when one volt is applied to its terminals. Scientists who must establish definite standards of measurement for these important units have defined the ohm as "the resistance of a column of mercury of a specified length, cross section, mass and temperature." Resistance is a physical part of the circuit and is changed only by physical changes in the circuit. Any increase in resistance decreases the current because the voltage or pressure has greater obstacles to overcome. Any decrease in resistance increases the current.

47. Voltage

Voltage has just been described as the pressure that forces current through a circuit. In a hydraulic system, no fluid flows unless there is a pressure to move it. The same is true in an electrical system. An electrical generator or a battery is the device which supplies the pressure, which is often called the potential difference of emf. When there is no potential difference, no current will flow. The potential drop through the circuit equals the emf applied to the circuit. Scientists have established a standard reference for a volt as the emf of a Weston cell (of standard construction and temperature), but the units of current and resistance described above are more readily produced and maintained. In practice, a volt is more readily defined as a "potential difference that will cause one ampere to flow through a resistance of one ohm."

48. Insulators

Materials which offer very great resistance to the flow of current are called insulators. There is no perfect conductor or perfect insulator, but there is a clear distinction between the two groups. In general, metals and carbon are good conductors while organic and vitreous substances such as rubber, oil, glass, and quartz are poor conductors. The resistance of insulators is expressed in megohms and is measured by an instrument called a megger. This instrument is used in routine shop inspections of locomotive circuits.

49. Ohm's Law

Ohm's law is one of the most commonly used fundamentals of electricity. It is essential to fully understand and remember the relationship which it establishes between the voltage, resistance, and amperage of a direct current circuit. It was discovered about 1827 by Georg Ohm, a German physicist. It states that in a simple closed circuit of fixed resistance, the current in the circuit is equal to the voltage divided by the resistance. (In alternating current circuits, the same factors exist, but must be studied in combination with additional new factors.) The cumbersome form of any written formula is simplified by adopting abbreviations or symbols to represent the factors in a circuit. Resistance is represented by R (the first letter of the word), voltage is represented by E (the first letter of electromotive force), and current is represented by I (the first letter of intensity of flow).

Note. Selection of symbols is naturally limited due to the use of certain letters for other factors of more complex circuits. The law as stated above can now be written—

$$I = \frac{E}{R}$$

This formula can be expressed in three possible arrangements, all of which conform to basic transformation in mathematics. They are—

$$I = \frac{E}{R}$$

or the current in the circuit equals the voltage divided by the resistance.

$$R = \frac{E}{I}$$

or the resistance of the circuit equals the voltage divided by the current. E = RI or the voltage applied to the circuit equals the current multiplied by the resistance. Any factor of the circuit can be changed, so variations in statements of the law are —for a fixed resistance, current varies directly as the voltage; for a fixed voltage, current varies inversely as the resistance; for fixed current, voltage varies directly as the resistance. A graphic aid in memorizing Ohm's law appears in 1, figure 35. The symbols are arranged as shown in the left-hand circle. If any symbol is covered, the relative position of the other two symbols is identical with that in the formula. Thus, if I is covered, the position—

$$\frac{E}{R}$$

completes the formula given above for I. If R is covered, the position—

$$\frac{E}{I}$$

completes the formula for R. If E is covered, the position IR completes the formula for E. The same rule applies in using the power equation formula 2, figure 35—P = Power, E = Voltage, I = Current.

50. Power and Work

a. Power is the rate of doing work. When used to rate a machine, it is the capacity for doing work. Force tends to produce motion. Work is the result of an applied force which results in motion. The amount of work is the product of a force times the distance along which it moves, or Work = Distance x Force. Work is expressed as foot-pounds, while power is expressed as foot-pounds per second, or—

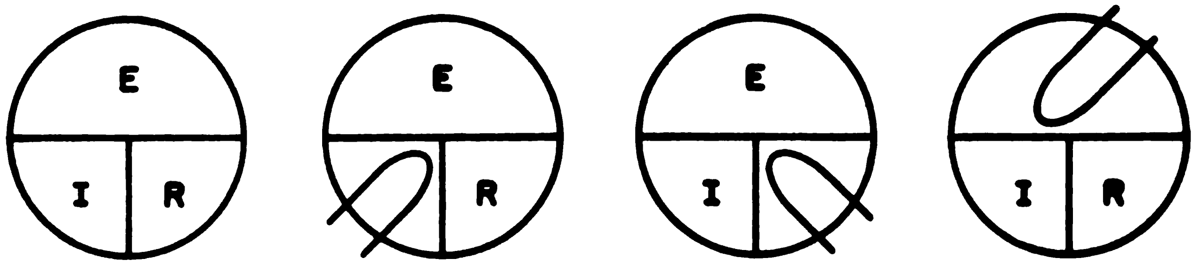
$$\text{Power} = \frac{\text{Distance x Force}}{\text{Time}} = \frac{\text{Work}}{\text{Time}}$$

In estimating the capacity of early steam engines, they were rated about equal to the horses they displaced. A strong horse could work for a short time at the rate of 33,000 foot-pounds per minute. Machines were then rated in horsepower on the basis of their work per minute divided by 33,000, or—

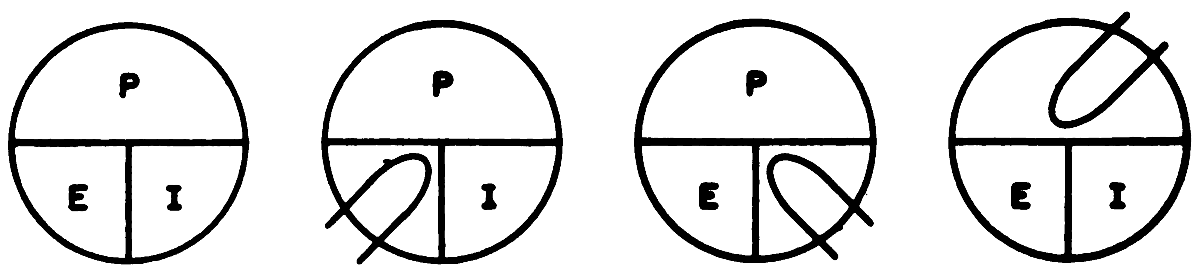
$$\text{Horsepower} = \frac{\text{Foot-pounds per minute}}{33{,}000}$$

Electrical power is the product of volts x amperes and the unit of power is known as the watt. If the output of a motor is measured by a Prony brake (absorption dynamometer), the work done in one revolution is Distance (circumference of the brake x Force), and the work done per minute is Distance x Force x Revolutions per minute. Since this can be readily expressed as horsepower, by the above formula, a definite relationship between watts and horsepower has been established. The relative values, which should be remembered, are: 1 Horsepower = 746 watts; 1 kilowatt (1,000 watts) = 1.34 horsepower.

b. Power and work are often confused and further simple illustrations are warranted to picture these units in the mind. The work done in raising 20 pounds of water 10 feet (in 1 and 2, fig. 36), is 200 foot-pounds. All work done on a body can be accounted for by an increase in its potential energy, an increase in its kinetic energy, or by the production of heat in opposing friction. Kinetic energy is the mechanical energy a body possesses because of its motion. Potential energy is that possessed because of its position. The potential energy of the water has increased by 200 foot-pounds. If, in 2, figure 36, the water is allowed to run down the pipe, its potential energy becomes kinetic (energy in motion) which can be harnessed by using the pump as a water wheel and the motor as a generator. Of course, this is a poor way to get water power. However, hydroelectric-power-generating plants work on this principle.



① OHM'S LAW.



② POWER EQUATION.

Figure 35. Ohm's law and power equation.

If a 2-pound horizontal force moves 100 feet in a cart on a level road (3, fig. 36), 200 foot-pounds of work are done, but neither the potential energy nor the kinetic energy of the water has changed and the work has all gone into heat of friction. If a 3-pound force is applied on a slant instead of a 2-pound force horizontally, the friction is merely increased and the additional force is dissipated as heat. Heat is energy if it can be harnessed, but it is often wasted if it is expended without performing work, whether the waste be muscular exertion or the exhaust from fuel combustion. If a train is driven at a constant speed on a level track, neither the kinetic energy nor potential energy changes and all the energy from the fuel is expended in overcoming friction. A locomotive running at a rate of 20 miles per hour indicates a certain amount of power is employed. The tractive effort is the force; therefore, in the second formula in a above, power would read as—

$$\frac{\text{Miles}}{\text{Hour}} \times \text{Tractive Effort}$$

But, no information is given concerning the distance traveled until power is multiplied by time. It makes no difference whether the train moves 10 miles in a half hour (a rate of 20 miles an hour) or in a quarter hour (a rate of 40 miles an hour). The amount of work done is the same, but it takes more power to do it at the faster rate. To apply the same reasoning to an electrical circuit, the watt (or kilowatt) is a measure of power or the capacity for work. Electrical energy is actually generated, used, and paid for on the basis of work performed. To measure this work, multiply power by time and the result is watt-hours, or for convenience, kilowatt-hours. This is expressed in symbols as P = EI. This can be transposed to show current —

$$I = \frac{P}{E}$$

or voltage as —

$$E = \frac{P}{I}$$

A memory aid similar to that for Ohm's law appears in 2, figure 35.

a. Power loss in a circuit is due to the resistance of the circuit and produces undesired heat, except in processes like a heater where power is put to work as heat. In a motor, the power input is distributed between mechanical work and heat losses. Mechanical work is the product of voltage and current where voltage is termed a back-emf, and is almost equal to the applied voltage. Heat loss can be expressed by the power formula, but to separate it clearly from the total power, the equivalent of E as expressed in Ohm's law is substituted in the power formula. P = EI then becomes P = RII, or more familiarly,

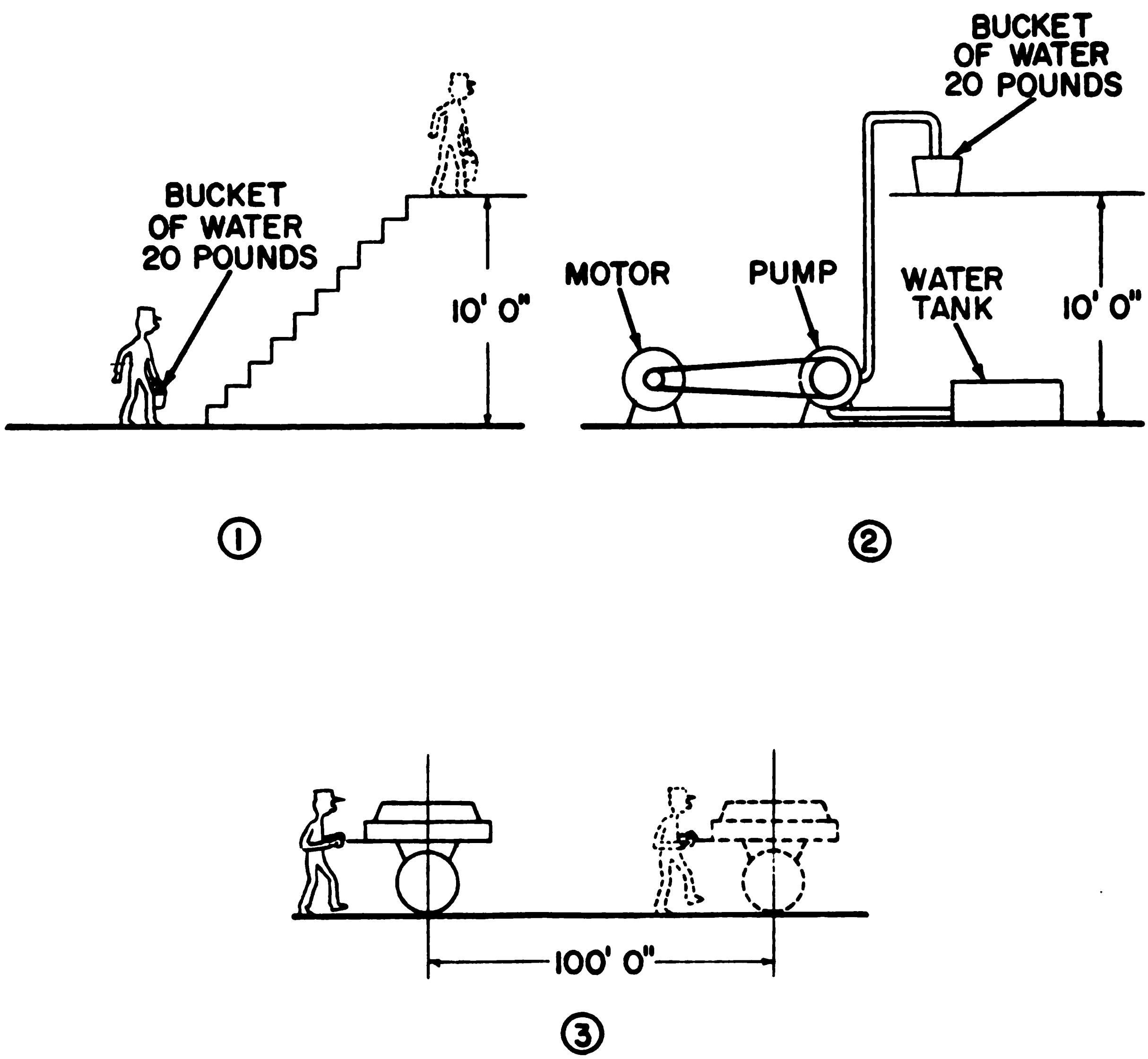


Figure 36. Illustration of work.

I^2R. The important fact in this formula is that heating increases as the square of the current. This characteristic should be clearly remembered in connection with load limits and traction motor blowers when they are discussed later. Another important loss from a generator to a motor is the line loss. Line loss not only produces undesired heat but decreases the delivered voltage. These factors are the responsibility of the designer (in contrast to motor overloads being the responsibility of the operator), but a knowledge of this factor is a part of basic electrical fundamentals. The voltage drop in a line is $E = RI$ where R is the resistance of a line, and I is the current. The power loss in a line is $P = I^2R$. See 1 and 2, figure 37, for typical meter circuits.

51. Magnetic Field

a. A conductor carrying current is surrounded by magnetic forces set up by the current. The space affected by these forces is called a magnetic field. Thus, a magnetic field is a region wherein magnetic forces act. A magnetic needle in a magnetic field takes a fixed position in line with these forces. The direction of the field can be traced by moving a compass through it because the compass needle will continually point along the lines of force. These lines form concentric circles around a freely suspended wire. On 1, 2, and 3, figure 38, the direction of the magnetic field is indicated by the arrows on the lines of force. A simple rule has been set up to find the direction of the magnetic field when the direction of the current is known. This rule is the right-hand rule for determining the direction of the magnetic field about a current-carrying conductor, and stated simply, is as follows: Grasp the conductor in the right hand with the thumb pointing in the direction of the current flow. The finger will point in the direction of the magnetic field (para 55*b*). The strength of the field has been found to increase as the current increases and to decrease as the distance from the wire increases. These lines of force are also called flux and their strength, as pictured by the number of lines in a given area, is called flux density. If the conductor carrying the current is turned into a coil, the strength of the field increases as the number of turns increases. Energy is necessary in setting up a field, but after the field is established no energy is required to maintain it at a constant strength. Additional current is needed to increase the strength of the field. If the strength of the field is decreased, energy is released and delivered back to the circuit as electrical energy. Therefore, changes in field produce a current. The change can take place by opening a simple circuit as just described or by any change in the position or strength of neighboring fields which are not electrically connected to the circuit and current being affected. The motor and generators are built on this principle which is described in detail in paragraphs 66 through 78.

b. Field, current, and forces or motion, therefore, constitute three related factors whose fundamental relationship should be clearly understood in order to understand power equipment. A coil with a current flowing through it in the direction shown in 1, figure 38, sets up a field in accord with the principles stated in *a* above. When the field of a coil is at angles to the lines of force in the field of an instrument, the coil will tend to turn and, if freely pivoted, will turn. Several laws or visual aids will be helpful in remembering this fact and determining the direction of motion.

(1) A conductor carrying current across a magnetic field tends to move at right angles to both the direction of the field and the direction of current.

(2) Currents through conductors which make an angle with each other produce fields which tend to force the conductors into parallel paths with their currents flowing in the same direction (4 and 5, fig. 38).

(3) Two coils carrying current tend to place themselves so that they will embrace the largest possible number of lines of force.

(4) There is no such thing as two different lines of force at a given

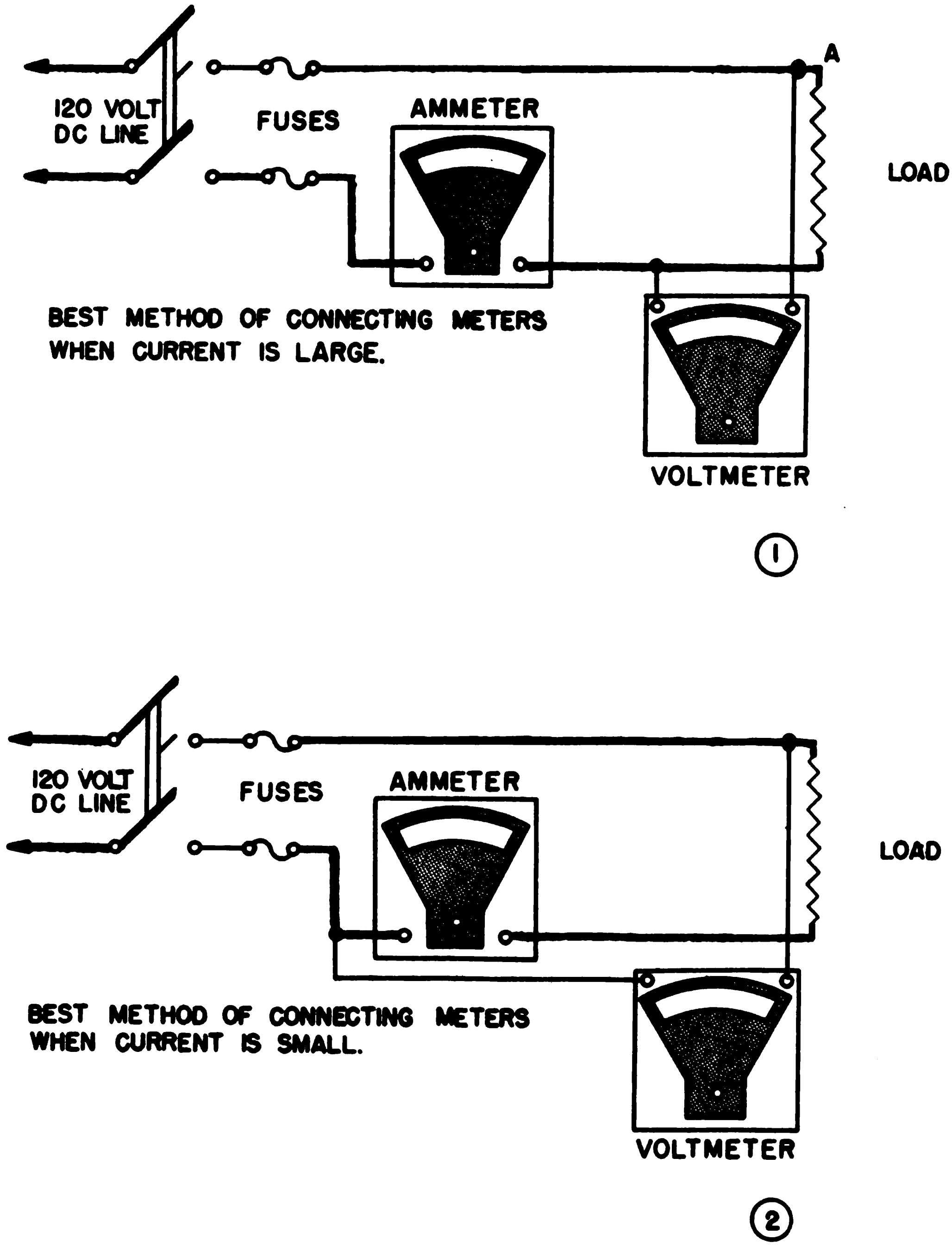
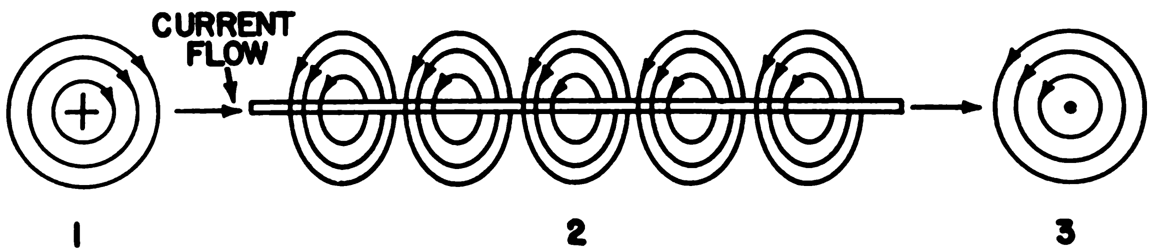
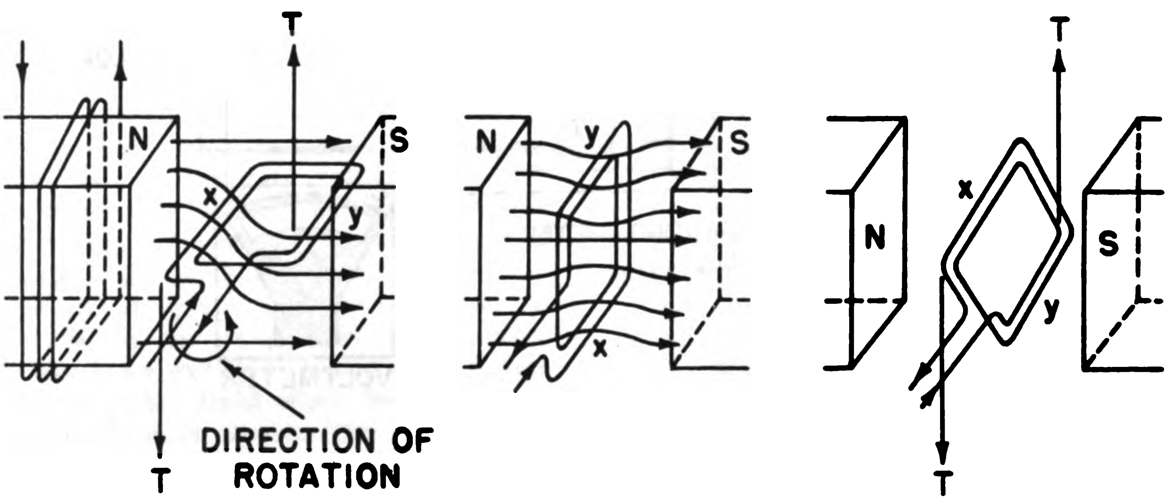


Figure 37. Typical meter circuits.

point because they merge into one resultant force. The densities and directions of these lines at different points around the movable coil may be likened to stretched rubber bands, which tend to strengthen and force the coil to turn in the direction indicated (T = torque). A conductor carrying current will always move from a strong magnetic field to a weak magnetic field. In 5, figure 38, is



MAGNETIC FIELD AROUND A CURRENT-CARRYING CONDUCTOR



4
RESULTANT
FIELD

5
COIL TURNED
TO NEUTRAL POINT

6
COIL AFTER
COMMUTATION

Figure 38. Actions of a loop in a magnetic field.

shown the final position of a freely-suspended coil under these conditions. In an instrument, the coil turns against a spring until such time as the force of the spring balances the turning torque of the coil. In a motor, the current reverses as soon as it passes the neutral point shown in 5, figure 38 (current flow out from X), and torque is in the direction shown in 6, figure 38. Another set of coils comes into the position shown in 4, figure 38, and the process is repeated again and again, causing rotation. If the coil is moved by an outside force, as in a generator, the same principles apply.

52. Direct Current Measuring Instruments

a. The principle on which most instruments operate is that a coil may so be placed in a magnetic field that the coil will turn when a current flows in it. The principles of the magnetic field are discussed in paragraph 51, and must be thoroughly understood in order to comprehend completely the construction of instruments, generators, motors, and other electrical equipment. This paragraph is concerned mainly with the use of instruments.

b. Current is measured with an ammeter. Since it measures a quantity of flow, it must be placed in the path, or circuit, like a watermeter. The total load current passes through it or its related shunt. No ammeter is complete without a shunt. A shunt is a bypass which carries most of the current and it must be carefully designed to work with the ammeter so that there is a definite relation between the current flowing through the shunt and the current flowing through the coil of the ammeter. If this were not done, the turning effort of the coil would be an uncertain quantity. When it is so designed, a pointer can be attached to the coil which turns against a carefully designed spring so that the deflection is proportional to the current. The dial over which the pointer swings can then be marked to read amperes, or quantity of current flowing. Unless the meter has zero at the middle of the dial which permits the pointer to swing in either direction, the positive and negative terminals must be connected in the corresponding directions in the circuit so the needle will not swing backward and be bent. The meter and its shunt have very low resistance and any voltage connected to it will result in a short circuit which burns out the instrument. Always connect an ammeter in the circuit in series with the load. When this is done, as shown in 2, figure 37, all the current through the load goes through the ammeter and nearly all the voltage from the source is applied to the load because the resistance and voltage drop of the ammeter are almost negligible.

c. Voltage is measured by a voltmeter. There is no difference in the principle of the moving coil in a voltmeter or ammeter. However, it must have a very high resistance in order to avoid short circuiting the voltage. Therefore, the coil is connected in series with this resistance and no shunt is permissible. This resistance is built into a voltmeter but it is often impractical to have an ammeter shunt built into an ammeter. Voltmeters are connected across the line or across the load, which is distinctly different from the connections for an ammeter. Since voltage has been likened to pressure, a voltmeter can be compared to a pressure gage. It should be noted that neither a voltmeter nor a pressure gage has anything to do with the main flow. A voltmeter must have its connections completed to the low voltage (pressure) side of the line. A significant difference in the appearance of voltmeters and ammeters is that ammeters have heavier terminals to which the wires are connected. The proper positive and negative connections are designated on voltmeters as well as ammeters.

d. Power has been shown to be the product of volts x amperes. Some care is necessary in order to obtain true values of voltage and current. Meters connected as shown in 1, figure 37, measure true voltage on the load, but the ammeter reads the sum of the current through the load and through the voltmeter. Meters connected as shown in 2, figure 37, measure true current through the load, but the voltmeter indicates the sum of the voltage across the load and the ammeter. The percentage of error depends on the refinements of the instruments and the nature of the load. The best connection to use for large loads is 1, figure 37, because the current diverted through the voltmeter instead of the load is negligible and has negligible effects on the ammeter reading. However, if the ammeter reading is high, the voltage drop, if included in the voltmeter connections, might be significant. The best connection to use for small loads is 2, figure 37, because the current of the voltmeter may be an appreciable percentage of the current through the load, and the connection as shown gives an ammeter reading which applies to the load only. However, because of the small current, the voltage drop in the ammeter is negligible and the voltmeter reading is substantially the same regardless of its point of connection.

e. To further illustrate the possible error in careless connections, assume that it is desired to measure the wattage of a 25-watt incandescent lamp and that the instruments are first connected as shown in 1, figure 37. The instruments used are a 0.300-ampere ammeter having a resistance of 0.17 ohm and a 150-volt voltmeter having a resistance of 15,000 ohms. The ammeter scale indicates 0.218 ampere and the voltmeter scale indicates 119.5 volts. The indications obtained from 1, figure 37, are —

$$\text{Apparent Power} = \text{Volts x Amperes}$$
$$= 119.5 \times 0.218 = 26.05 \text{ Watts}$$

$$\text{Voltmeter Watts} = \frac{\text{Volts x Volts}}{\text{Ohms}}$$
$$= \frac{119.5 \times 119.5}{15{,}000} = 0.95 \text{ Watts}$$

$$\text{True Watts} = 26.05 - 0.95 = 25.10 \text{ Watts}$$

$$\text{Percent error} = \frac{0.95}{25.10} \times 100 = 3.78 \text{ Percent}$$

Since the ammeter has a resistance of 0.17 ohm and is carrying 0.218 ampere, the voltage drop across it is, by Ohm's law —

$$\text{Volts} = \text{Amperes x Ohms}$$
$$= 0.218 \times 0.17 = .037 \text{ Volt}$$

The true line voltage is then the sum of the voltage across the load plus the drop across the ammeter.

$$\text{Line Volts} = \text{Load Volts + Drop across Ammeter}$$
$$= 119.5 + 0.037 \div 119.537 \text{ Volts}$$

It is often practical to read only to the nearest half of a scale division which is 0.5 volt. Therefore, with the instruments connected as shown in 2, figure 37, and the same line voltage as in 1, figure 37, the voltmeter would still indicate a reading of 119.5 volts. However, use the calculated figure given above in order to work out the error in this method of measurement. If the voltmeter is then connected outside the ammeter, as shown in 2, figure 37, the ammeter will read the true current passing through the lamp. This current will be equal to the ammeter reading for 1, figure 37, less the current passing through the voltmeter.

$$\text{Voltmeter Current} = \frac{\text{Volts}}{\text{Ohms}}$$
$$= \frac{119.5}{15{,}000} = 0.008 \text{ Ampere}$$

Current passing through the lamp is then —
0.218 - .008 = 0.210 Ampere

$$\text{Apparent Power} = \text{Volts x Amperes}$$
$$= 119.537 \times 0.210 = 25.102$$

Since the true wattage is 25.10 watts —

$$\text{Error} = 25.102 - 25.10 = 0.002 \text{ Watt}$$

$$\text{Percent Error} = \frac{0.002}{25.10} \times 100 = 0.008 \text{ Percent}$$

The error is so small as to be negligible. When tests are made on larger loads requiring several thousand watts, the loss in the voltmeter becomes so small in comparison to the amount of power measured that it is negligible. However, the losses in the leads and connections between the point where it is convenient to connect the ammeter and the load to be measured become important factors which must either be accounted for or eliminated from the calculations altogether. The exact amount of losses in the leads and connections is difficult to determine, since they consist of not only the ohmic resistance of the conductors and shunt but also include the losses due to contact resistance wherever there are joints. Because contact resistance is variable and not easily measured, precautions should be taken in testing to eliminate its effect as much as possible. When small currents are to be measured, the error due to contact resistance is small and, when care is taken in making connections, will have very little effect on the meter indications. But, when the currents are large, the contact losses become an appreciable amount of the power to be measured and, for accurate work, measurements must be so taken as to eliminate this error.

f. A wattmeter is an instrument in which the deflection of the moving coil is proportional to both voltage and current. It, therefore, has a second coil to create a field in which the moving coil turns instead of the simple magnet field in the ammeter and voltmeter. It indicates watts (or kilowatts) at any instant and fluctuates with the current on any line having constant voltage. However, if both the current and voltage fluctuate, a wattmeter indicates the result of both components of power.

g. A watt-hour meter is used to determine the total power delivered over a period of time. The second formula in paragraph 50*a* can be transposed to read Power x Time = Work. The watt-hour meter is similar to the wattmeter except that the coil is arranged to rotate at a rate dependent on the power delivered by the circuit. It, thereby, accumulates the total work obtainable from the power supply in much the same manner as figures on an odometer indicate the total mileage traversed over a period of time at varying rates of speed.

53. Magnetic Circuit

In studying lines of magnetic force, many points of similarity to electrical circuits appear and the path of these lines of force has become known as a magnetic circuit. Their path forms a closed loop; there must be some source of force; and they are more easily carried through certain conducting materials, all of which is true of electrical circuits. The force sustaining an electrical current is called electromotive force; that sustaining a magnetic circuit is called magnetomotive force. The restriction to the flow of current is called resistance; the restriction to the path of a field is called reluctance. However, a current is closely confined to its conductor, while a field (or flux, as it is called) experiences considerable leakage through the surrounding medium. In order to get the greatest flux density at the desired points, materials with a low reluctance are used to carry as much of the flux as possible. For this reason, a metallic core is used for most coils in pole pieces, magnet valve relays, and similar equipment.

54. Kirchoff's Laws

a. The study of complex circuits requires more rules than those given by Ohm's law. The application of Kirchoff's laws is used in solving many problems. They are also applicable to magnetic circuits by substituting magnetomotive force for voltage in the first law and flux for current in the second law below.

b. Law 1 states that the algebraic sum of the voltages around any closed path in a network is zero. *For example,* the voltage of a generator (algebraically positive as a source of power) equals the voltage impressed on powerlines and motors (algebraically negative) which consume power.

c. Law 2 states that the algebraic sum of the currents arriving at or leaving any junction point is zero. Bridge circuits make extensive use of Kirchoff's laws and Ohm's law. They are widely used in instrumentation where four resistances are connected in a diamond-shaped circuit with voltage applied at two opposite corners (*for example,* second base and homeplate), and an instrument connected to the other two corners (first base and third base). When resistances or voltage drops in the network are balanced, no current flows through the instrument. Bridge circuits have other applications, chief of which in locomotive circuits are the wheel slip relay connections in which the coil of the relay is connected as an instrument and the traction motors are arranged as the resistances (in a series-parallel motor circuit). Balanced or unbalanced conditions actuate the relay as described in paragraph 96.

Section II. PRINCIPLES OF POWER EQUIPMENT

55. Dynamo

a. A dynamo is a machine that converts mechanical energy into electrical energy, or electrical energy into mechanical energy. When the output is electrical energy, it is called a generator and when the output is mechanical, it is called a motor. A generator and motor have the same basic construction and either may be called a dynamo. Dynamos are reversible and capable of operation as either a generator or a motor. In practice, there are minor differences in design and adjustment for efficient performance, and they are, therefore, designated according to the service they perform. Dynamos have the following essential parts:

(1) Magnetic field.

(2) Armature winding.

(3) Commutator or collecting rings (except in certain induction motors).

(4) Mechanical parts which support the core and bearings. The relation previously described between fields, currents, and motion creates electromotive forces necessary to convert mechanical and electrical energy. It makes no difference whether the relative motion is obtained by stationary fields or moving fields. However, in locomotive applications, the fields are stationary and consist of magnetic pole faces bolted to the frame. Coils wound around the field poles are called field coils and the amount of current in these coils determines the strength of the magnetic field. The magnetic field, or flux through the poles, is called field excitation. The stationary poles and frame are called the stator. The rotating coils are called the armature or rotor and carry the load current.

b. The relation that exists between the direction of the field, the direction of the motion, and the direction of current should be remembered. Any one of these can be determined if the direction of the other two is known. The determining method for generators is Fleming's right-hand rule and for motors is Fleming's left-hand rule (fig. 39). In each case, the thumb, forefinger, and middle finger are held at right angles to each other. The thumb points in the direction of motion, the forefinger points in the direction of the field, and the middle finger points in the direction of the flow of current. When a force causes a conductor to move through the field, the current which flows is caused by an induced emf or voltage and the machine is a generator. When an impressed voltage sets up fields which cause the conductor to move and do mechanical work, the machine is called a motor.

56. Basic Generators

a. Since electromotive force (emf) is related to changes in field and motion, it logically follows that the amount of emf is related to the amount of change in field and motion. The value of the emf depends upon the rapidity of the changes, which is generally termed the rate at which lines of magnetic force are cut. The following three factors have the greatest effect on the emf of a generator:

(1) Changes in speed of rotation (or revolutions per minute) of the armature will cause a corresponding change in emf, other things remaining unchanged.

(2) Changes in flux density will cause a corresponding change in emf, other things remaining unchanged. Flux density is changed by changing the current flowing in a given field coil, or by changing the number of turns of wire in the field coil (as

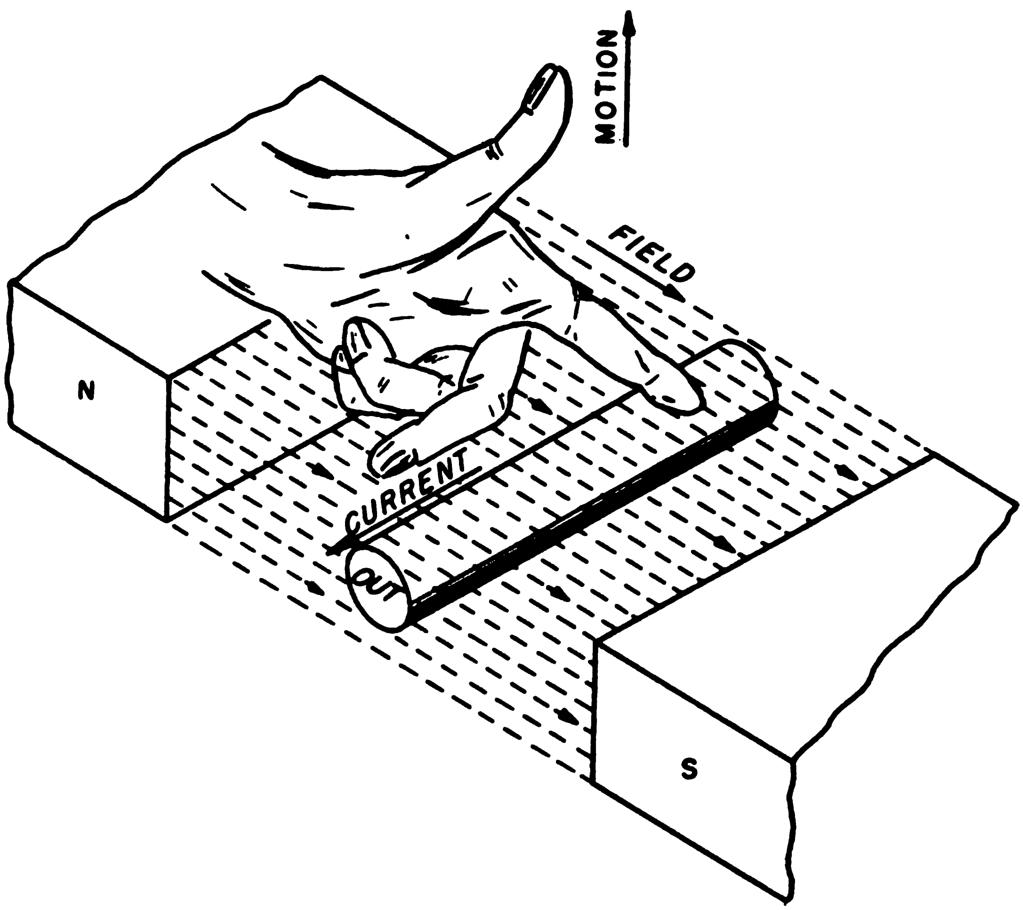


Figure 39. Application of the left-hand motor rule.

when a manufacturer builds a new design).

(3) Changes in size of the field or the size and turns of the rotating coil (a new design) will change the area of the flux path.

b. While the emf of a machine will vary in the manner outlined in *a* above, the emf in any single armature coil will vary while the speed of rotation and flux density remain constant. Figure 40 shows the position of the coil as it makes a half turn. The discussion which follows is concerned with the length of wire which sweeps the pole face which extends perpendicularly into the drawing. This is the wire along which emf is induced in figure 38. At the position shown, 0° in figure 40, no flux is being cut because the coil moves tangent with the flux (tangent being "along" instead of "across" the flux). At 20°, 1 line has been cut. At 40°, 4 more lines have been cut in the same period of time, since it takes as long to turn 20° at any part of the circular path when speed of rotation remains constant. At 60°, 6 more lines have been cut. At 100°, 7 more lines have been cut. The emf varies with the number of lines which have been cut and is zero at 0° and a maximum at 90°. These values can be plotted as a curve in which the circular path of one revolution is represented as a straight line and the emf at any point along the path is represented by the distance away from the line (1, fig. 41). At 180° the emf is zero for the same reason as given above for 0°. A curve of the same pattern is developed between 180° and 360°

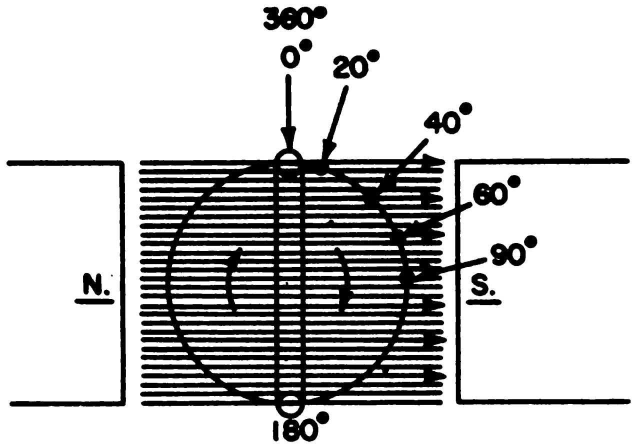


Figure 40. Relation of electromotive force to speed.

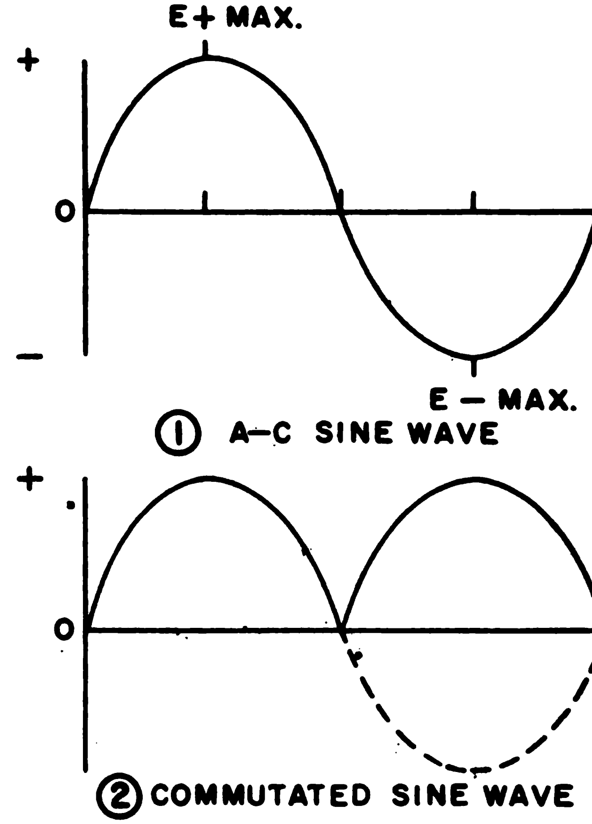


Figure 41. Sine waveform.

which brings the coil back to zero position. However, the emf is in the opposite direction (Fleming's rule) and the curve is drawn below the line. This curve follows a mathematical sine waveform but mathematics does not affect the present discussion.

c. When the alternating emf described above is impressed on a complete circuit, the flow of current will vary in the same manner. Such a device constitutes a simple alternating current (ac) generator (fig. 42), and the ac power systems supplied in this manner are one of the principal classifications of power systems. In an ac machine, the ends of the rotating coils are connected to continuous metal rings, called sliprings, which are mounted on the axis (armature shaft) and are insulated from each other. Metal or carbon blocks, called brushes, ride on the rings to make contact with the external circuit. The number of complete waves or cycles generated per second is called the frequency and depends on the speed and design of the generator. Standard commercial power frequency is 60 cycles.

57. Basic Commutator

There are many uses for a power system in which the current does not alternate. When the current always flows in the same direction it is termed direct current. A generator which supplies a direct current (dc) system is called a dc generator. Since the current in the armature is always alternating, some means must be provided to change the direction of flow before it enters the outside circuit. This can be done by using one split ring instead of the two sliprings (fig. 43). Such a device is called a commutator and it is essential that the external connections be changed at the proper time. The commutator must, therefore, reverse the connections of the coil with respect to the external circuit at the instant when the emf reverses in the coil. When this is done, the alternating current shown in 1, figure 41, becomes a pulsating direct current as shown in 2, figure 41. The end connections of the coils to the external circuit are called commutator segments.

58. Direct Current Generators

The direct current power supply described in paragraph 57 is not practical in commercial use, because the voltage reaches zero twice in each revolution of the generator and the power output would be small. A practical generator or motor

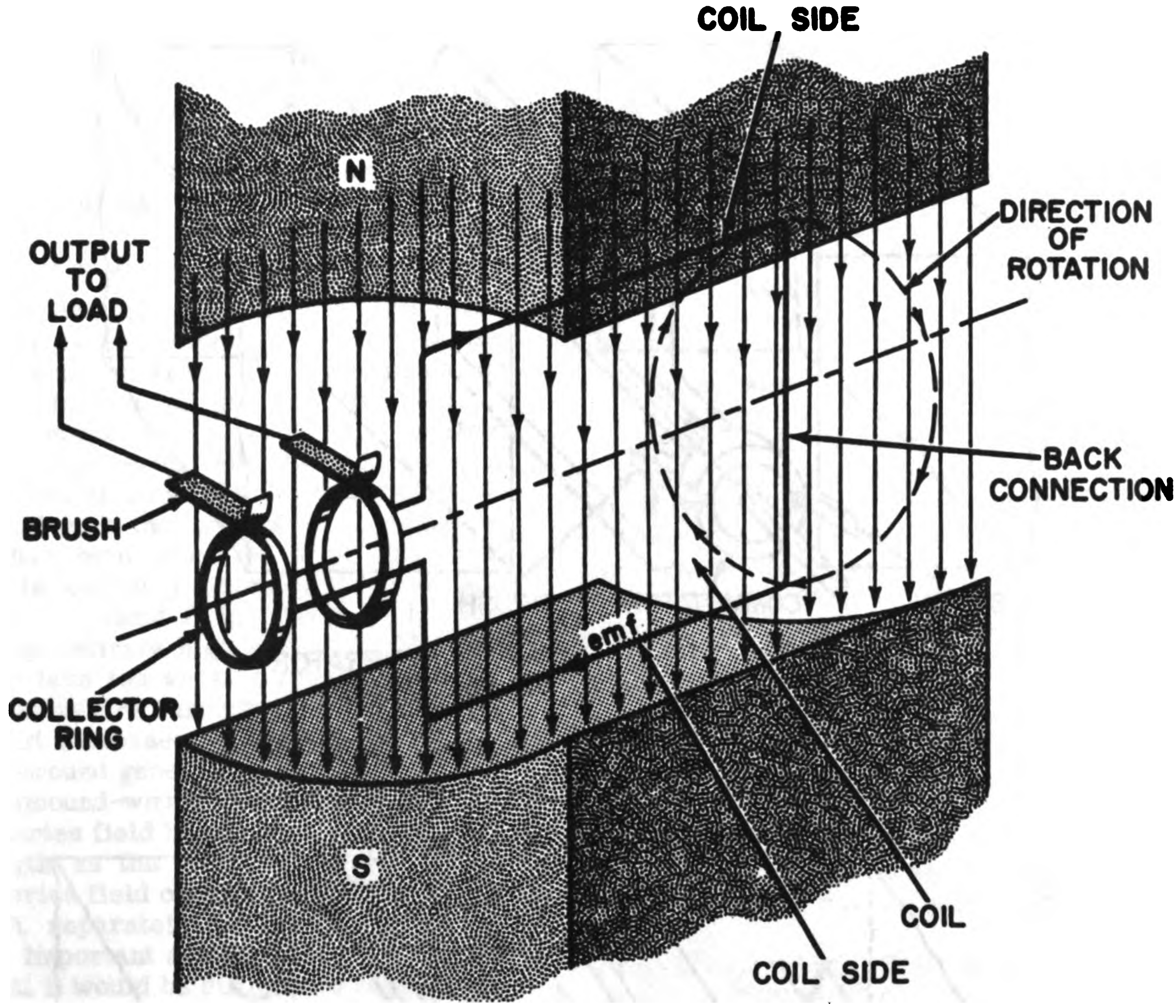
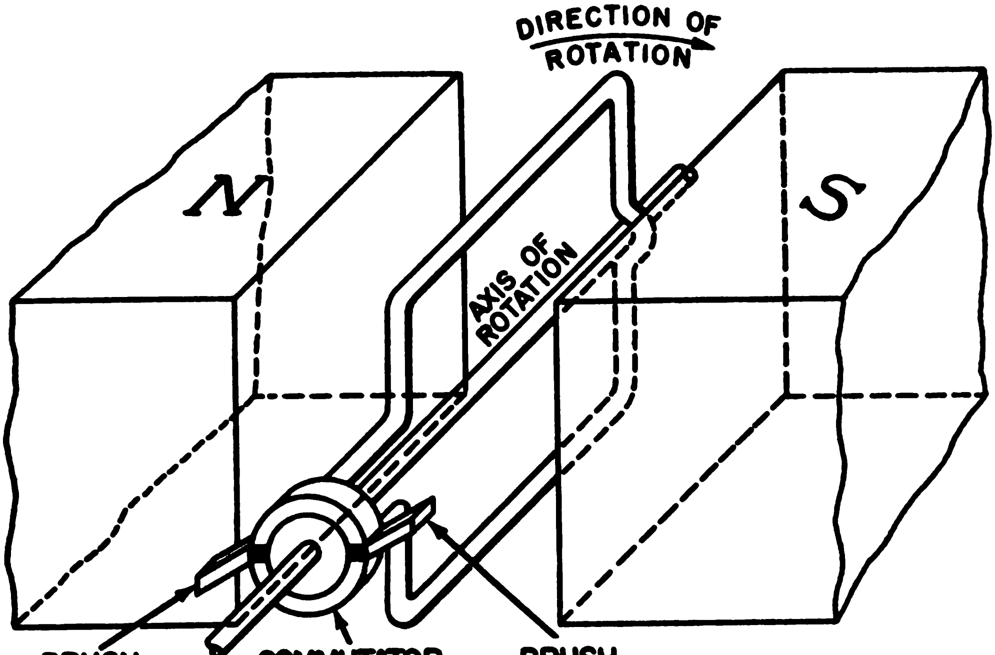
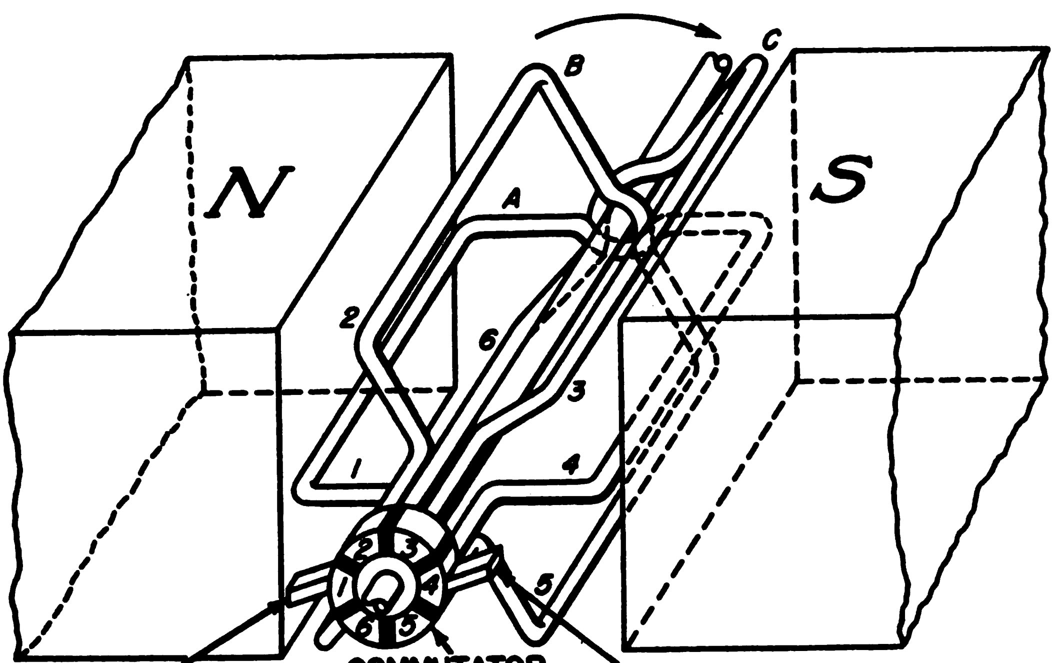


Figure 42. A simple ac generator.

must, therefore, have many coils. Each coil is connected to a pair of commutator segments. Such a generator is built by enlarging on the principles shown in figure 43. Three coils develop three separate sets of emf designated A, B, and C, figure 44. The dotted lines represent an unused emf since the brushes, as shown in figure 43, are not touching more than one pair of commutator segments at a time. The solid lines represent the time (or degrees) at which the brushes ride on coils A, B, and C successively. The contacts are made when the greatest emf is being generated in the coils and the line voltage has a value represented by the solid line. The ripple is smoothed out to a constant direct current when more coils are added. However, the dotted lines show that there is a large proportion of inactive coils and an armature wound as shown in these diagrams is called an open-circuit winding. If the coils are connected to each other to form a closed circuit, the emf represented by the dotted lines in figure 44 is added to the line, and the resultant emf is a dc ripple shown in D, figure 44, in which total emf is the sum of the individual emf's at any instant. The generator diagrams shown here have two poles,



SIMPLE DIRECT-CURRENT GENERATOR



DIRECT-CURRENT GENERATOR COMPOSED OF THREE LOOPS OF WIRE AND A COMMUTATOR OF SIX SEGMENTS

Figure 43. Typical dc generator.

but further improvements in construction and operation are possible by building machines with four, six, or more poles. The basic theory is unchanged in such machines. There are many types of circuits by which coils are connected for closed windings.

59. Types of Direct Current Generators

a. Generators are classified into three general types depending on whether the fields are connected in series, shunt, or a combination of the two (fig. 45). A series-wound generator has its field winding in series with the armature. A shunt-wound generator has its field in parallel with the armature. A generator that has both a series field and shunt field is called a compound-wound generator. A shunt field circuit must have a comparatively high resistance in order not to take too great a proportion of the total armature current. A drop in voltage as load increases is characteristic of a shunt-wound generator. This is avoided in a compound-wound generator by having the series field boost, or add to, the field strength as the load current (and hence the series field current) increases.

b. A separately excited generator has many important applications in regulating output. It would be difficult to regulate the field strength and generator output by changing the currents in self-excited windings. A locomotive is very definitely in this category, and the description of this special application is given later (paras 70 and 71).

60. Construction of Direct Current Generators

a. Interpoles. Paragraph 57 indicates on first glance that the voltage induced in a rotating coil would reverse itself halfway between the fields. Actually, the flux is distorted in the airgap and the zero emf in the coil occurs slightly off center. In a generator, this occurs in advance of the theoretical neutral point and in motor, it occurs behind the neutral point. If the brushes are not set at the point of zero emf, a current is broken as the commutator turns and there is sparking at the brushes. Brushes are mounted so they can be shifted to a leading or lagging position to avoid this sparking. However, a self-induced emf exists in a coil at the neutral point, and the brushes are always in the fringes of flux between poles in such a manner that it is difficult to obtain satisfactory commutation. The most satisfactory solution has been to introduce a separate flux which will produce a desired flux density in the neutral zone. This is done by small narrow poles called interpoles or commutating poles located between the main poles.

b. Laminations. Field cores and armature cores are built up of layers of sheet steel to reduce strap currents called eddy currents. Since iron is almost as good a conductor of electricity as copper, electrical currents tend to flow almost as readily in the iron as in the copper, but they lack an outside circuit. They, therefore, circulate within the cores and generate excessive heat which represents lost power. These eddy currents are much less in a laminated core than they would be in a solid core. Armature laminations can be keyed directly to the armature shaft and they are punched to provide passages through which air can circulate and carry away heat.

c. Self-Ventilation. The generator is provided with a built-in blower on the shaft which forces air through the machine when it operates. This air carries away heat which, if accumulated, would seriously limit the capacity of the generator.

d. Winding. Generators and motors may have only one set of brushes or as many sets as there are poles. Coils occupy only a portion of the circumference of an armature, and the types of connections with each other are called lap windings and wave windings. Many elements of design determine the choice of windings but, in general, coils in a lap winding overlap each other and are connected in parallel, while a wave winding proceeds in series around the armature. The coil voltage is lower than the line voltage on a wave winding, but the same current flows through all coils. Voltage is higher but

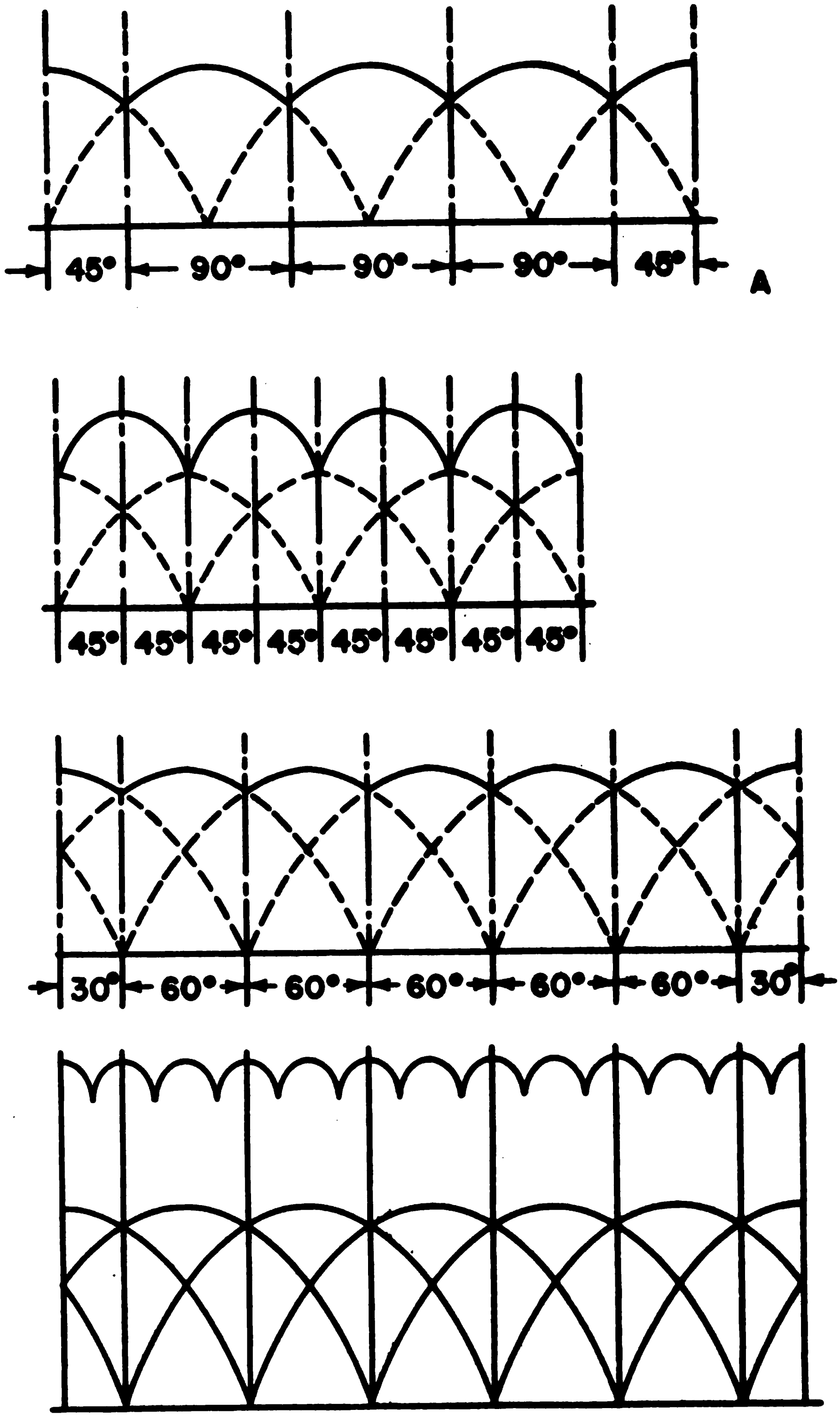


Figure 44. Composite commutated waveforms.

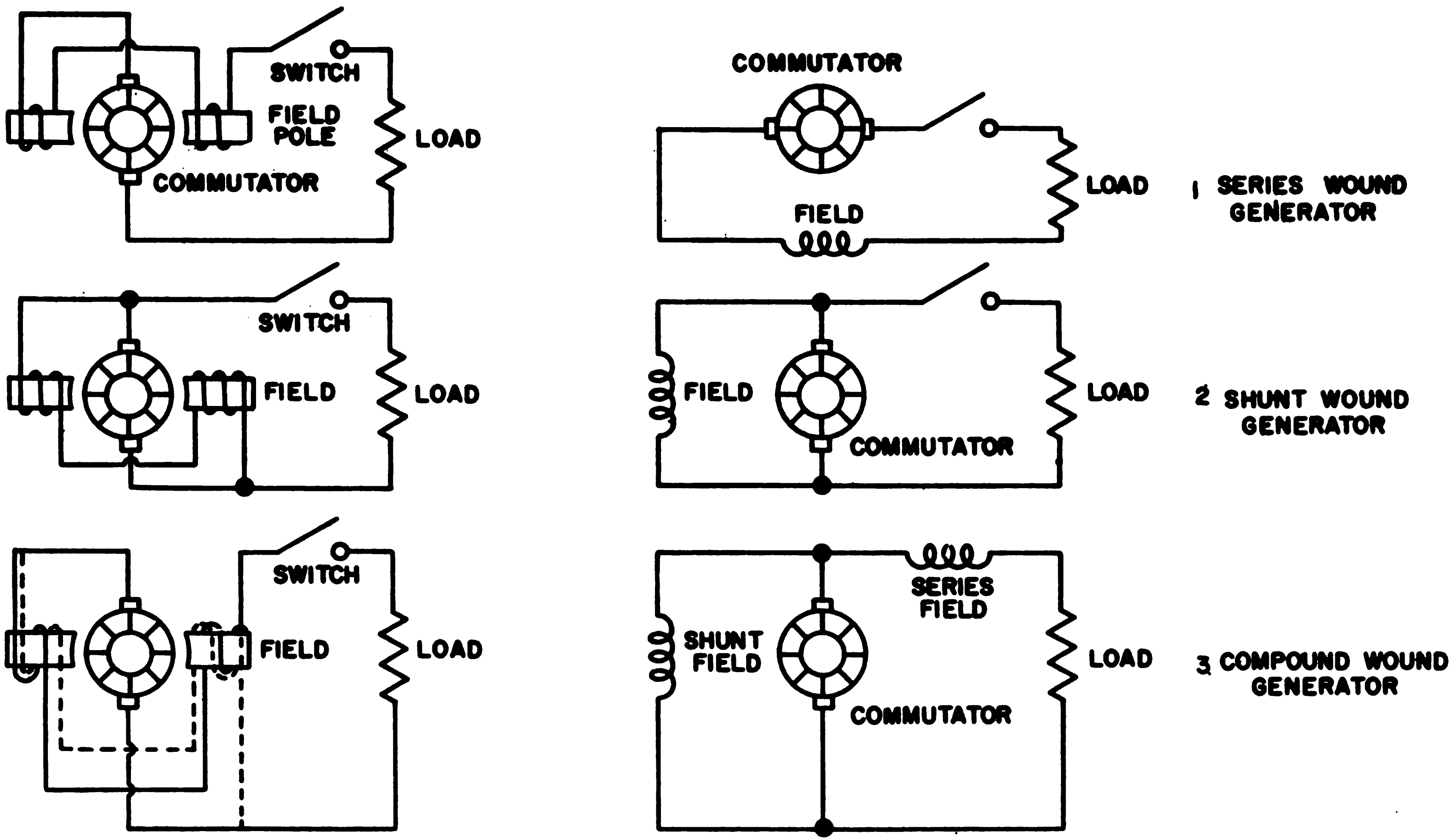


Figure 45. Shunt, series, and compound field windings.

current is lower in lap-wound coils than in wave-wound coils.

61. Direct Current Motors

a. Since a motor is similar to a generator, except for refinements in design, detailed descriptions for the generator will not be repeated here. However, it is well to understand why certain types are used in certain work. In general, voltage produces speed and current produces torque. Shunt motors are used where a substantially constant speed is desired. They are, therefore, suitable for driving the fuel supply pump, fan motors, and similar auxiliaries on the locomotive direct current powerlines. The speed of shunt motors varies only slightly with changes in load and they have a definite no-load speed. This is in great contrast with the action of a series motor which will speed up so fast that it will be seriously damaged. Series motors have several operating advantages in traction service, and it is fortunate that they are always connected to a load (unless wheels are derailed, which necessitates a special caution given later in the operating instructions). A locomotive requires high torque (and current) for starting and acceleration, but when speed increases, less torque and current are needed. Since voltage is the significant factor with respect to speed, a low voltage is sufficient when starting and additional voltage is needed when speed increases. This power system constantly adjusts itself gradually to the varying conditions of load. The power equation in paragraph 50 was expressed as a product of voltage and current and the diesel engine was previously described as having a constant output. Since the product of low voltage and high current, when starting the series motor, approximates the product of high voltage and low current when running, the power output to the driving wheels approximates the constant output of the diesel engine, and the design of related load control devices is simplified.

b. Field shunting of traction motors is generally provided by connecting a resistance shunt in parallel with the field. When the field is weakened by shunting part of the field current, there is an immediate increase in motor current because the back-emf is lower. This results in an increased torque and power. This increased torque accelerates the locomotive to a higher speed until a new balanced condition is reached. Field shunting takes place when current reaches such a low value that the product of voltage times current no longer equals diesel engine power output and the new set of conditions makes it possible to load the diesel engine to capacity throughout a broader operating range.

62. Overloads

a. An electrical circuit has previously been defined as a conductor through which current flows. It has also been shown that conductors offer resistance to current flow (para 44*c*(2)). The combination of current and resistance has been shown to produce heat and also voltage drop. Conductors, or wires, are kept small to keep costs and space requirements low. In a powerline or in a piece of equipment, the conductors are designed for their specific service. Because temporary heavy load conditions often occur, wires are chosen which can carry some load above normal. Excessive loads will damage insulation and equipment and any current above the practical limit is called an overload.

b. Overload protection is provided by devices which break the circuit before equipment is damaged. A fuse is a metal alloy with low melting point which is connected directly into the circuit to carry the current. Excessive current causes the metal to melt and open the circuit. A burned-out fuse must be replaced to establish the circuit again. The fusible element is mounted in a casing to confine the arc which is produced when it melts. Circuit breakers are switches which are opened or tripped by a magnet coil when the current in the circuit reaches a predetermined limit at which the coil exerts enough force to open the breaker. Breakers are permanent fixtures in the circuit and may be closed again when the fault is corrected.

63. Locomotive Circuits

a. The three basic types of circuits are series circuits, parallel circuits, and series-parallel circuits. In a series circuit, the same current passes through each device and connection in completing its path to the source of supply and the total resistance of the circuit is equal to the sum of the resistance of all portions of the circuit. In a parallel circuit, the current from the source divides through two or more parallel paths and the total current from the source equals the sum of the current in the parallel paths. The resistance of a parallel circuit is always lower than the resistance of any individual parallel path. A series-parallel circuit is a combination of series and parallel circuits. A string of Christmas tree lamps in which all lamps go out when any one lamp burns out (opens the circuit) is a familiar example of a series circuit (1, fig. 46), and each lamp can stand only a portion of the voltage from a house circuit. The more expensive Christmas lights in which the other lamps continue to burn when one lamp burns out is a parallel lamp circuit, and each lamp operates on house voltage (2, fig. 46). If motors are connected in the same manner as the lamps, the same circuit characteristics apply. The different operating characteristics of motors at different voltages are a chief reason for the relatively greater number of methods used for connecting traction motors.

b. The power from the main generator on a locomotive is carried by electric cables to the traction motors which are geared to the driving axles. The main power circuit is the path taken by the current as it flows from the generator through the cables and motors and back to the generator. The circuit is opened and closed by heavy duty power switches (para 72). The electric drive, in effect, is a variable transmission with an infinite number of gear ratios. While the throttle remains in the first notch, the current (amperage) decreases rapidly after the initial surge of power, because the motors which are also increasing speed develop a greater countervoltage or back-emf and the power delivered by the locomotive decreases. The engine and generator can deliver more power if their speed is increased by moving the throttle to a higher position, which increases the fuel supply as described in paragraphs 35 through 37. This increases generator voltage and amperage and locomotive tractive effort. While the throttle remains in this position, the current again decreases. The various positions of the throttle represent a continual adjustment of voltage, current, and tractive effort to get from the engine the power which it is capable of delivering. The principal limits are the electrical overload limitations and tendency of the driving wheels to slip or spin. When the throttle is advanced as far as possible, the engine speed and generator voltage are at their maximum. However, the locomotive speed continues to increase, the current decreases as before, and power output (the product of current times voltage) decreases. Under these conditions, the power which the diesel engine can deliver is no longer being used. Fuel-power output can again be put into use if the current can be increased. This can be done by changing the traction motor connections. In starting a train, the following requirements are encountered:

(1) High pulling power (tractive effort).

(2) High current (amperage is necessary because the torque of a motor is proportional to the amperage).

(3) Low voltage is sufficient to produce high current when the locomotive is standing still or traveling very slowly. The diesel engine and generator are turning at a low speed because the throttle is at a low notch.

c. Contactors are magnetically operated switches used for opening and closing circuits. They are energized by low voltage current from the battery circuit. Several types are installed on locomotives, each suited to its particular application. However, the operation and maintenance of all types are essentially the same. The low voltage control circuit energizes an

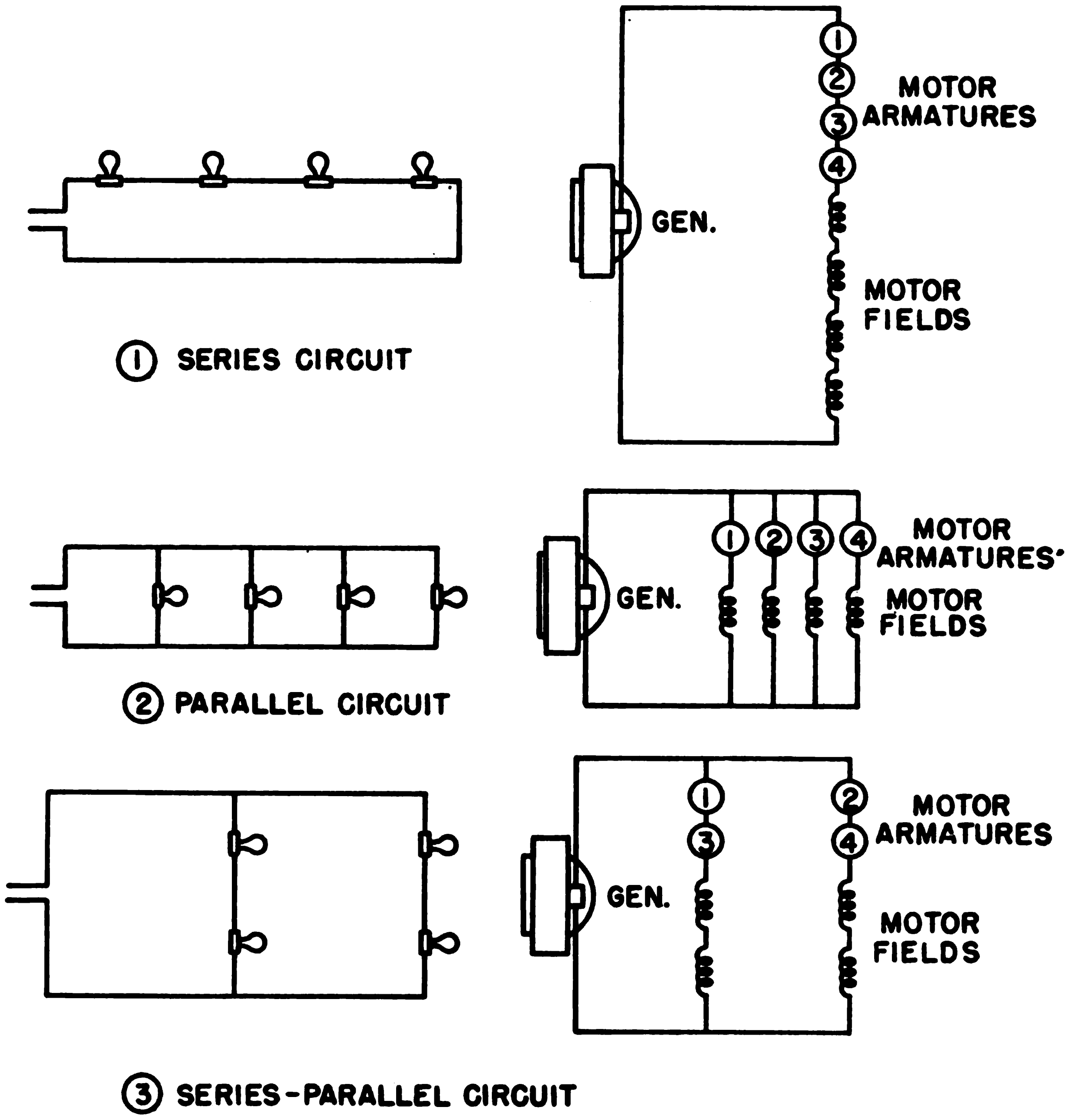


Figure 46. Basic electrical circuits.

electromagnet which brings a movable contact into touch with a stationary contact in the main circuit. A spring moves it in the opposite direction when the electromagnet is deenergized. The low voltage current may be fed through varied interlocks, automatic controls, or hand-operated switches and the consequent flexibility in installation makes it necessary to consult the proper wiring diagram to determine the exact operating circumstances for any contractor. Blow-out coils adjacent to the contacts minimize arcing and arc shields protect adjacent parts from burning by the arc.

d. Interlocks are auxiliary switches

mounted on and controlled by another switch, contactor, valve, or similar equipment. The controlling switch is operated by a cam or linkage which opens or closes the contacts in a definite relationship to the position of the main piece of equipment. The purpose is to control the making or breaking of related circuits only when proper conditions exist. Interlocks are classed as "in" interlocks (closed when main switch is closed) and "out" interlocks (closed when main switch is open). Several interlocks may be mounted on a piece of equipment in any required "in" and "out" combination.

e. A magnet valve consists of a magnet coil and a core acting upon an air valve. The coil is in the low voltage control circuit and connected through interlocks, automatic controls, or manual controls in the same manner as the coil on a contactor. It usually returns to its deenergized position by spring action. The valve and coil are used in such applications as shutter control, compressor synchronization, and sanding, as well as in reversers and power switches as a built-in portion of the equipment.

f. A relay is a small magnetic type electric switch which consists of a coil and several small contacts. The device changes connections in one part of a circuit in response to changes taking place elsewhere in the circuit. The coil may be in either the high voltage or low voltage circuits of the locomotive. Relays operate in much the same manner as contactors, but are not required to carry heavy current, and are generally much smaller. They may be adjusted to open and close at various voltages to respond to the various operating conditions. When the contacts of a relay close, they close the circuit to the solenoid of a contactor or magnet valve which is controlled by the relay. More than one contactor in a magnet valve can be controlled by a relay by building the relay with several sets of contacts.

64. Symbols

When an electrician or designer decides to connect electrical equipment in a certain way, he must put the information in some form that conveys the same information to anyone who wants to build it or needs to repair it at some future time. Pictures of the parts in a circuit are sometimes used for training purposes in elementary work. For any large circuit they would be difficult to draw and to read. If the equipment is represented by simple sketches with specific meanings, the circuit can be easily drawn and read. These sketches are called symbols. Symbols most frequently used in locomotive circuits are shown in figure 47. There are so many advantages gained in using them that universal standards are adopted so they convey the same information. There are revisions or deviations from time to time, but familiarity with their normal usage will clarify many problems. The symbols represent basic parts of apparatus instead of a separate symbol for each piece of equipment. *For example,* the coil of a ground relay, a wheel slip relay, a field shunting relay, and others, are aways represented by the same symbol for an operating coil and the contacts are always represented by the same symbol for contacts. They always perform the same basic function. An operating coil always magnetizes and moves a plunger which opens or closes the contacts in electromagnetic equipment, or opens or closes a valve in electropneumatic equipment. The drawing symbols are, therefore, supplemented by letters which are often an abbreviation of the equipment, such as GR for ground relay, or WS for wheel slip relay. These letters tend to become standardized within a given field, but a legend is so readily supplied that it often appears on each drawing. The symbols for various parts of a piece of equipment are often separated in a wiring diagram. *For example,* a ground relay is used to protect the high voltage power circuit and its operating coil is in that circuit. The response to a closed relay consists of lights, bells, and idling controls, all of which are in the low voltage circuit.

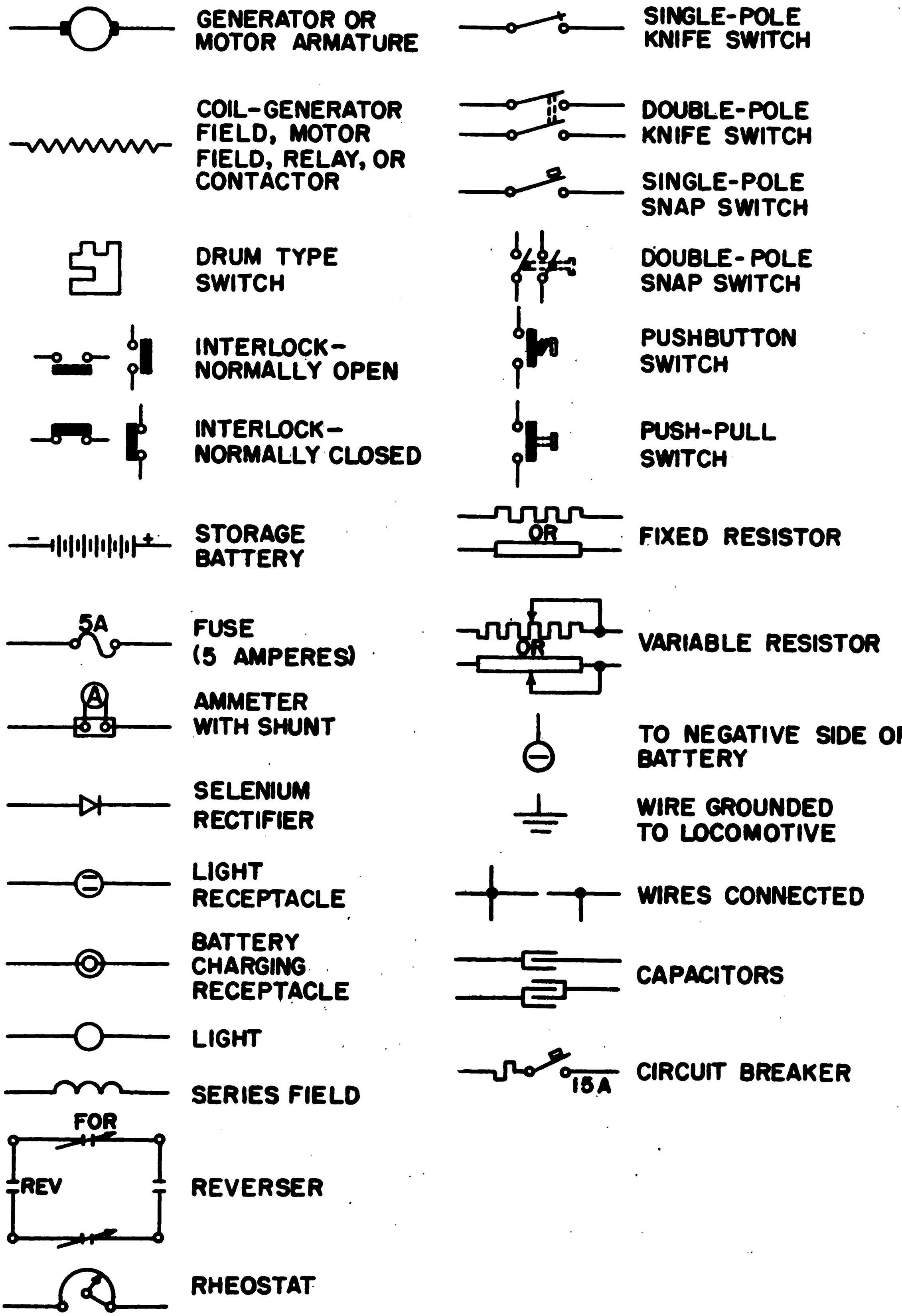


Figure 47. Electrical symbols.

65. Schematic Diagrams

a. A schematic wiring diagram is a sketch of a circuit in which the connections are shown in a different form than the actual wiring, with the objective of explaining the operation more clearly. The circuit is generally drawn as a simple line diagram with as little turning, crossing, or "back tracking" of the lines as possible. The actual wiring diagram corresponds more nearly to the actual location of apparatus, conduit, and wire. A simple circuit as it would first be pictured in someone's mind is shown in 1, figure 48, and it has little use except in elementary training programs. The schematic circuit which conveys the principal functional or operational purposes of the parts of the circuit is shown in 2, figure 48.

b. An actual wiring diagram is prepared from the schematic diagram after the schematic has been studied enough to assure the satisfactory operation of the circuit. Typical additions to the circuit would be a generator to charge the battery; then a fuse or circuit breaker to protect the circuit; then, in the case of locomotives, an interlock to guarantee that the circuit is open under certain operating conditions. The involved nature of any form of diagram other then a schematic diagram is quite apparent. The addition of only three symbols in the existing line of the schematic diagram will clearly convey the information. In the actual wiring diagram on a locomotive, the simple block of wires in the schematic diagram must be shown as running from the auxiliary generator in the engineroom to the battery beneath the frame, with intermediate wiring to the battery ammeter at the control panel and the battery charging resistor in the electrical cabinet. This becomes so involved that the diagram is broken up into several parts which terminate at termainal boards which are strategically located at key points through a locomotive.

c. Groups of wires between terminal boards with no direct connection to apparatus are called wiring harnesses. In tracing a circuit, it is well to assume a starting point at the source of power. This is designated as the positive side of the circuit in direct current systems, which are used exclusively for diesel-electric locomotive power and power control apparatus. The main power circuit (fig. 49) is one of the easiest to trace. Recalling that current flows from positive to negative, a glance at any motor circuit in the diagram shows that current must pass through a power switch, the motor armature, one set of contacts on the reverser, the motor fields, and another set of contacts on the reverser to reach the negative side of the circuit leading back to the generator. In tracing a control circuit, the positive side of the auxiliary generator, or battery, is the source of power which establishes the starting point. The engine starting circuits of all locomotives are fundamentally alike. They extend from the battery, which is the source of power, through the main battery switch and starting contactors to the generator, which cranks the engine, and thence back to the negative side of the battery. Likewise, all throttle control circuits extend from the source (battery) through the control stand, and thence to the operating coil of various power control equipment to the negative side of the control circuit.

d. A review of paragraph 64 will now show the purpose of separate symbols for the operating coil and the contacts. The control circuit has just been completely traced through the operating coils of such power control equipment as the reverser and power switches, but the action of the contacts which these coils operate take place in the main power circuit first traced. Protective interlocks and similar devices add other symbols to the diagram. Any study of circuits must be supplemented by experience, and thorough training on a specific circuit is necessary to fully understand how to trace a circuit. This is seldom necessary in locomotive operation but is extensively done in maintenance work. Fundamentally, the replacement of a fuse, the closing of a circuit

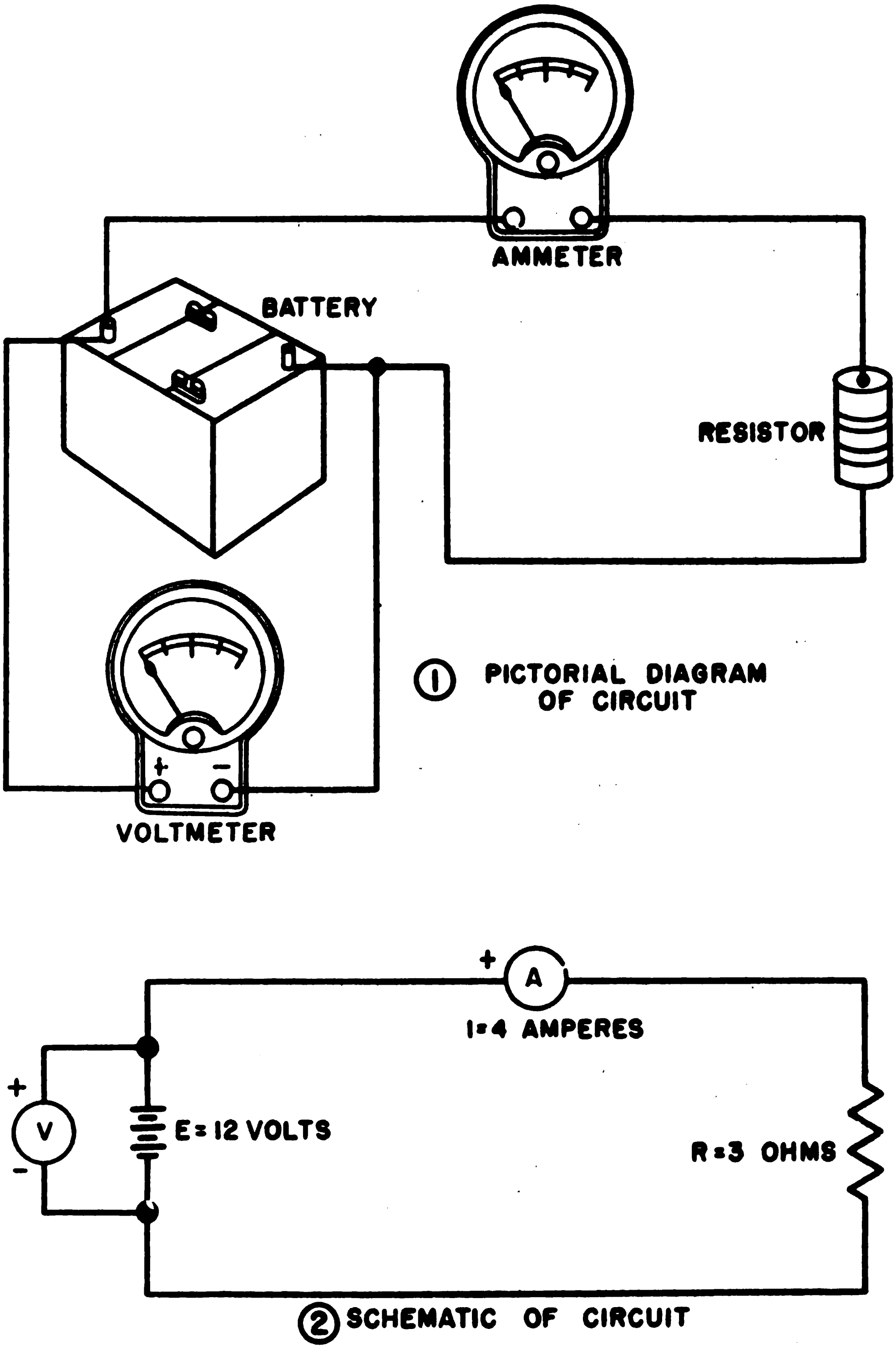


Figure 46. Diagram of a basic circuit.

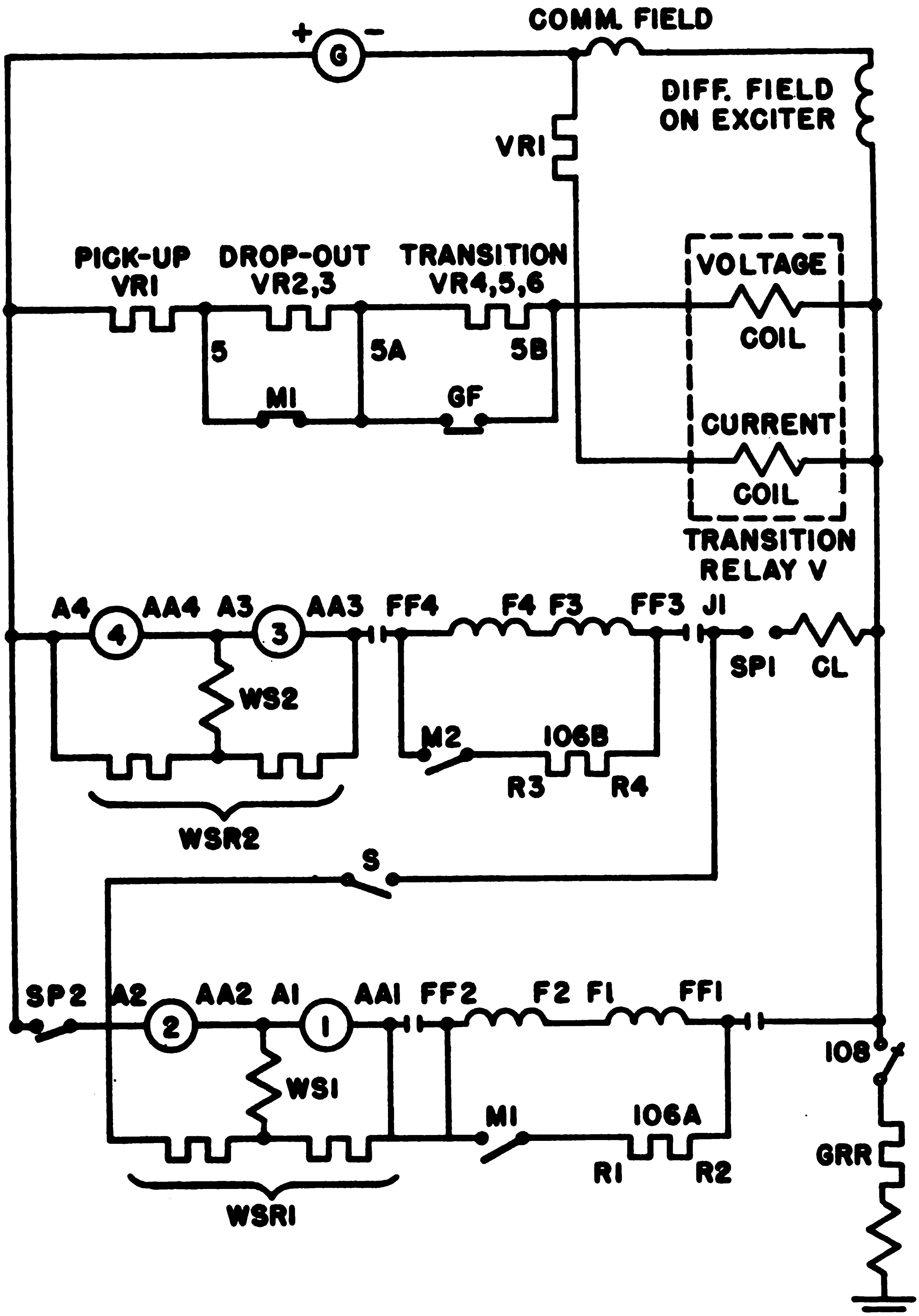


Figure 49. Main power circuit.

breaker, or alternate settings of a cut-out switch for emergency operation are the same as detailed sequence testing for maintenance and repair work; but the indicating and control devices are set up for prevalent road troubles so that the crew can attempt remedies by rule of thumb measures, whereas the shop electrician must make a more thorough study of details.

CHAPTER 10
MAIN POWER SYSTEM

Section I. POWER TRANSMISSION SYSTEM

66. Main Power Circuits

a. The main power circuits are those carrying heavy current at high voltage from the main generator to the traction motors through heavy-duty power switches, reversers, field shunting contactors, and related equipment. If the locomotive has no ac power system, motor-driven engine cooling fans (when used) are operated in the main power circuit. The circuit is remotely controlled by apparatus in the control circuit. Power wiring diagrams are relatively easy to trace. Many different circuits are used. Figure 49 shows a basic series, series-parallel, and series-parallel-shunt motor connection for a four-motor transistion-type locomotive. Each motor circuit is independent of the others, except for the small wires in the wheel slip relay circuit.

b. Motor connections in other type locomotives are permanently connected in series-parallel and no contactors are used. A tie between the motor circuits exists when the unused portion of the motor circuits is in series-parallel. When the motors are in series connection, a contactor closes when the tying circuit is in use and other contactors open the circuit to and from the generator so that full generator voltage is not applied to any one motor circuit but is applied to the motors in series. The main power circuits operate at voltages ranging from 600 to 1,200 volts, or more. The generator, motors, and electrical equipment cabinet are the chief points of possible exposure. Personnel should keep clear of reversers, contactors, generators, motors, and cables when locomotive is under load. Adequate safety precautions must be observed.

67. Main Generator

a. The main generator converts the power output of the diesel engine into electrical power for the operation of the traction motors (fig. 50). It furnishes direct current at varying voltages up to about 1,200 volts. It is mounted on and driven by the diesel engine and the speed, therefore, varies with engine speed between approximately 350 and 1,800 rpm. It is self-ventilated by a fan mounted on its shaft. The generator fields are especially designed to meet requirements peculiar to diesel locomotives. The main field is supplied by a battery or an exciter which is under the control of a load regulator. A differential field is wound to oppose the main field. It is in series with the generator output and the strength of the opposing field varies with generator output. The purpose is to vary the total field strength so that a constant kilowatt output is obtained. There are other fields, such as starting fields used when cranking and commutating fields, which improve performance.

b. The main pole pieces are of laminated steel carefully riveted together and held to the frame by tapbolts or studs through the frame. The field coils are impregnated and baked with insulating compounds to guard against movement and chafing within the coil and to permit free flow of the internally developed heat to the surfaces. The armature is built to withstand high speed and all of the vibrations (lateral and torsional) incurred in operating with a diesel engine. It is dynamically balanced both before and after winding to reduce vibration, and is supported at one end by the antifriction bearing and at the other end by the engine crankshaft. Typical construction provides adequate ventilation without allowing pockets for the accumulation of dirt and moisture.

68. Traction Motors

The traction motors convert the electrical energy of the generator to mechanical

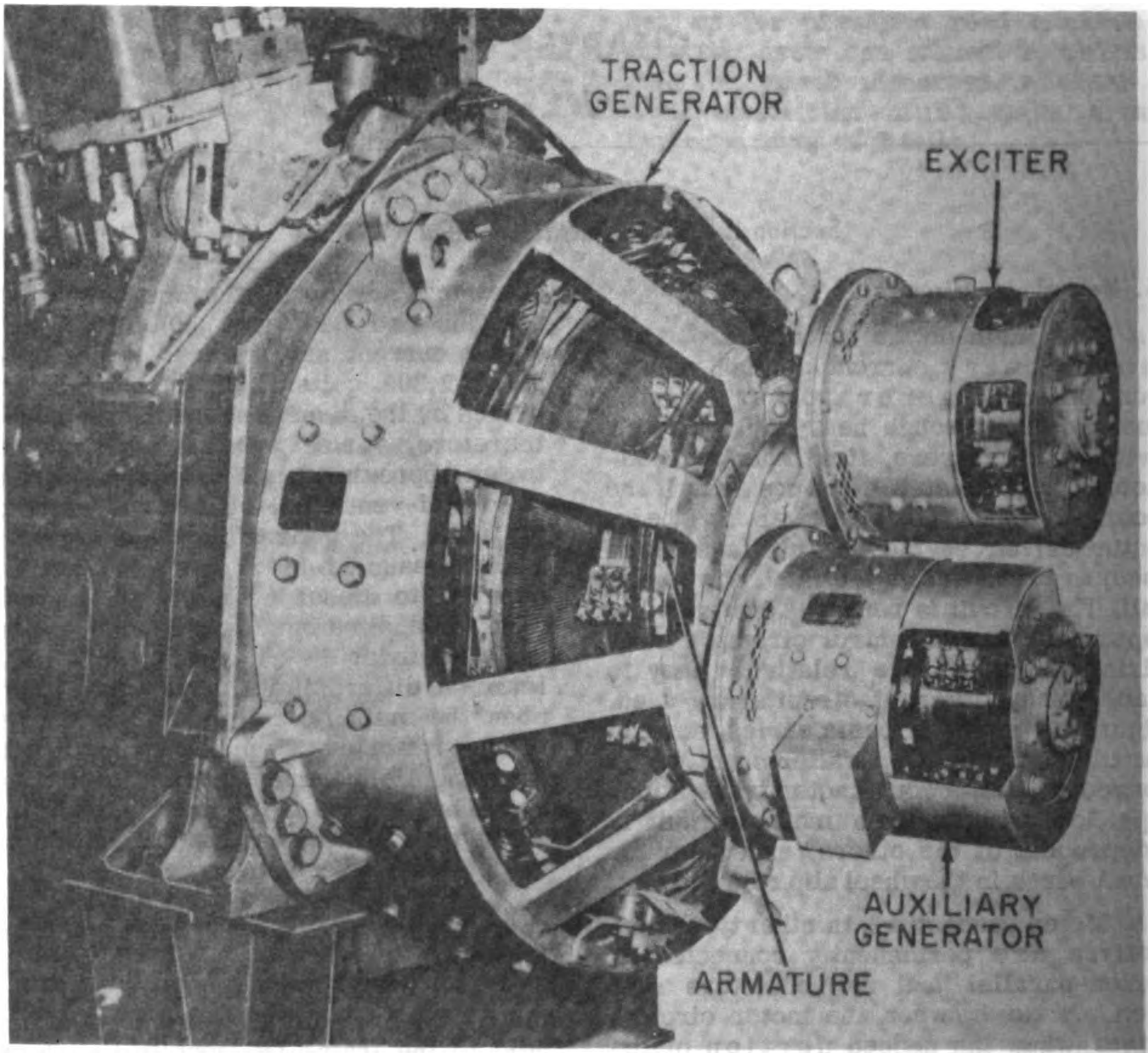


Figure 50. Main generator.

energy at the wheels in the form of tractive effort. They are series-wound direct current motors (fig. 51). The motors are mounted in the locomotive trucks and are geared to the locomotive axles. About half of the weight of the motor is supported on the truck frame through a nose on the motor frame and the other half is supported by bearings on the axle. They may be connected electrically in permanent series-parallel connection or may be arranged for transmission from series to series-parallel connection. The armature turns on roller bearings in the motor housing. The axle bearing is a split-sleeve type with waste-pack oil lubrication. Torque reaction is a greater load than that due to the weight of the motor, and lubrication of the bearing is a more difficult problem than the somewhat similar packing and lubrication of journal boxes.

69. Traction Motor Blowers

Blowers are provided in larger locomotives to force a large quantity of cooling air through the traction motors. This forced ventilation of the motor is necessary to prevent it from overheating. A LOCOMOTIVE MUST NOT HAUL A

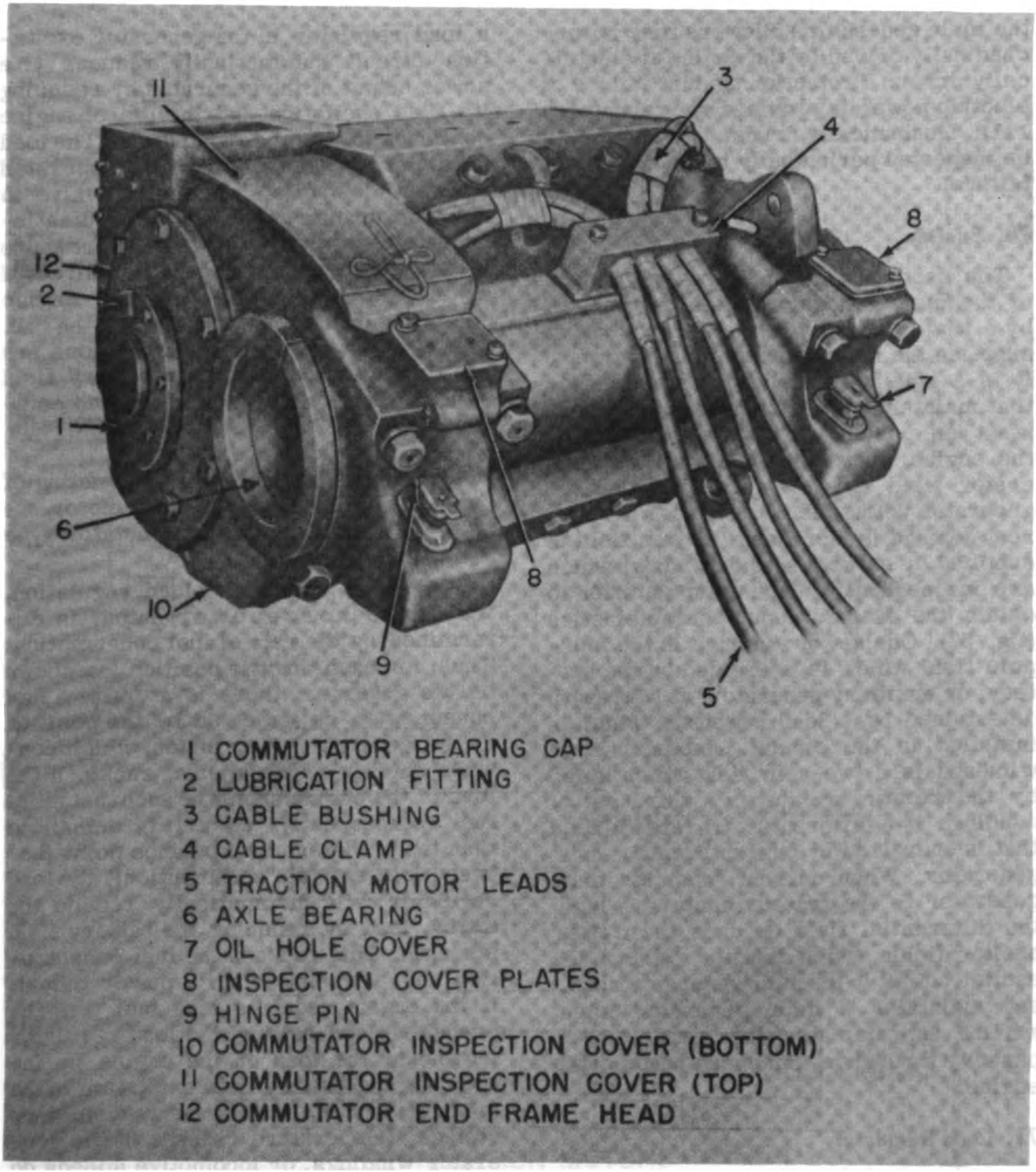


Figure 51. Traction motor.

TRAIN UNLESS THE TRACTION MOTORS ARE ADEQUATELY COOLED. The heat generated by heavy currents will damage the motors if it is not carried away. Blowers are mounted on the floor of the locomotive and ducts carry the air through the underframe to the motors. (On ALCO MRS models, the rear blower is attached directly to the power takeoff gear unit of the main generator.) Blowers may be mechanically driven by the engine or electrically driven. Protection against failure of electric power is provided by a relay (para 111). Mechanically driven blowers should be inspected periodically to guard against failure.

70. Exciter

The exciter is mounted on the gearbox of the main generator and is gear driven by a shaft extension inside the gearbox. It supplies the main generator field current. It is a small, specially wound generator that maintains power output as nearly constant as possible. To avoid overloading the engine, the strength of the main generator field must be varied so that the generator voltage is decreased as the current demand is increased. Its own field is supplied by several sets of windings which are independent of each other in order to obtain the desired ouput characteristics (fig. 52). One set of windings is the four-pole field which is energized by the battery, or auxiliary generator, at a strength determined by a load regulator which is installed in the circuit. Another set of windings is a two-pole field which is fed by the exciter armature. A third set of windings is a differential (reversed) field that is energized by current from the main generator. When current from the main generator to the traction motors is high, the differential field opposes the other exciter fields which thereby reduces the exciter output to the main generator fields, and maintains a main generator output which approximates the engine power capacity throughout the speed range of the engine.

71. Load Regulator

a. Control of the power ouput of the main generator, so that the engine speed will not fall below that called for by the throttle setting, is known as load control. As load is imposed on the engine, the governor admits more fuel until the fuel limit for that speed is reached. Any attempt to increase the load beyond this point will cause the engine to slow down. At such time, a load regulator in the generator excitation circuit automatically reduces the power output of the generator by reducing its field excitation and the diesel engine continues to run at normal speed. The load regulator is an automatically operated rheostat controlled by a pilot valve in electrohydraulic governors or pneumatic-hydraulic governors. Engine oil pressure is used to move the rheostat, as directed by a pilot valve, loading the engine according to the throttle setting in the cab. The only external wiring connections are two leads to the generator battery field circuit. The load regulator has two components—

(1) The pilot valve.

(2) A self-contained unit consisting of a hydraulic vane-type motor attached to the commutator-type rheostat.

b. For the purpose of load regulation, the engine horsepower output is determined by the rate of fuel consumption. Thus, for each throttle position (as shown on the governor) there is a definite fuel consumption as indicated by the position of the governor power piston, which controls opening of the injector racks. If the load of the engine should be such that more fuel (consequently, power) is demanded than the predetermined balance point (between load and fuel consumption), the load regulator will automatically reduce the engine load by reducing the battery field strength. This reduces the fuel consumption and, correspondingly, power output. If the engine requires less fuel than the predetermined setting, the load regulator increases the load on the engine by increasing the battery field excitation of the main generator. In this manner, battery voltage, temperature changes in the generator windings, or locomotive speeds do not cause overloading or underloading of the engine and a constant power output is maintained for each throttle setting.

72. Main Power Switches

The power contactors illustrated which connect the traction motors to the main generator are pneumatically operated,

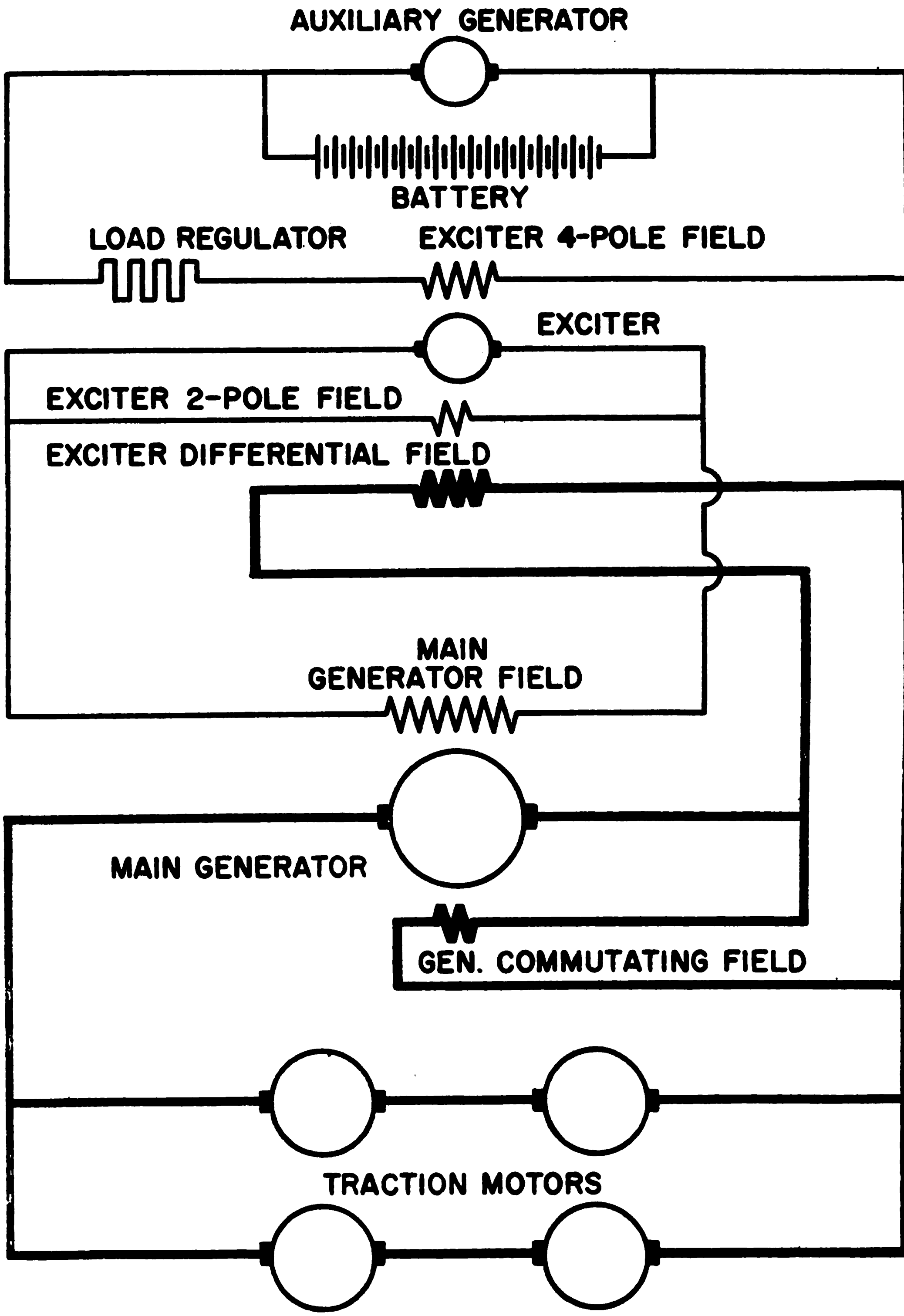


Figure 52. Exciter circuit.

heavy-duty single-pole switches rated at approximately 1,200 volts and 800 amperes (fig. 53). They are located in the high voltage electrical equipment cabinet. The contactor (variously called a unit switch or pneumatic power switch) consists of one fixed and one movable contact, a magnet valve, an arcing horn, arc box, and blowout coil. The magnet valve is energized by the low voltage control circuit when the throttle is advanced to the first notch. This is usually accomplished through an intermediate power control contactor in order to obtain proper interlocking and avoid cumbersome wiring to the throttle which would be necessary if all related equipment were connected directly. An energized magnet valve admits air to the cylinder, thereby moving the piston and linkage to close the contacts. Spring action on the piston or linkage opens the power contactor when the control circuit no longer energizes the magnet valve. Even though circuits are designed so such contactors normally open when traction motor current has dropped to a negligible quantity, provision must be made for interrupting heavy current when the contactors occasionally open under load, as during an emergency brake application. Standard construction for such conditions consists of an arcing horn to carry the current and avoid pitting the main contact tips, an arc box to confine the arc and prevent burning other parts of the contactor, and a blowout coil by which the magnetic field of the coil forces (or "blows") the arc away from the tips. As the path of the arc increases in length, the difficulty in jumping the gap increases, the arc is ruptured and current ceases to flow. These contactors are also used to establish the various connections of the traction motors between each other during transition, in addition to the connections with the main generator. The coil of the magnet valve of a contactor in the transition circuits must be connected to the transition controls which determine when the contactors open or close. When the transition controls are in series position, only the power contactors in series motor connections are energized (closed); when the transition controls are in series-parallel position, only the power contactors in the series-parallel motor connections are energized.

73. Reverser

The reverser is an electropneumatic switching device which reverses the connections of the traction motor field windings (figs. 54). The traction motors change their direction of rotation when the fields are reversed, thereby changing the direction of travel of the locomotive. A rotating cylinder, or drum, is the main switching element of the reverser. Copper segments on the surface of this drum are so arranged that contact is made with different combinations of sliding-fingers as the drum rotates through a small angle. It is controlled by the reverse lever at the control stand in the cab. When this lever is in the forward or reverse position, the corresponding magnet valve on the reverse is energized and air is applied to the pneumatic operating mechanism (air engine) to turn the drum and establish the proper electrical connections (the actual turning may occur only after other controls are set, depending on individual design). If the coil of a magnet valve is burned out, the reverser may be thrown manually by depressing a button (pin) on the magnet valve. The shaft may also be turned manually if the air supply fails, by applying leverage to a handle at the base of the drum. A neutral position is seldom desired but is available on some types of reversers. When the engine is dead, the drum can be turned by hand. Small cams are mounted on the drum to operate interlocks in the control circuit. The magnet valves on the reverser are fed through interlocks on the main power switches (or related equipment) so that the reverser will not turn except when the power circuits are open. The reverser does not break any current, and there should be no burning or pitting of the main contacts.

74. Traction Motor Field Shunting Equipment

Traction motor fields are provided with shunts which divert or bypass a portion of the field current when the full power

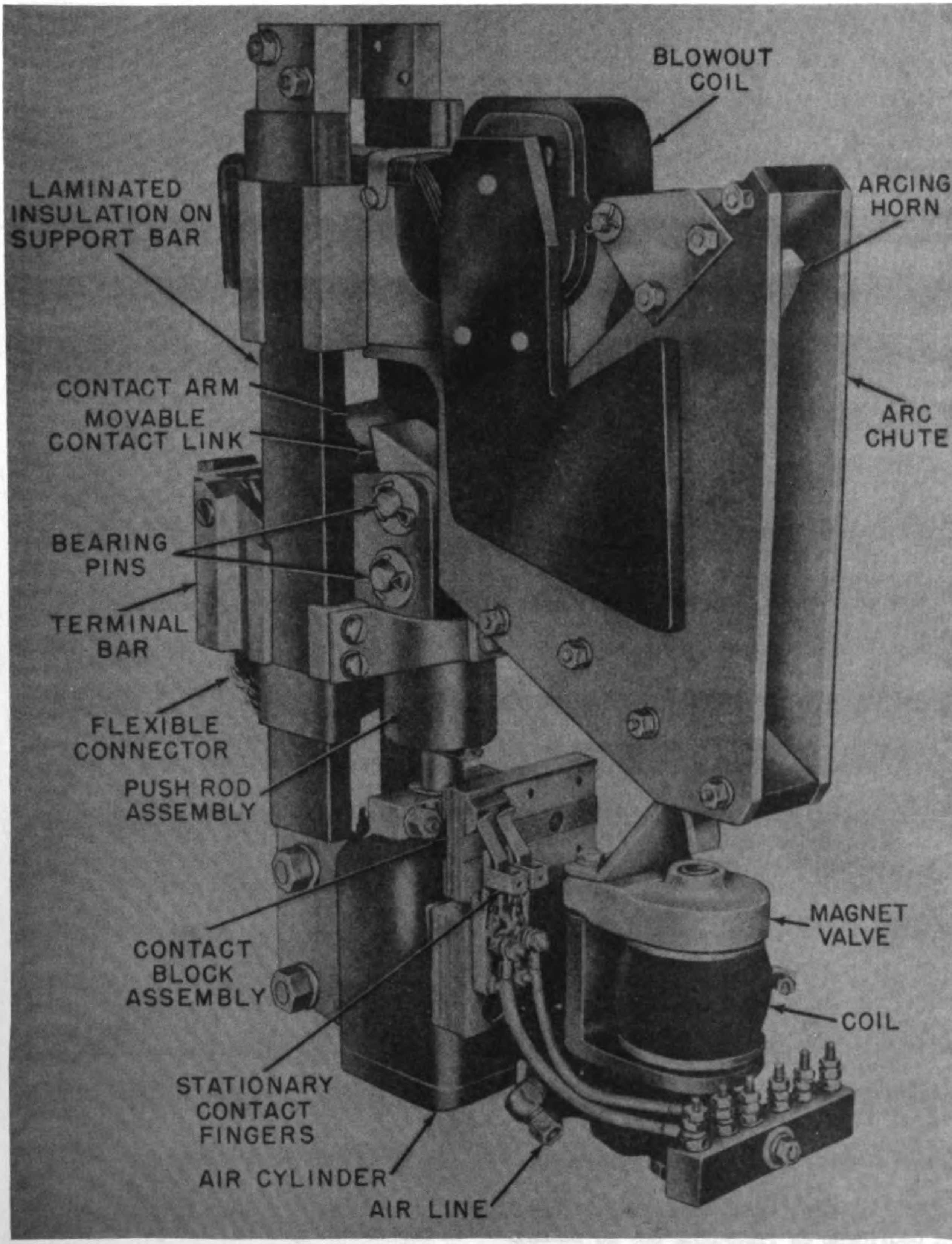


Figure 53. Power switch.

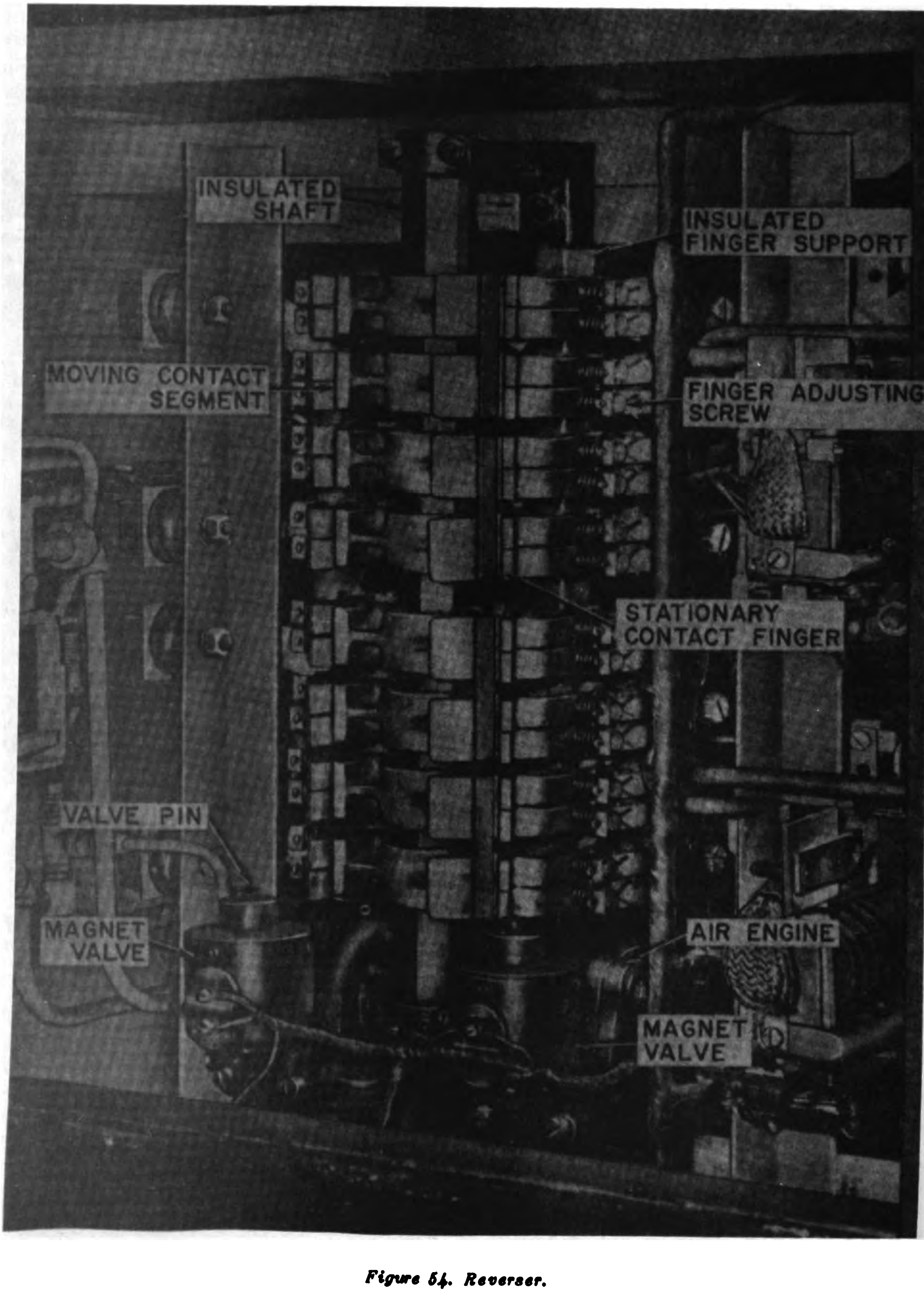


Figure 54. Reverser.

output of the diesel engine cannot be absorbed by motors with full field strength (para 61*b*). Field shunting takes place during certain steps of manual transition and automatic transition, and on locomotives which do not change their motor connections except for shunting. Some manufacturers use field-shunting contactors which are pneumatically operated by magnet valves; others are operated by electric relays. A relay operation is one of the easiest to understand. Relays are set to open and close at certain generator voltages, which are reached at certain locomotive speeds because of the definite relationship of speed and voltage. The relays then close the field-shunting contactors which permits some of the current to flow through the shunts, thus weakening the fields. This is equivalent to visual observation of the speedometer to ascertain the proper time for manual field-shunting transition, plus the manual shifting of the transition lever to close the field-shunting contactors. When the fields are shunted, the current increases about 200 amperes and is clearly indicated by the load ammeter. The motors are then absorbing a greater diesel engine power output. The contactors are electromagnetically operated, similarly to those described in paragraph 63*c*. In disassembling shunting contactors, care must be taken to never drop the piston, or piston head, or cylinder head. These parts require accurate tolerances and a mar may ruin the machined surfaces.

75. Load Ammeter

An ammeter connected to the main power circuit is mounted near the control stand where the operator can readily observe it. It is frequently connected in one of the motor circuits, in which case other motor circuits are carrying an equal amount of current and the main generator current is the sum of all motor currents. The scale of the ammeter may be divided into colored zones which indicate short time ratings for overload operation. In addition to figures showing the current in amperes, it may be marked in minutes to the overloaded portion of the scale which indicates the maximum time the locomotive may be operated at that load. Heavy current flows at low speed and decreases as speed increases (fig. 55). The greater the current is, the greater the heating is, and a correspondingly shorter time limit is allowable before reducing the load to continuous rating (in the white zone if colored bands are used). The dial may also indicate "series only" controller settings for transition type locomotives. An instruction plate below the ammeter gives directions for the use of these short time ratings.

Note. If the ammeter is in a circuit which is opened by the traction motor cutout switch, it will not indicate any current, but proper transition and overloading limitations must be observed.

76. Load Limits

a. *Continuous Rating*. A diesel-electric locomotive will overload itself without stalling the engine. Therefore, it is necessary to provide the operator with limiting controls. The limitations cannot be specified in detail for all conditions of loading, and much is left to the judgment of the operator, who should thoroughly understand the nature of these limitations. The greatest damage is likely to come from overheating the traction motors. The continuous rating of the motors is the load at which the heat generated by the current flowing through the motors equals the rate at which the heat is dissipated and the temperature remains constant. If the motor starts cold, it takes more than one hour of operation at the continuous rating to reach the constant temperature. Motors must be carefully designed to be able to stand this temperature without melting solder, loosening connections, and roasting insulation so it becomes brittle and fails to insulate. The constant temperature is also the approximate maximum safe temperature. Higher temperature may cause a motor failure, either immediately or in normal service in a comparatively short time after being damaged. The continuous rating designated on the ammeter, as described in paragraph 75, is determined by those heating factors.

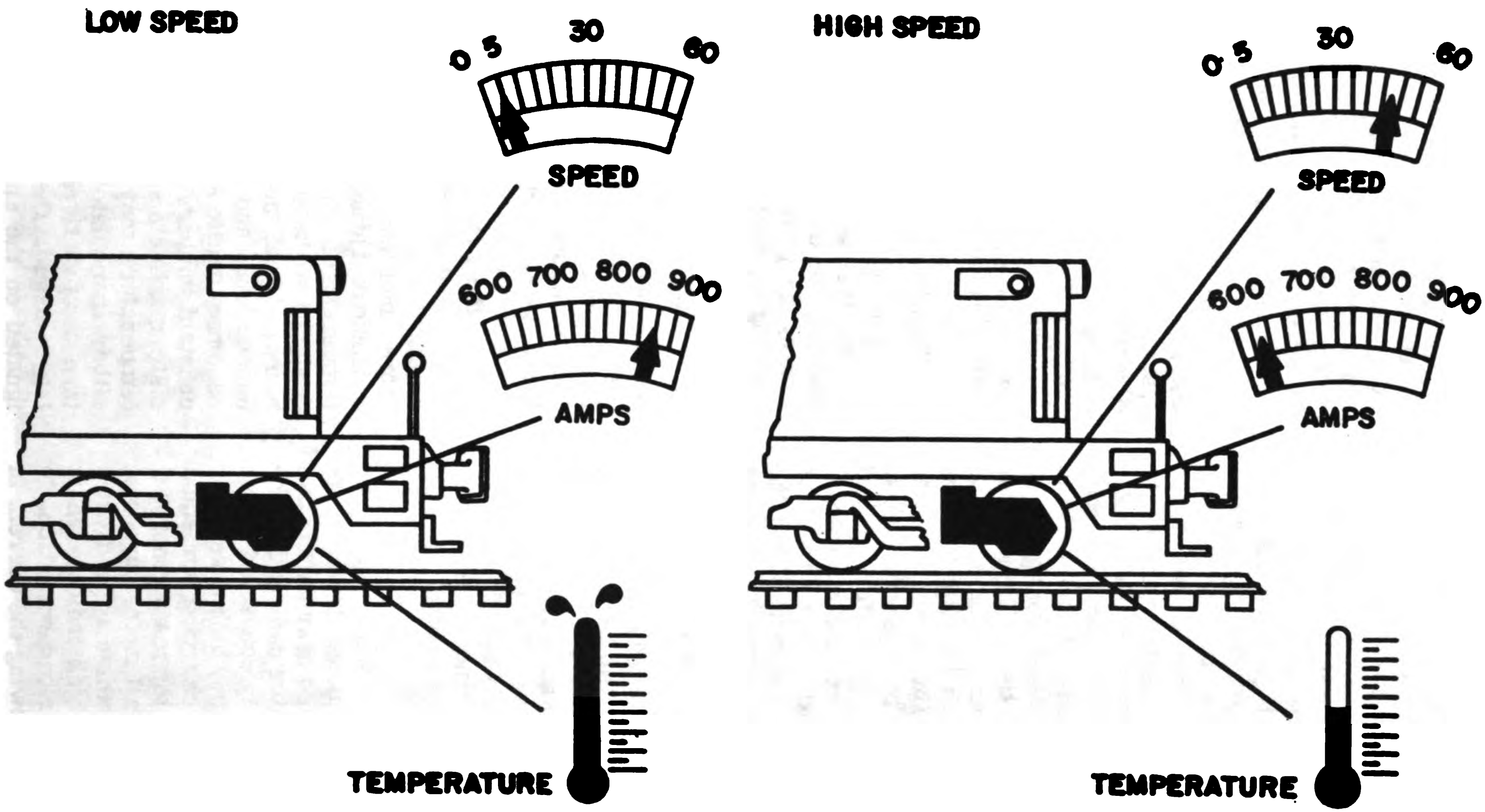


Figure 55. Load characteristics.

b. Overloads. Any ammeter indication greater than the continuous rating constitutes an overload. Electrical apparatus will safely carry an overload for a limited time if maximum allowable temperature has not been reached. There are many times when it is desirable and safe to use this overload capacity in a locomotive, but the greater the load, the sooner the limit is reached. The loads allowed under such conditions are called short-time ratings. A 1-hour rating means that, starting cold, the continuous temperature will be reached in 1 hour. A 30-minute rating is permissible for 30 minutes, and a 10-minute rating for 10 minutes, under similar circumstances. The dial of the ammeter may be marked in like manner; *for example,* 20 percent greater current (load) for about 20 percent less time than that required to reach maximum temperature at continuous rating, or 40 percent greater current for 40 percent less time. Any overload which begins when the motors are partly warm should not be imposed for as long a time as when starting cold, and any motor which has been operating at the continuous rating for a long time does not have any overload capacity. If the point remains between two different overload ratings, the operator can estimate an intermediate permissible time. If the load changes, the operator is again confronted with a situation where judgment must be exercised. *For example,* a train accelerates from a cold start with the locomotive ammeter at a 10-minute short-time rating, but in 10 minutes has reached a speed where it is working at the 30-minute short-time rating. Even though the ammeter shows danger, it is safe to continue the load for 10 more minutes. Assuming the locomotive enters an upgrade where it works at the 20-minute short-time rating, and half the allowable overload (heat accumulation) has been consumed in the first 10 minutes of acceleration, there remains a 10-minute period in which the locomotive may climb the hill at the 20-minute short-time rating. Trains in routine railroading are made up so that locomotives may successfully negotiate the ruling grade. If part of the locomotive's power is lost (or cut out), load limits on a judgment basis assume great significance for the remaining power in use. When Army personnel find it necessary to operate in strange territory, the load limits must be promptly ascertained from any available records or established by railway personnel who thoroughly understand the various factors involved.

77. Transition

Transition is the act of changing traction motors from series connection to series-parallel or parallel connection, or closing field shunting circuits to weaken the traction motor fields. Its purpose is to change the flow of current to obtain a more effective use of power. Field shunting is relatively simple and can be done in two or more stages if desired. Automatic shunting relays usually control the changes. Transition of motor connections is frequently done automatically, although hand operated transition controls are in use. Transition occurs when the proper circuit values prevail on either increasing or decreasing locomotive speeds. It is normally called backward transition when original connections are made in the opposite sequence as speed decreases. When motors are connected in series, the same current flows through each motor and the generator voltage is impressed on the entire group of motors, resulting in a comparatively low voltage for each motor. If the connections are changed to put motors in series-parallel or parallel with each other, higher voltage is impressed on each motor resulting in a corresponding increase in current through each motor and a corresponding increase in power output of the generator. When the fields of a series motor are shunted, only a portion of the current continues to flow through the fields. This weakens the field and the countervoltage, or back-emf. This is equivalent to lowering the resistance of the circuit and results in an increased flow of current. Increased current in every instance increases the torque, the tractive effort, and the power drawn from the generator, and a balanced condition for voltage, current, and tractive effort is reached at progressively higher speeds.

78. Dynamic Braking

Locomotives are often provided with additional electrical equipment through which the energy of a train moving downgrade is converted to electrical energy which is dissipated as heat in special resistors. The speed of the train is kept down by the force required to generate the electricity, and the feature is known as dynamic braking. Its use, particularly on long grades, reduces wear on brakeshoes throughout the train, prevents excessive heating of the wheels, and eliminates operating stops for cooling wheels. The traction motors act as generators driven by the axles during dynamic braking. The motor connections are changed during braking, and the amount of braking is regulated by changing the field excitation of these motors. The controls are built into the throttle and reverse lever. This system is independent of the airbrake system which may be used simultaneously on the train, although the airbrakes are automatically interlocked out of action on the locomotive to prevent sliding the wheels. Dynamic braking necessarily bunches the train; therefore, slack should always be adjusted gradually. Controls are simple, but detailed instructions for each model should be obtained from the appropriate instruction manual. The technique of graduated release and application of brakes is simpler than with airbrakes, but the technique of handling long trains in conjunction with airbrakes should be carefully studied. Individual relays and contactors are inspected and maintained in the same manner as other relays and contactors. Maintenance and adjustment of an installation on the locomotive must follow individual testing instructions on sequence, relay pickup, and loading. Operating instructions must be obtained for each locomotive, but a brief summary of typical operation is given in the operating section. U. S. Army-owned diesel-electric locomotives are not equipped with dynamic braking.

Section II. POWER CONTROL SYSTEM

79. Power Control Circuits

Control circuits are low voltage circuits that control through relays on contactors the heavy switching equipment necessary for handling the high voltage power circuits. The equipment is a typical control circuit (fig. 56) and is both manually and automatically operated. The principal manual controls are at the operator's position shown in figure 57, but there are many automatic features in the circuit to insure a proper sequence in closing and opening switches, thereby removing much burden and responsibility from the engineman. Other apparatus is entirely automatic such as the field shunting controls. Power is generally fed through a master control switch from the source. The operating coils in the heavy switching equipment appear next to the negative return line of the control circuit. The intermediate equipment between the control switch and the operating coils consists of manual controls, automatic controls, and interlocks which determine when the heavy switching equipment is energized. Abbreviated illustrations of tracing a circuit are shown in figure 56. Except on small locomotives, a reverser valve must be energized to throw the reverser. This requires that the control switch be closed, the throttle be advanced (the contactor symbol on the throttle "rides" the segment on the ON line when the throttle is advanced from OFF), and the reverse lever be in FOR or REV (the contactor symbol on the reverse lever "rides" the segment on the REV line when in the REV position). A pneumatic throttle is shown. An electric throttle functions similarly in the portion of the circuit just described, but is more complicated, because it has eight "on" positions. In the diagram shown, interlocks on the reverser close to complete the circuit between the reverse lever and the power cutout switch and engine control switch. If circuit conditions are satisfactory, the power control coil is energized. The power control contactor then closes, which (other interlocks permitting) sets up the circuit to the coil of the power switches. When these coils are energized, the power switches close. The combined reverser and the power switch settings have not connected the traction motors to the generator. It is fundamental that all heavy-duty contacts of control apparatus appear in the main power diagram and the low-voltage operating coils appear in the control diagram. Diagrams for specific use in manufacturing and repairing the equipment carry wiring details showing all coils, contacts, and interlocks in one assembly. Wires are identified by numbers. For example, a detail of power switch P1 would have coil connections identified as 52 and N (negative), interlock connections as 43 and 44 in accord with the control circuit diagram, and main contactor connection designated for proper wire connections to the number one motor in accord with the power circuit diagram. These numbers are generally painted on the equipment and banded to the wires on a stamped tag.

80. Control Station

The operator's control station located in the cab includes a control stand, brake stand, control panel, instrument panel, speed indicator or recorder, headlight switch, and all essential equipment for controlling locomotive movement (fig. 57). All locomotive movement is controlled by four (or five) handles: the throttle, reverse lever, transition lever, if installed, automatic brake valve handle, and independent brake valve handle. Some locomotives have dual control stands in the same cab, but they are interlocked so that the locomotive can be controlled from only one stand. Much of the accessory equipment is not duplicated in dual control installations.

81. Operating Instruments and Controls

a. The throttle lever controls the speed of the diesel engine and, consequently, the power delivered to the traction motors. The throttle that functions through an electropneumatic governor or electrohydraulic governor is called an electric throttle and must be connected electrically to the governor. A throttle that functions through the air system is called a pneumatic throttle and must set the governor through a pneumatic actuator. Some locomotives have a mechanical linkage between the throttle and governor.

(1) A typical electric throttle has seven or eight running positions in addition to a stop position and idle position. As the throttle lever is moved through its operating range, various electrical connections are made between the low voltage control lines and the solenoids in the governor. Fingers making sliding contact with segments on a rotating drum or cylinder in the throttle, thus determine the fuel setting of the governor. The drum may also have auxiliary contacts to maintain proper sequence or interlocking of other equipment, the most typical of which is in the control circuit to the main power switches. The throttle is also interlocked mechanically with the reverser and with the transition lever if transition is controlled manually. These features insure the opening of the main power switches when necessary during various stopping and reversing operations.

(2) A pneumatic throttle is equivalent to a pressure regulating valve. The pneumatic actuator responds to the pressure established by the throttle to determine the fuel setting of the governor. It has auxiliary contacts similar to the electric throttle, for sequence and interlocking features. Except for notches at the ends of its arc of travel, the throttle moves smoothly through an infinite number of positions. Multiple-unit operation of locomotives with pneumatic throttles requires an air line at control reservoir pressure between the units.

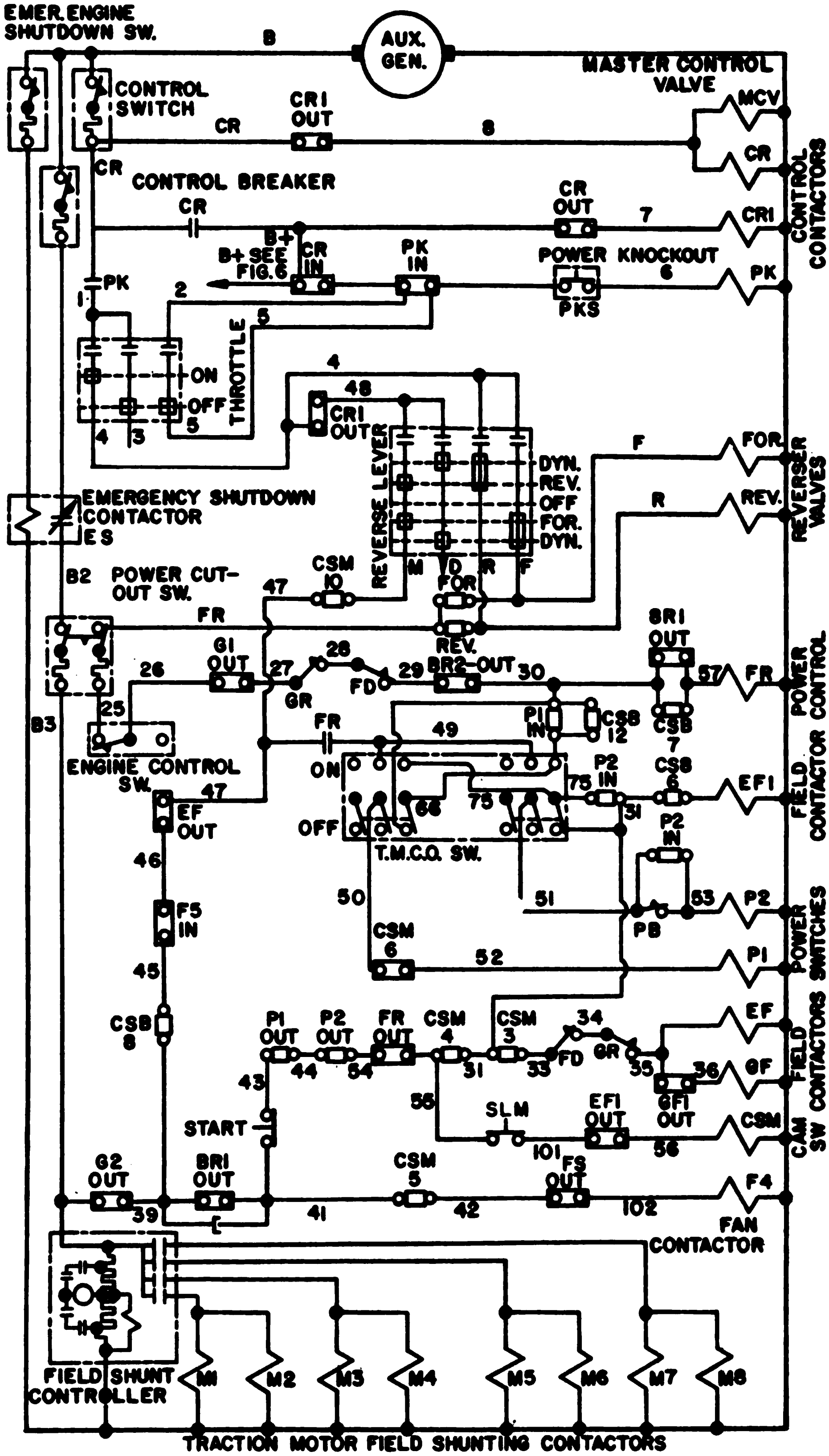


Figure 56. Power control circuits.

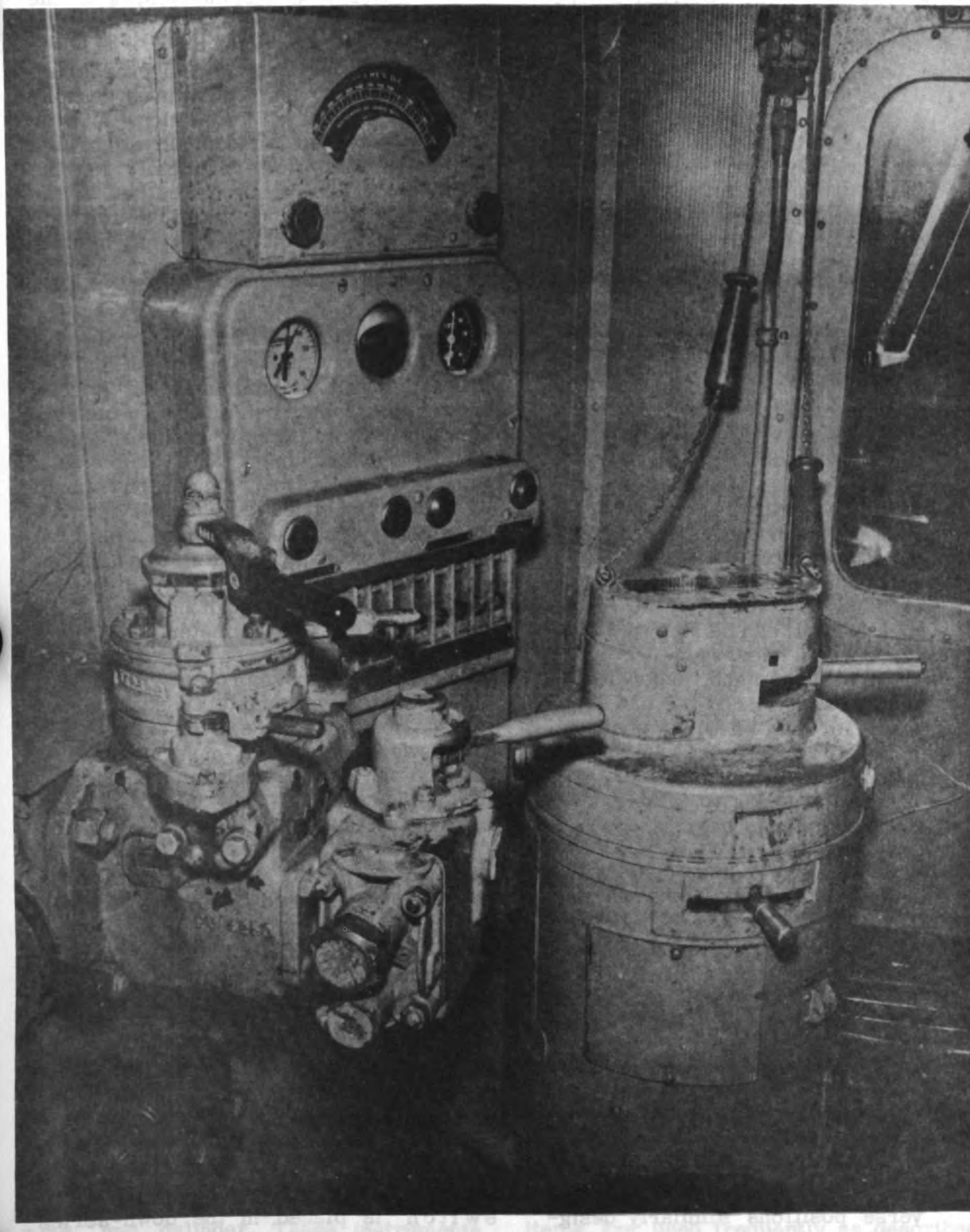


Figure 57. Operator's controls.

b. The reverse lever controls magnet valves in the reverser, which is thereby turned to change the connections of the traction motor fields.

(1) There are several types of reverse levers all of which are easily handled. For any information or modification, not clearly understood from the following typical descriptions, refer to the instruction manuals for the specific locomotive. In its simplest form, the reverse lever has three positions—FOR, REV, and OFF. In the OFF position, the main power contactors will not close when the throttle is advanced. In the FOR position, the forward magnet valve of the reverser is energized, which turns the drum and changes motor connections as described in paragraph 73. In the REV position, the reverse magnet valve is energized. This lever must not be moved when the locomotive is moving, because circuits are likely to be short-circuited. It can be removed from the control stand when it is in the OFF position (and, depending on model, with throttle and transition lever in idle or off position). It should be removed if the locomotive is unattended, even briefly, in order to interlock the controls in an inoperative position.

(2) A five-position reverse lever may have dynamic braking forward and reverse positions added. The lever is, of course, moved to the braking position while moving, but should be moved between FOR, OFF, and REV *only at standstill,* as directed above for the three-position reverse lever.

(3) A seven-position reverse lever (possibly called controller by some manufacturers) has an off position, three forward positions, designated series, series-parallel, and reduced-field, and three reverse positions similarly designated. Such a lever is used on certain manually controlled transition-type locomotives, and the transition lever (*c* below) is omitted.

c. A transition lever (or selector lever) is provided on locomotives having manually controlled transition. It may also be installed on locomotives having automatic transition, principally for the purpose of controlling trainlined transition circuits during multiple-unit operation with locomotives having manual transition. It usually has five or six positions— OFF, 1, 2, 3, and 4. A braking position is sometimes provided for dynamic braking. The proper step of transition is usually indicated on the dial of the load ammeter, or speedometer. The relationship between current and speed is sufficiently definite to permit either instrument to be used as a guide for transition. Transition should be made when speed (or current) changes to a different range, in both acceleration and deceleration. It should also be changed when decelerating with throttle in the idle position, even though no current is registered on the ammeter, to avoid a subsequent advance of the throttle with the traction motors improperly connected. Approximate appropriate speeds for the various positions of the lever are position 2 between 17 and 23 mph, position 3 between 23 and 49 mph, and position 4 above 49 mph. (This information is descriptive and should be checked for any given locomotive.)

d. A transition forestalling switch on the control panel is used to prevent undesired forward transition on automatic equipment. An example of its usefulness is an upgrade operation with short intermediate dips which may result in frequent changes of speed (and current) into a different range and consequent excessive changes in motor connections if transition continued automatically. In a typical installation when the switch is in the up-auto position, forward transition will take place automatically at the proper time. When forward transition is not desired, the switch is placed in the down-series position. Traction motor connections will then stay in series or series-parallel, regardless of locomotive speed, generator voltage, or position of load arm. The transition forestalling switch should not be moved from the series to the auto position unless the throttle is in the 6th position, or lower. However, if the speed of the locomotive is below the forward transition speed, it is permissible to move the switch to the auto position with full throttle operation. This will prevent any possibility of forward transition taking place at an excessively high voltage. Movement of the switch from the auto to the series position may be done at any time, as this will not cause backward transition to take place. Backward transition is determined only by the operation of the backward transiton relay, or by reducing the throttle to the idle position. The operation of the transition forestalling switch is not trainlined. In multiple-unit operation, the forestalling switch in each unit must be placed in the position in which it is desired to operate the locomotive.

e. The automatic brake valve controls the operation of brakes on the locomotive and on the cars when properly connected. The independent brake valve controls the operation of brakes on the locomotive only. A separate portion of this manual describes the air system.

f. A switch, usually designated as the control switch, is mounted at the control stand to connect the control circuits to their source of power. The locomotive lights can be lit and the engine starting circuit will function (on some models) without closing this switch. All other control equipment is normally fed through this switch, or through interlocks whose setting is dependent on this switch. It is, therefore, equivalent to a master switch for locomotive controls on the locomotive and on any trailing locomotive to which the controls are connected in multiple.

g. The instrument panel consists of a load ammeter and two duplex air pressure gages showing pressure in the main reservoir, equalizing reservoir, brake pipe, and cylinder. These instruments together with the speedometer (if installed) are those continually used in operating the locomotive. A road locomotive usually has no other instruments in front of the operator, although water temperature gages and oil pressure gages in the fuel, engine lubricating, and turbocharger lubricating system should be observed frequently. In a switcher, those gages may be in front of the operator because the cabinet on which they are mounted is part of the front cab wall. On a road locomotive, they are found on the rear cab wall or along an aisle of the engineroom. Also, if the locomotive has more than one power unit, separate gages are installed for each unit. They are properly part of a control panel, and are best considered separately, even though they are mounted directly in front of the controller in some models.

h. The control station normally consists of instruments and manually operated switches which are associated with a power unit. The engine control panel houses the speed setting, engine shutdown and signal relays controlling the diesel engine. It also contains the resistors, rectifiers, capacitors, and wiring, comprising portions of the speed control and alarm circuits. The diesel engine is started at the control station. The starting button, fuel pressure gage, fuel pump switch, and auxiliary generator field switch are part of the control station (fig. 57). The battery charging ammeter, the warning lights in alarm circuits, and a few switches are on the control panel and instrument panel (fig. 58). In general, the control station is used in starting an engine or when special operating problems arise such as isolating an engine and resetting the ground relay. The equipment should be handier than the less frequently used manual equipment inside the equipment cabinet, but need not be placed where the operator observes it constantly.

i. Miscellaneous controls such as the horn, bell ringer, sander, and deadman pedal are found at the control stand. These items are used frequently as described in separate paragraphs. Various selector

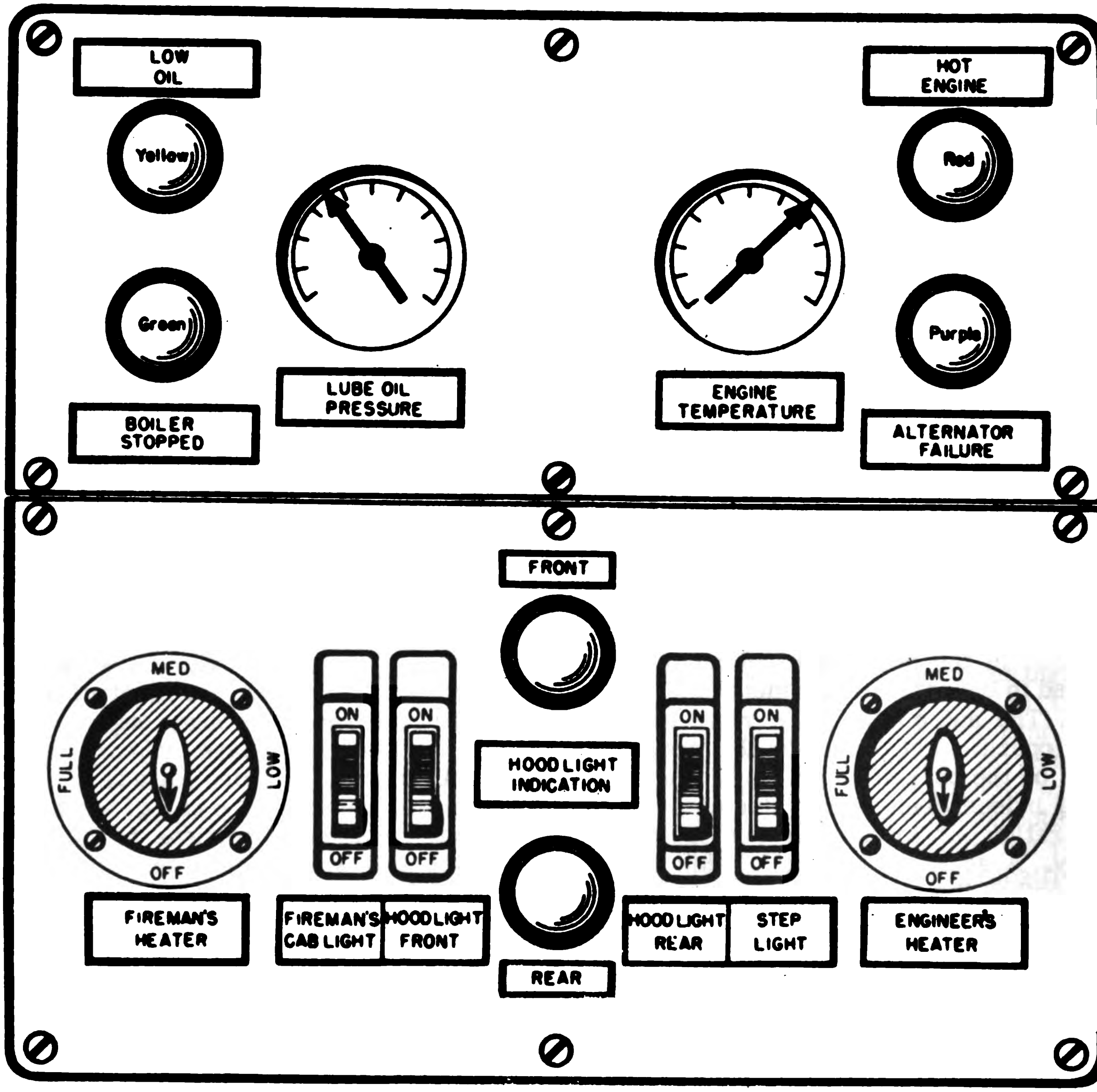


Figure 58. Control panels.

cocks, doubleheading cocks, and similar air system fixtures may be on the brake pedestal, or may be under the floor. If they are under the floor, they may be accessible by trap door, or from an outside door which is perfectly feasible since their setting is changed only when standing still. Control stand switches in circuits to various lights, heaters, and accessories are clearly identified by nameplates.

82. Electrical Equipment Cabinet

a. Most of the electrical equipment on the locomotive is mounted in a centrally located cabinet which is the "nerve center" of electrical circuits. Unless the apparatus does work on some mechanical part, or has work done upon it, it is usually mounted in such a cabinet. Some large locomotives may have a second auxiliary cabinet, or some apparatus such as a steam generator or winterization heater may have its own cabinet and panel. A water temperature switch, or low oil pressure switch, is mounted where it responds directly to temperature or pressure, and a shutter valve or radiator cooling control is mounted on the radiator bulkhead. Figure 59 shows typical equipment found in an equipment cabinet from which wires run to all parts of the locomotive. For example, a wire runs from the positive side of the generator to the power switch in the cabinet. Another wire runs from the power switch to the armature of the traction motor. After the circuit passes through an armature, or two or three armatures according to design, a wire returns to one side of the reverser. From the reverser, a wire runs to the fields of the corresponding traction motors. The circuit then returns to another set of contacts on the reverser. This apparent roundabout wiring is more then offset by many amplifications. *For example,* one reverser serves all traction motors and any interlocks such as those between reverser and sanders, or reverser and power controls, are connected by short wires to neighboring equipment within the cabinet, and testing and trouble-shooting can be done at a central point.

b. Most of the equipment in the cabinet functions automatically. Only qualified personnel should attempt to make any adjustments to the equipment. The manually operated switches are operated at irregular and infrequent intervals. The battery switch, fan switch, auxiliary generator switch, and motor cutout switches are typical of those found in the cabinet. They are all in low voltage circuits, and are well encased, so there is no exposure. However, much neighboring equipment operates at high voltage and hazards of exposed wiring must be avoided. Separate paragraphs of this manual are devoted to the various items in the cabinet.

Warning: High voltage is used on much of the equipment in the electrical equipment cabinets. Cabinet doors should be kept closed as much as possible. When doors are open, adequate safety rules must be observed.

83. Traction Motor Cutout Switches

a. A traction motor cutout switch is used to take the motors out of the circuit if there is an electrical failure, such as a short circuit or ground, in the circuit. There are three types of cutout switches —

(1) A simple toggle switch in each motor circuit which has an open position and closed position.

(2) A multipole rotary switch which controls all motor circuits according to designations on its nameplate.

(3) Manually set contacts mounted on the reverser as on the MRS-I locomotive (electric motor driven only).

b. Only one rotary switch is needed for each unit. In installations of rotary or toggle-type cutout switches, the control circuit to the main power switches passes through the traction motor cutout switch. When the cutout switch (para 72) is open, the main power switches are deenergized (opened) and the corresponding motors are disconnected from the generator. The switch setting should not be changed under heavy load because heavy currents are likely to arc and burn the contactors. Idle the engine by the throttle, or by an isolating switch, before opening a power circuit.

84. Engine Shutdown Controls

There are so many methods of stopping a diesel engine that only general descriptions can be given here. However, after basic information is acquired, the operation of various installations is more readily understood. Operators should clearly recognize the difference between routine stopping and emergency stopping, and familiarize themselves with the various provisions thereof on different locomotives. The fuel supply is shut off by the various stopping controls listed below, but some act more promptly than others, and some act on an individual engine only, while others stop all engines in multiple-unit operation.

a. Stop Position on Throttle. When a throttle is provided with a stop position, the fuel control shaft on the engine is turned to the no-fuel position, usually by

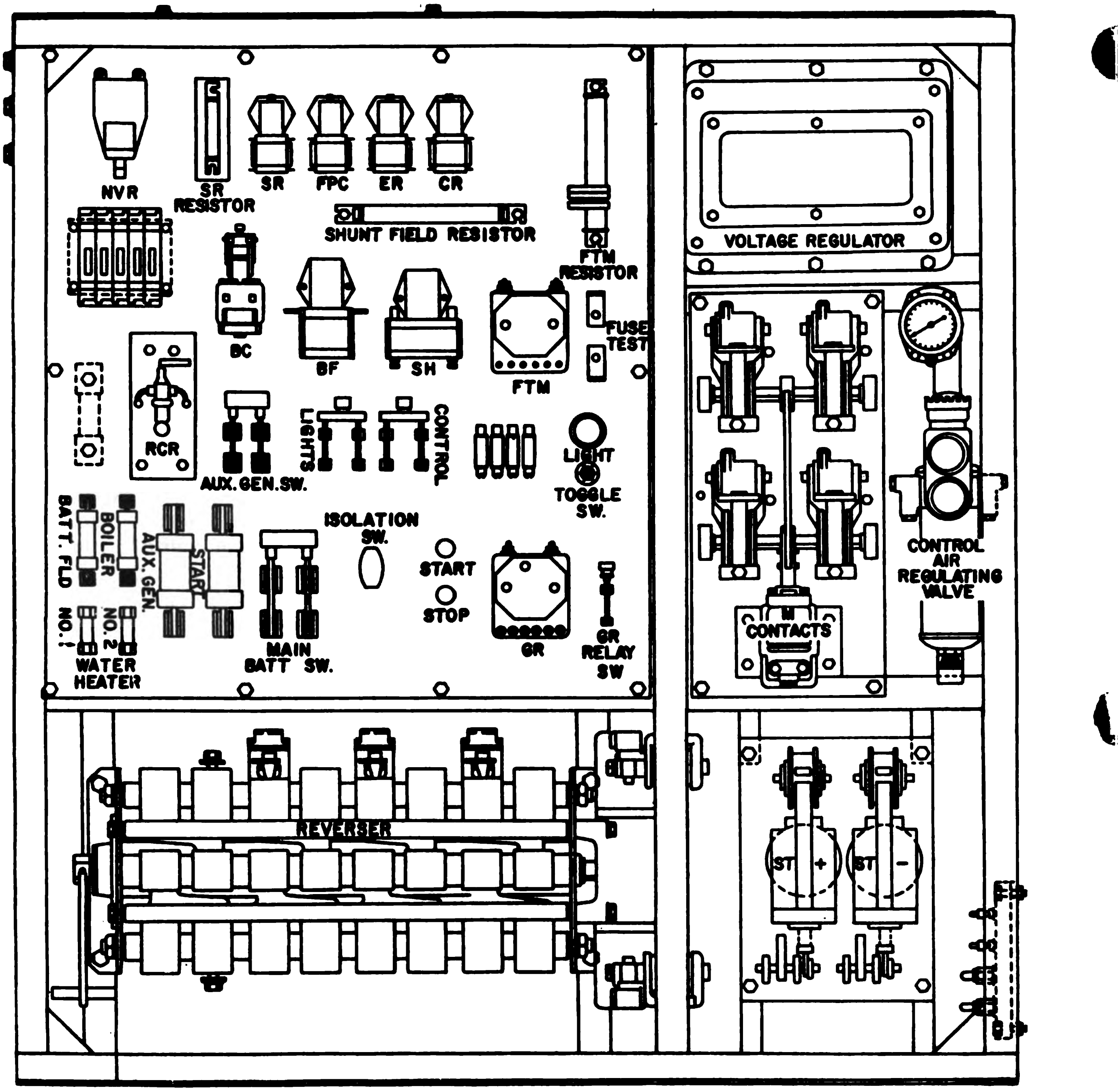


Figure 59. Typical electrical equipment cabinet.

a solenoid in the governor, or a related shutdown valve which is not built into the governor, but acts on the fuel control shaft in the same manner. The throttle is provided with interlocking which prevents unintentional movement to the stop position. The stop position of the throttle stops all engines in multiple.

b. Governor Shutdown Plunger. A plunger on the governor may be pressed by hand to shut down the engine. The fuel control shaft is turned to the no-fuel position by the governor, but only one engine is affected.

c. Engine Stop Button. The engine may be stopped by an engine stop button which closes the stop circuit in the same manner as the stop position on the throttle. The button may be installed at a strategic point in the engine compartment and affords quick shutdown from either leading or trailing units. If the throttle does not have a stop position, a stop button of the adjacent control panel stops the engine routinely, or cuts out a single power unit if other units in multiple are kept in operation. Buttons elsewhere are generally called emergency stop buttons and affect all engines in multiple.

d. Automatic Controls. Any protective device may be connected to stop the engine if desired. Low lubricating oil pressure protection is universally incorporated with stopping controls. Hot water protection and ground relay protection may be in either a stopping circuit or an idling circuit and are described in detail under their respective headings.

e. Miscellaneous Fuel Supply Controls. The engine will stop if fuel is shut off by opening the fuel pump switch, opening the control switch, or tripping the emergency fuel cutout valve operated by pull rings. These are seldom used as routine or emergency stopping methods and are listed here for information only.

85. Pneumatic Control Switch

Engine power output should be reduced when there is any emergency brake application or penalty applicatione from safety control, overspeed control, train control, or similar devices. This is done automatically on many locomotives by a pneumatic control (PC) switch which is normally closed, but which trips open under certain brake pipe pressure reductions. Electrical connections differ on varions models, but, in general, relays or interlocks are brought into action which idle or stop the diesel engine, stop the fuel pump (on some installatione), and turn on indicating lights. The switch automatically resets itself when the throttle is returned to idle and brake pipe pressure has been restored (para 151*g*).

86. Multiple-Unit Equipment

In multiple-unit operation, all connected locomotives are controlled from one cab (para 147). In addition to the conventional coupling of drawbars and air lines, the electrical control circuits of the two locomotives must be connected to each other. A jumper for this purpose contains a number of wires connected to a plug which is keyed so it can be inserted in end receptacles on the locomotives in the correct position only (fig. 60). Controls are set in multiple-unit operation so that the power and brakes on all units are controlled from only one cab. The locomotive from which operation is controlled is called the leading unit, and all other connected units are called trailing units. As a general operating policy, the locomotive with the highest horsepower should be used as the lead or control unit. (The front unit usually happens to be the leading unit in actual practice, but any unit can be the so-called leading unit regardless of its position among several coupled locomotives.) The engine on all trailing units is started at the control panel on each unit. The battery switch (and a few other switches on some models) is kept closed. In all other respects, operation is controlled from the leading cab in the same manner as a single unit. Locomotives must be of similar design to connect them in multiple. A clear distinction should be noted between multiple-unit operation and doubleheading operation. Operation when coupled to a steam locomotive, or a diesel locomotive which cannot be connected electrically, is termed doubleheading. Power systems on units in multiple remain independent of each other. Typical control wires in the connecting jumper are as follows:

a. Control switch.

b. Forward-reverse control.

c. Throttle circuits.

d. Sanding circuits.

e. Alarm and indicating circuits.

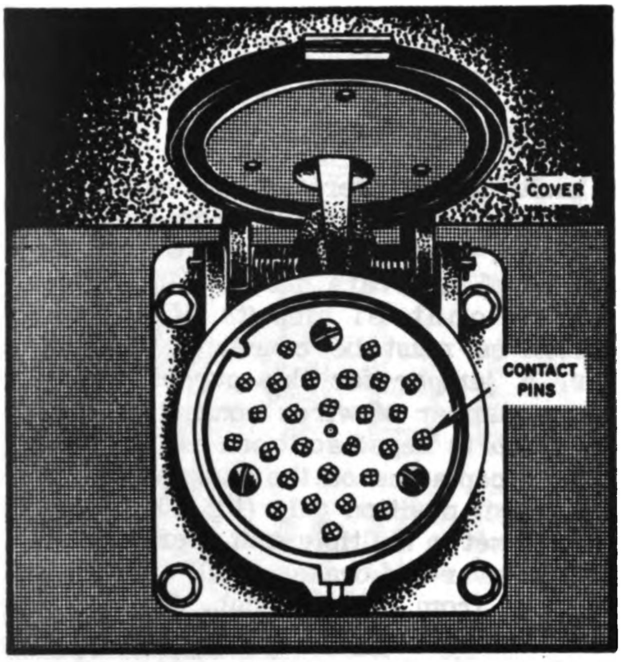


Figure 60. Multiple-unit end receptacle.

f. Compressor valve (if compressors are synchronized).

g. Fuel pump motor (except on some models, the closing of the control switch accomplishes the same thing).

h. Headlight control (if rear headlight is controlled from leading cab).

i. Emergency engine shutdown switches.

CHAPTER 11
AUXILIARY POWER SYSTEM

Section I. POWER SYSTEM AUXILIARIES

87. General

The auxiliary power system includes all low voltage circuits (usually 64-74 volts) fed by the battery and auxiliary generator. This includes control apparatus, engine starting circuits, battery charging circuits, lights, and electrical accessories. Some equipment operates partly in the main power circuit but is described here in its entirety. Much of the equipment functions automatically. Details of the installations vary greatly between models. Operators need little information beyond the basic data given here. Maintenance men must obtain pertinent data from unit instructions.

88. Auxiliary Generator

An auxilary generator of about 10 kw capacity is used to provide auxiliary power to operate control equipment, charge the storage battery and to supply the low voltage circuits for lighting, fuel pump motor, and field excitation. It may be belt driven or gear driven from the shaft of the engine or main generator and is usually mounted on the frame of the main generator. The regulated voltage is slightly above battery voltage, and the auxilary generator assumes the load after the battery has supplied power for starting the engines.

89. Auxiliary Generator Switch

A two-pole auxiliary generator switch disconnects the auxiliary generator when opened. It may be a breaker-type switch which automatically gives protection against excessive current, or a simple double pole, single throw knife switch with protection against excessive current furnished by a fuse. If this switch or fuse is open, the battery must supply all low voltage requirements.

Warning: Replace this fuse only after opening the auxiliary generator switch. Most recent locomotives also have an auxiliary generator field switch or breaker. If this switch is open, the auxiliary generator will not supply the low voltage system. On locomotives having both these switches, the field switch is usually on a panel in the cab and the auxiliary generator power switch is in the equipment cabinet. The field switch is opened when the locomotive is shut down and kept open until after the engines are started again.

90. Temperature Controls

Water temperature in the engine cooling system is regulated automatically on larger locomotives. As water temperature changes, a thermostat operates temperature switches which activate fan motor contactors in definite relationships to the water temperature (para 95*b*).

91. Fan Motors

Some engine cooling fans are motor driven and receive their power from an alternating current generator (alternator). Various combinations of fan contactors provide for fan operation through an intermediate tap in the traction motor circuit. The fan contactors are energized through the temperature controls described in paragraph 90. A double-throw fan switch is usually provided in the control circuit. If the automatic controls do not function, continued operation may be assured by throwing this switch. Refer to figure 61 for typical circuits.

92. Eddy Current Clutch

a. General. An eddy current clutch is a magnetic clutch through which power

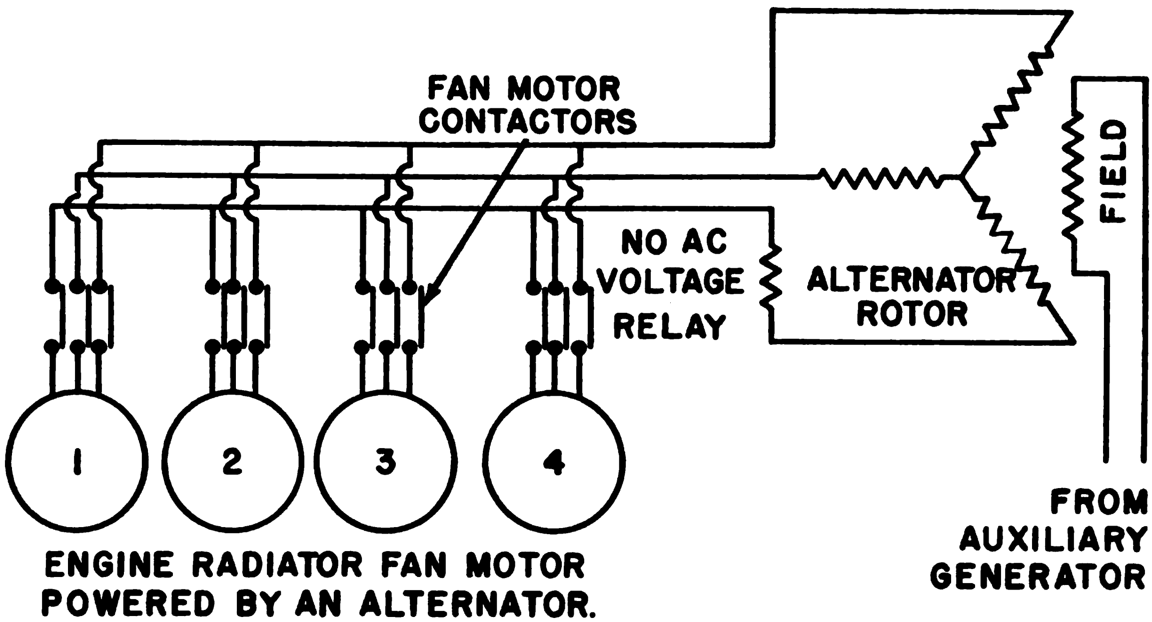


Figure 61. Fan motor circuits.

is transmitted to drive the cooling fans without any direct mechanical connection. On the ALCO 244 engine, powering the 120-ton road switcher, the eddy current clutch is installed on the drive end of the radiator fan gear unit. The clutch consists of the following three main parts:

(1) Brush holder housing (stationary part) which is mounted on the end of the gear unit.

(2) Inner rotor installed on the horizontal shaft of the gear unit.

(3) Outer rotor which is bolted onto a flange on the end of the drive shaft and supported on a double row, self-alining bearing inside the inner rotor.

b. Operation. In operation, radiator fan speed is varied by changing the excitation of field coils on the inner rotor. The control diagram is shown in figure 62. Thus, the amount of slip between the inner and outer rotor may be varied to adjust fan speed with engine revolutions. The thermostat in the cooling system gradually changes air pressure in the control lines so that as water temperature increases, the medium-speed relay closes first, and a further increase in temperature closes the full-speed relay. As water temperature drops, the same series of events takes place in reverse order.

93. Shutter Valves

When shutters are positioned automatically they are operated by pneumatic cylinders which are actuated by air supplied from the main reservoir through magnet valves. In a typical installation, the magnet valves are energized by the shutter relays which, in turn, are operated by the engine temperature control switch. The control switch is connected by a capillary tube with a temperature bulb located in the cooling system between the engine and the radiators. Current for the temperature control switch and the magnet valves is taken from the low voltage system. When the engine temperature control switch of each engine closes, it energizes the corresponding shutter relay. Closing of the shutter relay energizes magnet valves, which admit air to the operating cylinders of the corresponding shutters,

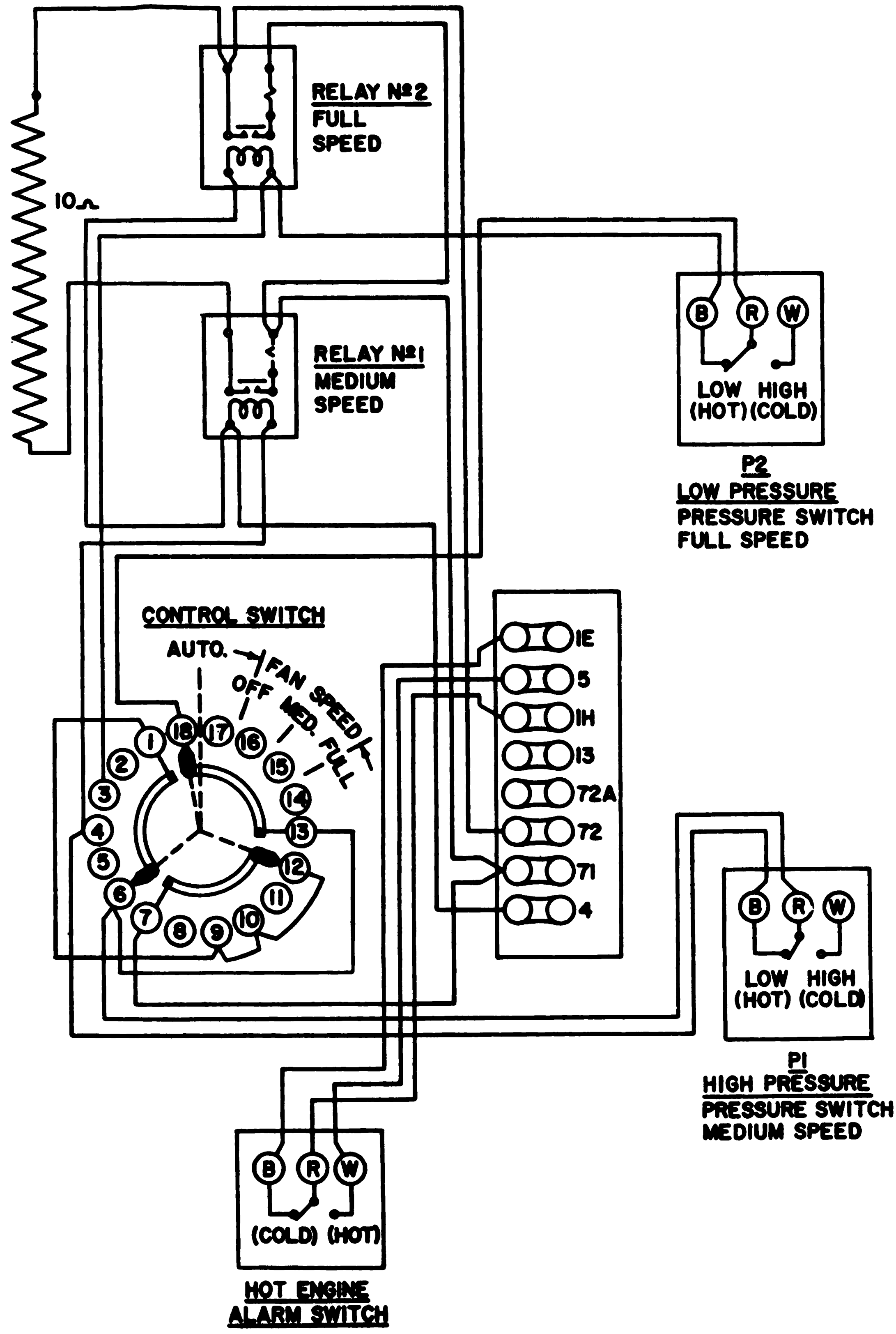


Figure 62. Eddy current clutch control diagram.

causing them to open. In each set of shutters, a system of linkage operates both the right- and left-hand shutters. The linkage is connected to a lever which is latched to a notched quadrant. The quadrant is moved by the action of the air cylinder, carrying the lever with it and thus operating the shutters. This construction permits manual operation of the shutters should any failure of the electropneumatic shutter control system occur. During automatic operation, the lever is left latched in the closed notch of the quadrant.

94. Water Temperature Switch

A water temperature switch is provided on some locomotives to close an alarm circuit if the engine cooling water becomes too hot. The switch may be connected (directly or through interlocks) to light an indicator lamp, ring a bell, and idle the engine. It can be connected to stop the engine, but it is better to dissipate some heat at idling speed if possible. Some locomotives have only the bell alarm for hot engine trouble, and when locomotives are used in multiple-unit operation, only the bell alarm is trainlined to other units. The switch is closed by a thermal element which responds to engine water temperature. The point of closing is adjustable to temperatures ranging between about 160° and 200° F. The point of opening when water cools is determined by a differential adjustment screw.

95. Ground Relay

A ground relay is installed in the main power circuit to warn the enginemen if a ground develops in this circuit. When connected, as shown in figure 63, no current will flow through the relay until some portion of the circuit is grounded. When a grounded condition actuates or closes this relay, its contacts close circuits to an alarm bell or indicator light and, in most designs, idle the engine and disconnect the traction motors. This is accomplished through a throttle valve or corresponding solenoid on a governor whose circuits are fed through the ground relay or related interlocker. Typical connections are shown in figure 63. A holding coil keeps the ground relay closed after it is energized even though it was closed by a transient condition which has cleared up. A ground relay reset button is provided to release the relay in such instances. A ground relay cutout switch may be provided to make the relay entirely inoperative. A single ground from the power circuit to the frame will not seriously affect the unit, but only limited operation should be attempted because a break through another point of weakness would be very serious. It is, therefore, possible to move a locomotive, and a train if need be, to a siding or terminal even though a ground persists. However, judgment should be exercised as to the urgency of the movement, and any rules governing the use of the ground relay cutout switch should be strictly observed. In multiple-unit operation, the indicating light is the only action usually extending to other units.

96. Wheel Slip Relay

A wheel slip indicating system is installed on the larger diesel-electric locomotives such as the 120-ton MRS-I (fig. 97). Wheel slip relays, as shown, are connected to resistors in the traction motor circuit (fig. 64). Under normal operation, balanced voltage conditions in the motor circuit do not result in a flow of current through this relay. When a pair of wheels slip, unbalanced voltage conditions cause current to flow through the relay. When this relay is energized, the contacts energize a governor solenoid which reduces engine speed and operates a buzzer warning and/or indicator light in the engineer's cab. Interlocks reduce generator excitation at the same time. When slipping stops, balanced voltage conditions exist and power is automatically restored. The buzzer or light is trainlined to all units in multiple, but engine speed is reduced only on the slipping unit. The discussion of bridge circuits in paragraph 54 describes the fundamental

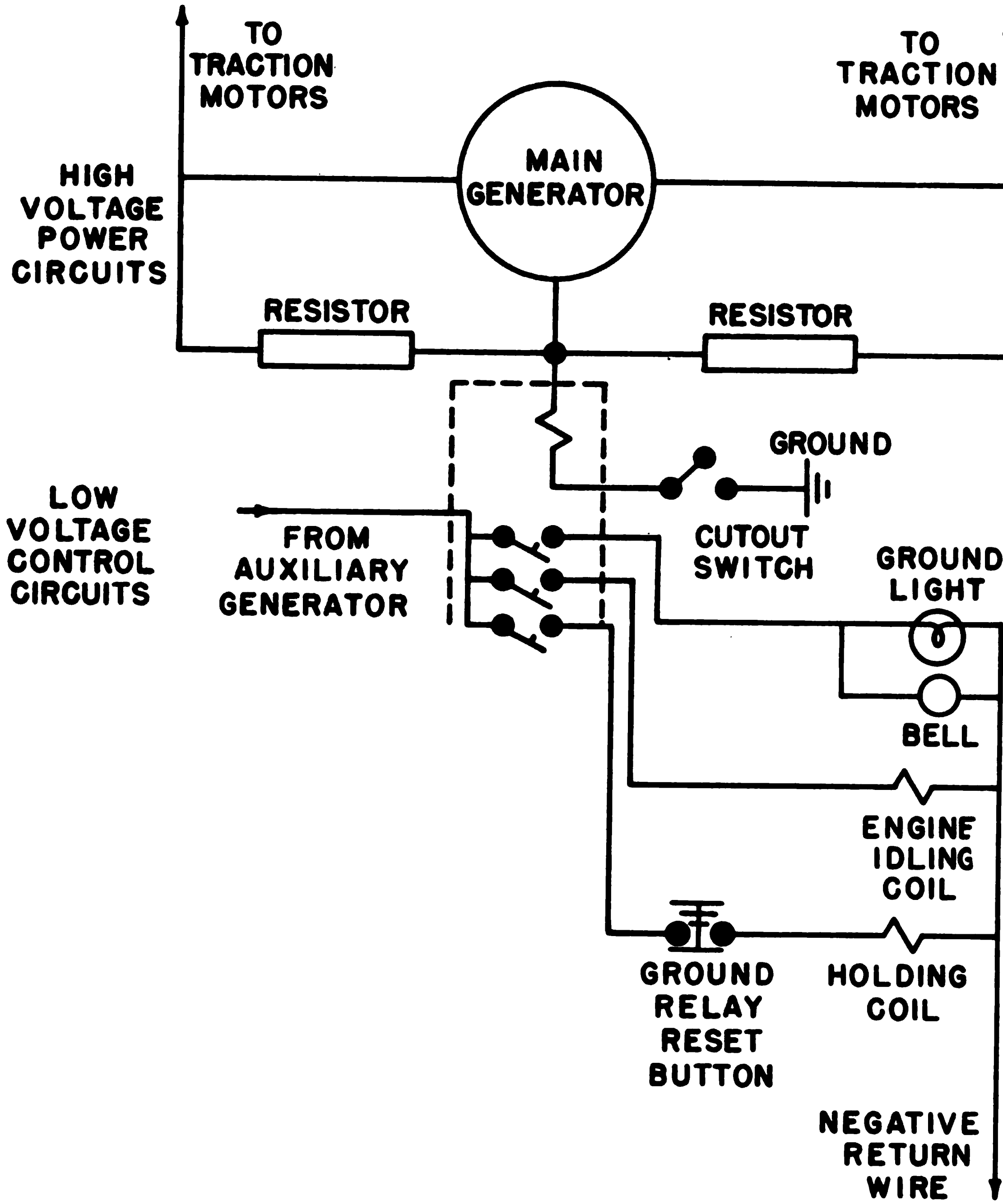


Figure 63. Ground relay circuit.

principles involved. Various motor connections require modification of the relay's connections, but the same general objective is obtained. The voltages at which the relay picks up and drops out are adjusted to avoid continual response to minor fluctuations. The operating coil of the relay for three motors on a truck is in the high voltage circuit in the upper portion of figure 64. The corresponding contacts in the low voltage control circuit in the lower portion of figure 64 are fed by PC wire (hot wire from source of control circuit). In the circuit shown, any wheel slip relay (WSR) that closes energizes auxiliary relay (WSA) which has three contacts. These contacts energize and deenergize coils in the governor controls and energize the warning devices in the indication (WS) circuit.

97. Miscellaneous Relays

Many relays are used for miscellaneous purposes and take a name derived from the purpose they serve. They are essentially alike in operation and construction except for the number of contacts desired on one relay. Typical examples follow.

a. The signal relay (sometimes called alarm relay) is generally connected to sound the alarm bells when any indicator lights give warning of faulty conditions. The various alarms actuate individual lights for each type of failure and, in multiple-unit service, actuate the faulty unit indicators only. However, the bells ring on all units for all types of faults for which a bell warning is desired. Flexibility is, therefore, needed and the details of wiring are more readily accomplished by employing a separate relay.

b. A time delay relay consists of a pneumatic time delay unit, magnet coil assembly, and a snap switch. The relay is located in the electrical cabinet. The pneumatic time delay unit is mechanically actuated by a magnet coil assembly of plunger design. Time delay is dependent upon the transfer of air from the upper to the lower chamber of the pneumatic unit through a regulated orifice. Rotation of a knurled knob gives a wide range of timing adjustment. Air returns from the lower chamber to the upper chamber through a clapper valve for instantaneous reset. The clapper valve is located in the upper chamber and is normally closed. The timing operation is initiated when the force of the spring-loaded (magnet coil) armature acting on the bakelite contact operating block is removed by energizing the magnet coil. This allows the operating block spring to apply force to the block which is coupled to the diaphragm through a bracket. The operating block follows the magnet coil armature at a rate depending upon the pneumatic time delay unit setting. The relay is used when it is necessary to delay an automatic change in electrical connections until any transient or residual effects have died down.

98. Sanding Magnet Valve

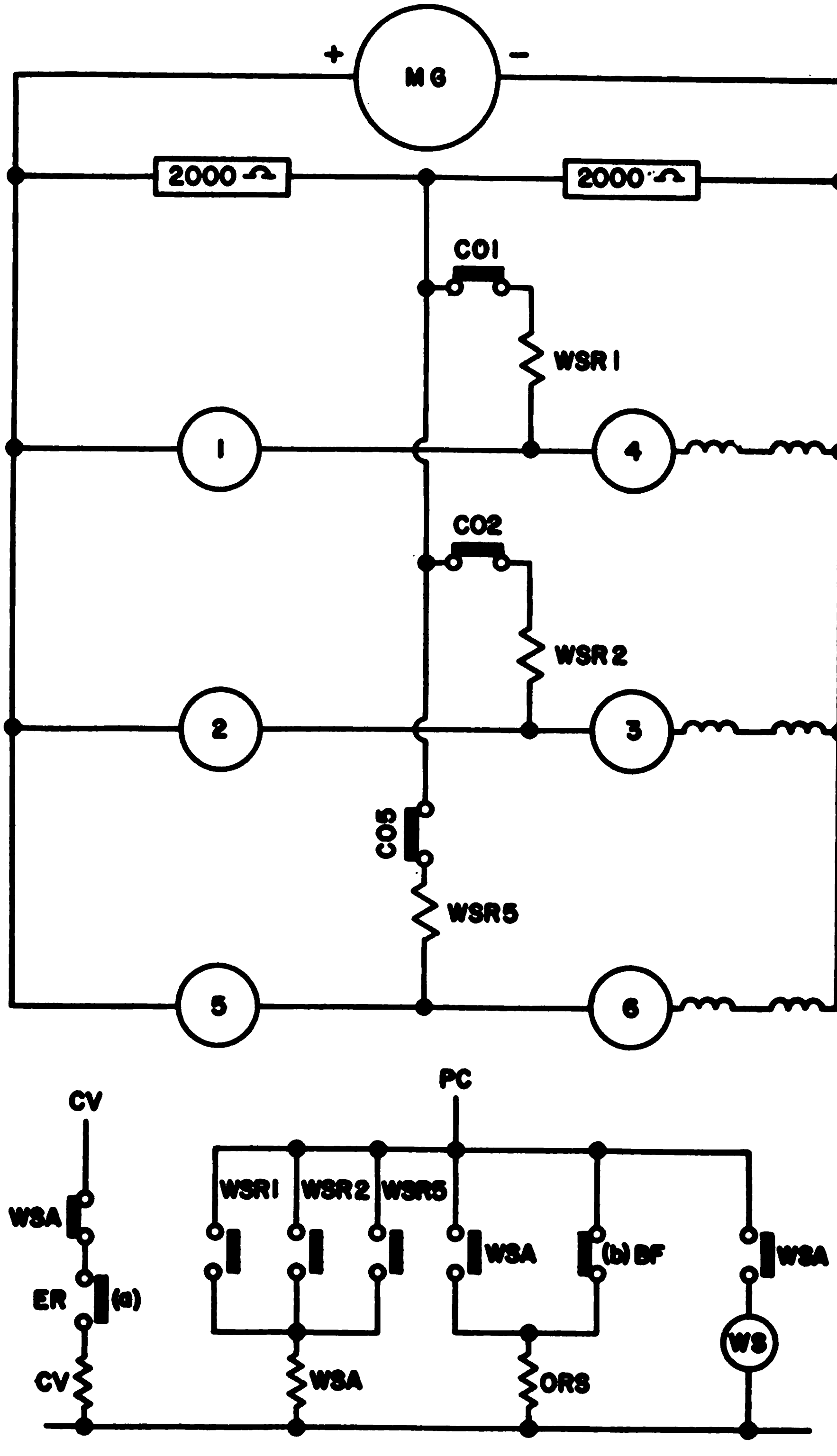
Magnet valves in the equipment cabinet control the flow of sand through the sand nozzles when sanding is controlled electrically. A forward sander valve controls sanding in front of the wheels and a reverse sander valve controls sanding in back of the wheels. The magnet valves are energized through a sander switch which may be manually operated in the cab on some locomotives or pneumatically operated by a control sand valve. The circuit is interlocked through the reverser so that sand is automatically applied to leading wheels only (that is, in the direction of travel). Sanders on all units connected for multiple-unit operation are similarly operated from the controlling cab through a trainlined sanding wire. The equipment is arranged to apply sand automatically during an emergency brake application. For sanding equipment which has no electrical connection, see paragraph 128*f*.

99. Overspeed Valve

Locomotive overspeed devices are of several types. An overspeed signal may be given by a speed recorder, an axle generator, or a governor in train control systems. In a simple form, an overspeed magnet valve acts to sound a warning whistle in the cab and apply the brakes. If the device is equipped with a recapture feature, a prompt brake pipe reduction will avoid a penalty application. After a penalty application is initiated, the entire recovery routine must be followed before normal operation is resumed. On some models, an overspeed device functions through a pneumatic control switch instead of through an overspeed valve.

100. Fuel Supply Pump Motor

The fuel supply pump (transfer pump) is driven by a small motor normally



(a) CLOSED DURING NORMAL OPERATION.
(b) OPEN DURING NORMAL OPERATION.

Figure 64. Wheel slip control schematic.

connected to the control circuit. It operates at constant speed to maintain fuel oil pressure at the fuel injection pump whenever the engine is running or being started. The pump is operated by a fuel pump switch, the control switch, or through a remotely controlled fuel pump contactor, depending on model. Small motors should be inspected often enough to prevent failure in service. Unless faults develop, properly maintained small motors should run 5 or 6 years before removal for general overhauling. When any replacement is made, maintenance men should connect the pump and motor carefully according to manufacturer's instructions. *For example,* Bulletin 802 for maintenance of MRS-I locomotive states that proper clearance must be provided in the coupling between the two coupling halves and the centerpiece to prevent end thrust on the pump shaft which, in turn, can damage the motor. Both single and dual pump units are equipped with a coupling, which should have a distance of 1/2 inch between the two coupling halves with the end play of the motor armature taken into consideration. There should be approximately 1/16-inch clearance between the composition centerpiece and the two die-cast coupling halves with the pump bolted in place and the motor armature pulled toward the pump shaft to its farthest position. It is a very common error in assembling not to take into consideration the end play of a motor armature. These pumps are not designed to take end thrust toward the pump cover, and extreme care must be taken to prevent thrust in this direction.

Section II. BATTERY SYSTEM

101. Battery

a. General. The principal purpose of the storage battery on a diesel locomotive is to supply power for cranking the engine. It also supplies the control and lighting circuits before the engine is started. The auxiliary generator normally supplies the control and lighting circuits after the engine is running. The battery is made up of 32 cells, furnishing 64 volts nominally, depending upon the working schedule of the locomotive and seasonal temperature changes. It is located beneath the underframe, or beneath the cab floor and adjacent running board, or in the compartment next to the cab. A battery consists of a group of positive plates meshed with a group of negative plates with wood or porous separators between them. The plates are immersed in a solution of sulphuric acid and water, called the electrolyte. In a fully charged battery, the acid is in the electrolyte and the specific gravity is at maximum. As the battery discharges, acid from the electrolyte combines chemically with the plates to form lead sulphate. When the battery is being charged, the reverse action takes place.

b. Battery Switch. This is a manually operated double-pole single-throw knife switch in the equipment cabinet or on a nearby panel which connects the battery to the auxiliary generator and control circuits (fig. 65). Personnel must not work on battery or in battery compartment without first opening the main battery switch. All flames such as lighted matches, cigarettes, or sparks must be kept away from batteries. Tools must not be laid on top of cells.

c. Battery Ammeter. The battery ammeter indicates the rate of charge or discharge of the battery. It should indicate zero or various charge readings when the engine is running, depending on the condition of the battery. Immediately after cranking an engine, the auxiliary generator starts to restore the current and the ammeter should register a charging current until the battery is charged. An excessive charging period may be due to a poor condition of the battery or voltage regulator. Continuous discharge will drain the battery. Both conditions require corrective maintenance.

d. Battery Charging. The battery is

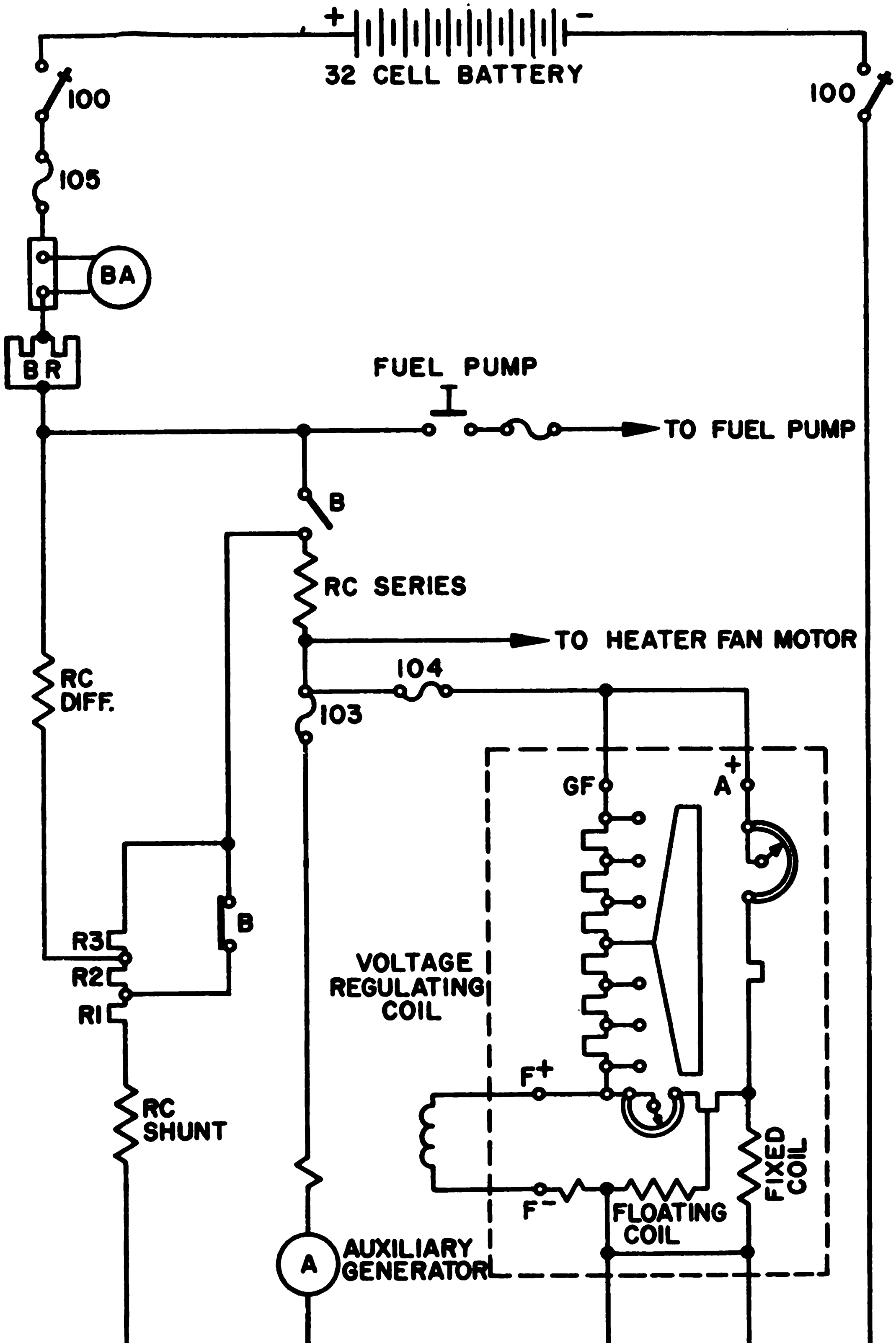


Figure 65. Battery circuit.

charged by the auxiliary generator. The voltage regulator maintains constant voltage across the battery at all engine speeds. The battery may also be charged from shop circuits or terminal yard circuits through external charging receptacles. Be sure to connect with a properly rated circuit for this purpose, and be sure to disconnect the external circuit before starting the engine (unless the shop circuit is capable of furnishing the heavy current involved). Approved or distilled water should be added once a month or before the level lowers to the splash cover. Do not add higher than 1/8 inch below the bottom of the filling tube. After adding any water, replace and securely tighten vent plugs. Written record should be kept of the amount of water added each month. Harmful overcharging is indicated if the monthly requirement is more than 1/2 inch per cell per month. If less than 1/2 inch per cell per month is required, undercharging is indicated. These figures on water addition are based on the locomotive being in daily service. Lesser amounts will be used in lighter service.

102. Reverse Current Relay (RCR)

a. A reverse current relay opens a battery contactor between the auxiliary generator and the battery when the engine is shut down or if the auxiliary generator voltage drops too low to charge the battery. This prevents the battery from discharging back into the auxiliary generator windings. The relay is magnetically operated by a voltage coil and a current coil. The combined field of both coils closes the relay when the auxiliary voltage builds up to a charging value and while current flows in the right direction (that is, charging). When the current flows in the opposite direction, the resulting field and spring action opens the relay.

b. The reverse current relay on the MRS-I locomotive consists of an armature yoke with a voltage coil and current coil mounted on a common magnetic circuit. The current coil circuit terminates at the two large studs at the bottom and the voltage circuit terminates between one of these large studs and one of the smaller studs at the top. The two adjustable resistors at the top are in the voltage coil circuit. A hinge armature, with one normally closed and one normally open interlock, makes contact with the stationary front and rear contact studs. The armature is held in the normally open position by a return spring. The armature yoke assembly consists of an upper and lower iron core bridge assembly. The upper core holds the voltage coil and the lower core holds the current coil.

103. Battery Contactor (BC)

The battery contactor opens and closes the charging circuit in response to the settings of the reverse current relay described above. It is a single-pole, heavy-duty, direct current contactor with conventional magnetic blowout coil to extinguish the arc. (Do not confuse this contactor with the battery field contactor in the main generator fields circuits during engine starting.)

104. Voltage Regulation

a. The correct voltage setting is one which will maintain the specific gravity of the electrolyte at about its full charge without generally exceeding the water loss given in paragraph 101*d*. The voltage regulator setting to use is not a fixed value, but depends on the working schedule of the locomotive and the seasonal temperature which necessitates a slight change in the voltage setting. The necessity for a change in the regulator setting can only be determined satisfactorily by maintaining continuous records of specific gravity readings, water additions, and temperatures. If the specific gravity shows a continued lowering or reads 10 to 20 points below the full charge value, the regulator is set too low for the locomotive's work schedule and should be increased. If gravity checks continuously at full charge value and the electrolyte temperature is more than 15° F., above the outside air, or the amount of water added each month exceeds the maximum (para 101*d*), the voltage regulator is set too high and must be lowered.

b. Voltage regulation of the auxiliary generator output is maintained by changing the strength of the auxiliary generator field. If the speed of the auxiliary generator increases, the shunt field strength must be decreased. A regulator may consist of a small torque motor or of relays which are sensitive to changes in voltage. The movement of these elements changes the resistance in the field circuit. Hunting may be prevented by a dashpot assembly or by electrical resistors. The regulator adjustment should not be changed except by personnel who are familiar with the various types. In a torque motor type of regulator, windings are connected to the main leads of the auxiliary generator being controlled. The shaft extends through the panel and operates the actuating shaft assembly in tandem. The actuating shaft assembly operates the air dashpot piston by means of the flexible recall spring coupling and also the main shaft assembly through a connecting link. The main shaft assembly operates the sectors which roll over the stationary commutator segments to cut resistance in and out of the auxiliary generator shunt field circuit as required to maintain constant voltage. By this method a very small movement of the torque motor armature is multiplied into much greater movement of the contact sector, with consequent rapid changes in shunt field resistance.

c. The operating principle of the voltage regulator is that the voltage generated is proportional to the shunt field strength. If the speed of the auxiliary generator increases, the shunt field strength must be decreased to maintain a constant voltage. The voltage regulator increases the resistance of the field, thereby reducing the flux or excitation. If the speed of the auxiliary generator decreases, the shunt field strength must increase to maintain a constant voltage. The voltage regulator will move its sectors to reduce the resistance of the field and increase the current flowing in the field. In operation, the torque motor armature will tend to change position with a change in voltage of the auxiliary generator but is restrained by the main spring.

d. The torque motor and the main spring settings are adjusted at the factory so that the same voltage is required to balance the armature against the countertorque of the main spring for any position. Thus, if external conditions such as generator speed, load, or internal shunt field resistance, due to temperature changes, cause a change of torque on the torque motor armature, the armature will move the sectors in such a direction as to cut in or out shunt field resistance and reestablish the set voltage at a new position of the armature. For this reason the setting of the main spring must not be altered from its factory setting unless it has been definitely determined that the armature does not balance at the same voltage for every position.

e. Any change from this "flat" characteristic of the armature will cause a corresponding error in voltage at different speeds and loads of the generator. A new main spring should be used in preference to changing the factory setting. As the actuating shaft assembly moves, the recall spring causes movement of the dashpot piston almost independently of the actuating shaft on the torque motor armature. Thus, for quick changes of field resistance, the sectors move to new position, and the dashpot follows an interval later. This is the antihunting feature of the regulator; it makes the restraining effect on the actuating shaft proportional to the error in voltage, and prevents overtravel of the sectors with resulting objectional variation of voltage, and at the same time, allows rapid restoration of the voltage after a change occurs. The antihunting characteristic is adjusted by means of the slides on the lever and the needle valve on the dashpot. The travel of the torque motor armature is limited by the pointer on the actuating shaft which operates between the two stops.

105. Starting Circuit

The starting circuit transmits the power from the battery to the main generator when cranking the engine. Basically, the starting button closes the starting contactors which are described in paragraphs 106 and 107. However, many automatic devices must be provided (fig. 66) and these are best understood by describing their general purpose without regard to the actual installation on any locomotive. The fuel supply system must be functioning, and since lubricating oil pressure does not exist in a shutdown engine, the starting switch or related connections must be interlocked to prevent a fuel shutdown until lubricating oil pressure builds up. The main power controls must be interlocked in an off position so that no power flows when the engine fires. The voltage of the main generator is too high for the control circuit immediately after firing, and the starting circuit must, therefore, be opened automatically instead of depending on the operator to release the starting button when the engine fires.

106. Starting Contactors

The starting contactors are used to connect the storage battery to the main generator for starting the diesel engine. These contactors are energized (closed) when the start button (switch) is pressed after necessary battery and control circuits are established. The contactors consist of coil-operated main contacts which carry the heavy starting current and smaller auxiliary contacts which are used as interlocks. Contactors in the generator field circuit (or battery field contactors, depending on manufacturer) close first, followed by contactors in the generator armature circuit. If this sequence was not established, the armature would short circuit the battery when its contactors closed. Interlocks on the contactors control this sequence automatically when the start button is pressed.

107. Starting Pushbutton

The engine starting contacts are energized (closed) by a manually operated pushbutton switch on the control panel. This switch usually has a pair of normally closed contacts which open when the button is pressed and thereby deenergize certain excitation circuits. Excitation and auxiliary generator circuits are opened during starting in order to reduce the demands on the battery to the minimum possible mechanical cranking effort. This switch usually bypasses the low oil pressure switch and is held in until normal lubricating oil pressure is built up.

108. Engine Relay (ER)

a. On a locomotive equipped with a Woodward electrohydraulic governor and an engine relay, the relay controls the current supply to the A, B, and C solenoids of the governor. Deenergizing this relay will stop the engine if the throttle is in run 5 or 6 or bring the engine to idle in any other throttle position. This relay is in the electrical cabinet. For operation of the speed control in any one unit, the ER must be energized and closed. The relay has contacts which open when the relay is deenergized and interrupt the circuits supplying the A, B, and C solenoids of the governor speed control. It has no effect on the circuit to the D solenoid. Thus, deenergizing the ER will cut out the A, B, and C solenoids and bring the engine to idle speed if the throttle is in run 2, 3, 4, 7, or 8. Should the ER become deenergized when the throttle is in run 5 or run 6, the D solenoid will remain energized and cause the engine to stop. The ER in each unit is energized by current received from the FP wire that runs throughout the locomotive. The 15-ampere fuel pump circuit breaker on the control panel and the PCR interlock AB in the lead unit must be closed in order to energize the FP wire; the PC switch, the main battery and control knife switches, and the 30-ampere control circuit breaker on the control panel must also be closed. The ER in each unit will become deenergized from any of the following causes:

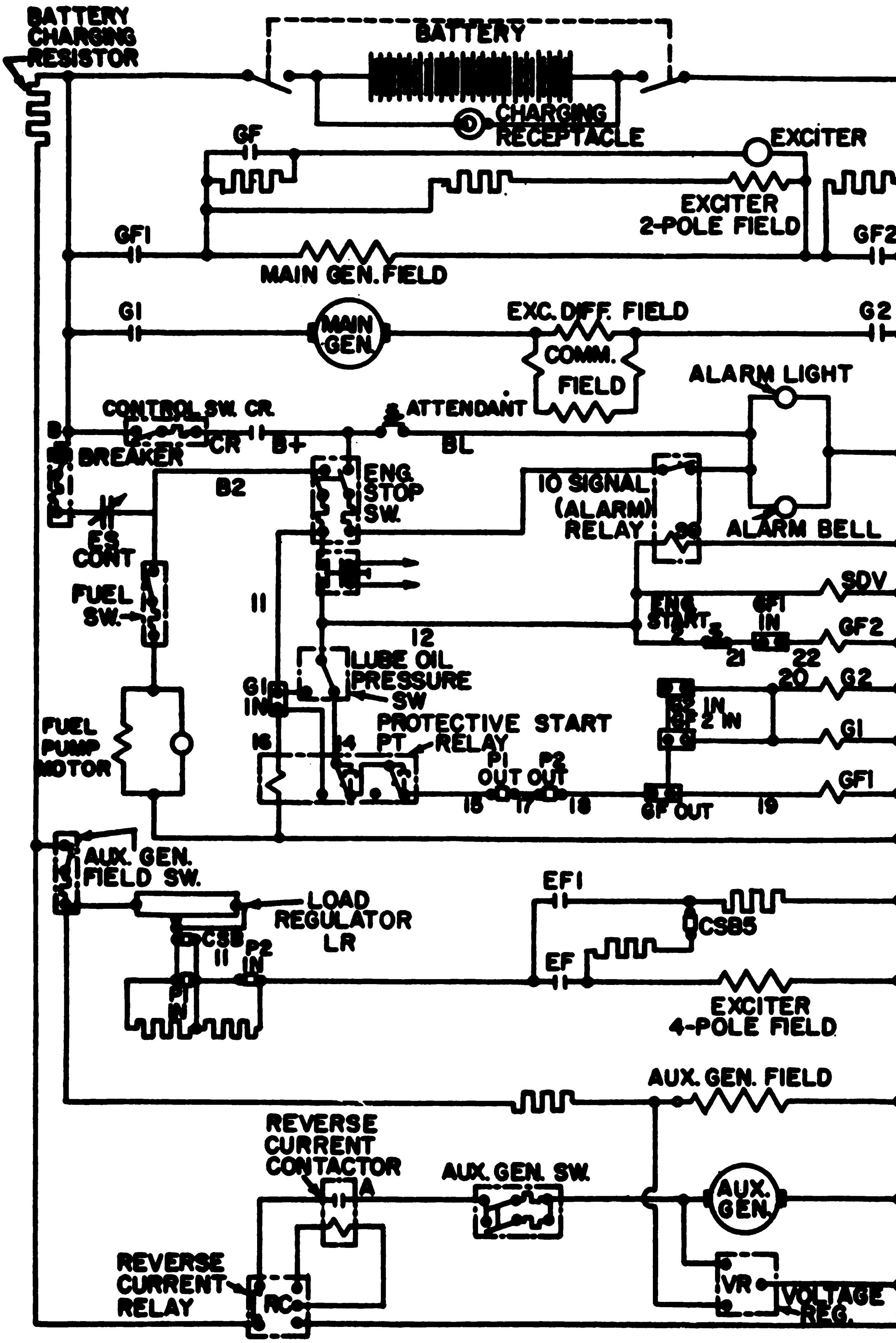


Figure 66. Starting circuit.

(1) Isolation switch not fully in the run position.
(2) Failure of the ac supply, causing the NVR relay to open.
(3) Ground protective relay, GR, tripped.
(4) Fuel pump circuit breaker open.
(5) Control circuit breaker open.
(6) PC switch tripped open, PCR deenergized.
(7) Control switch open.
(8) Main battery switch open.

b. When the throttle is moved to the stop position, it will cause the D solenoid to be energized in all units in which the isolation switch is in the run position; this causes the engine in those units to stop. A fifth solenoid (0 to 0RS) is included in the governor which affects engine loading only and does not change engine speed.

c. On locomotives equipped with a safety relay, the relay is activated due to overspeed, engine stop button, and low oil pressure, and causes the clutch coil of the governor to be deenergized. Deenergizing the clutch coil moves the fuel rack to shutdown position.

Section IV. AUXILIARY EQUIPMENT

109. Lighting System

a. General. Locomotive lights (para 173) are connected to the low voltage auxiliary power system. Most of them operate at battery voltage. Any lamp with a low voltage rating has a resistor installed in series with the lamp to drop the voltage at the same time to its proper value. A few essential lamps, with their individual switches, are connected directly to the battery. All other lamps will receive power only after the battery switch is closed except when using standby circuits. Standby lighting is frequently provided through a transfer switch, transformer, and outside receptacle. The transfer switch throws the lighting circuit from the locomotive supply lines to outside supply lines which are connected through the outside receptacle. The transformer reduces the voltage of outside circuits to that used on the locomotive. It is essential that the rating on the primary side of the transformer match that of the outside power supply. Lighting switches which are not adjacent to the light have nameplates designating their circuit. Modern switches are small circuit breakers which protect the circuit from faults or overloads. Earlier switches of the toggle or pushbutton types required fuses in the line for protection. Some circuits have dimming rheostats which may be part of the switch or be mounted separately.

b. Lights. Lights are designated as follows:

(1) Cab lights, usually in the cab ceiling, are to illuminate the cab.
(2) Engineroom lights illuminate the engine compartment (called hood lights on some models).
(3) Instrument (or gage) lights provide dim lighting of indicating instruments when cab lights are out.
(4) Cabinet lights are installed in the equipment cabinet and should be used whenever necessary to identify any manually controlled equipment in the cabinet.
(5) Running lights consist of number lights, classification lights, marker lights, and track lights, which are installed according to the operating conditions for which the locomotive was originally built. Red and green lenses are provided for each classification light and can be moved into a position between the bulb and the bull's-eye. To accomplish this, a locking pin is removed, the desired lens is swung into place, and the locking pin is replaced. The colored lenses are accessible from the outside of the hood since the classification lights are mounted on a hinged portion of the hood.

When both red and green lenses are out of position, the permanent bull's-eye lens will show a white light, thus making three colors available.

(6) Headlights are usually provided at each end. Each light has its separate switch in the cab and can be set to bright, dim, or off positions. These two switches may be incorporated into one 5-position switch (headlight dimming switch) which can be set to rear-full, rear-medium, dim (front and rear), front-full, or front-medium position (1, fig. 67). Headlight circuits for locomotives used in multiple-unit operation may be run through the end jumpers to a special selector switch (remote headlight switch) in the controlling cab. The nameplate on the switch gives instructions for using this switch (2, fig. 67).

110. Cab Heaters and Defrosters

Cab heaters are installed on most locomotives to keep the enginemen comfortable in cold weather. The hot water type is connected to the engine water system which supplies the heat. A small electric fan is built into the heater to circulate air over the water coils and into the cab. The heater switch in the cab connects the fan to the auxiliary powerlines. Fan speed can be varied by a rheostat which is incorporated with the switch. Cocks are provided for shutting off the flow of water and for draining the heaters. An all-electric heater is essentially the same as the hot water heater except that the heating element is an electric coil. Defrosters work on the same principle and have a separate control switch. Another method consists of ducts through which air from the engine radiators is forced to the cab and cab windows.

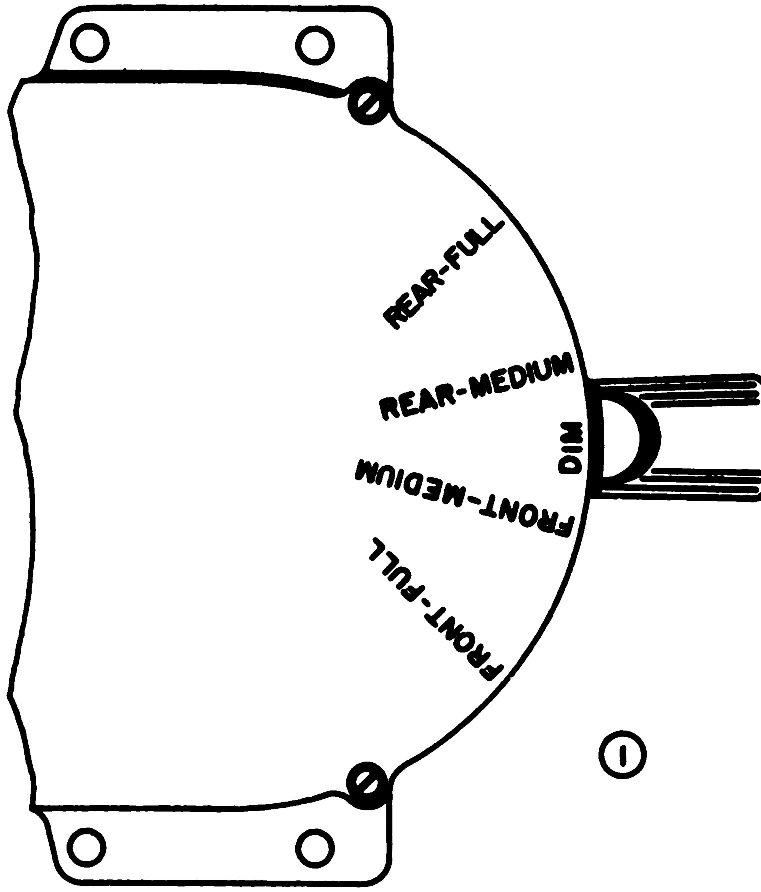
111. Auxiliary Power Systems

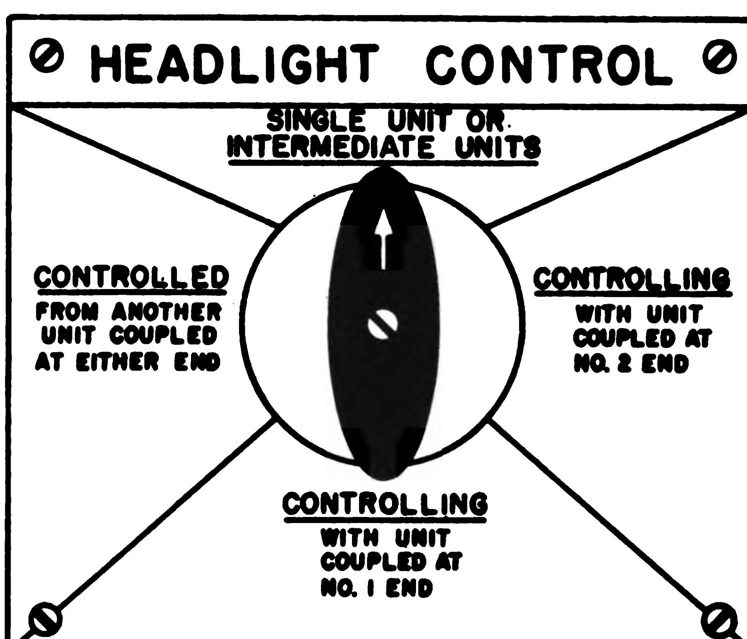
a. An alternator is provided on some locomotives to supply alternating current power to fans and blowers. The stator contains the 3-phase output winding and the fields are wound on the rotor. The field current is supplied by the auxiliary generator. A no-voltage relay is connected in the output circuit to give protection against failure of alternating current power. A fuse or circuit breaker is in the line supplying the alternator fielde, and if this circuit is open, there is no ac power output. The alternator is attached to the main generator frame and is driven at engine speed by the main generator shaft. The voltage and frequency of the alternator output, therefore, varies with the engine speed. The speed of motors fed by the alternator varies with the frequency of their power supply which varies with the engine speed.

b. Other types of auxiliary power may be installed on a locomotive but have nothing to do with the locomotive as a unit of motive power. There may be such equipment in a separate utility car in some operations. Army personnel are not likely to encounter such equipment. These systems vary in voltage and frequency according to purpose. They can be used to supply train lighting, train communications, train control which requires constant specially regulated power, or special loads in trailing cars, mostly in passenger trains.

112. Steam Generator

a. A steam generator is installed on locomotives used for passenger trains and ambulance trains to provide steam heat for the cars in cold weather. It is an independent oil-fired heating unit which operates automatically after being started. Full operating steam pressure is reached within a few minutes. The steam generating part of the unit consists of three sets of coiled water tubing, nested and connected in series to form a single tube several hundred feet long. Feed water, after passing through the heat exchanger, goes through the economizer coil and from there to the main coils of the steam generator. As the water progresses through the coils it is converted into steam. Heat is furnished by the combustion of the diesel fuel oil which is sprayed





67. Headlight control switches.

by compressed air through the atomizing nozzle in the fuel spray head into the firepot above the coils. Here the fine oil spray mixes with air supplied by a blower and is ignited by a continuous electric spark. The hot gases flow, first downward, then up and outward through the nest of coils, finally flowing out the stack. The supply of fuel is regulated to evaporate 90 to 95 percent of the water pumped through the coils. The excess water flushes scale and sludge from the coils and is carried over with the steam into a steam separator where the water and sludge are removed before the steam flows into the trainline. The excess water collects in the bottom of the steam separator. Water above the level of the return outlet flows out through a steam trap and through the heat exchanger where it gives up its heat to the incoming feed water. From the heat exchanger, the return water passes through return water flow indicator back to the water supply tank. One dc motor drives the converter, the blower, water pump, and fuel pump at a constant speed.

b. The water bypass regulator automatically controls steam generator output by regulating the amount of water fed to the coils. Before entering the coils, the water passes through servo-fuel control which admits fuel to the spray nozzle in direct proportions to the amount of water entering the coils. The servo-fuel control also adjusts the damper to admit the proper amount of air for efficient combustion of the fuel. The trainline steam pressure is regulated by adjusting the setting of the water bypass regulator. The length of train and weather conditions determine the setting. A remote-control panel is usually installed on a cab partition. It may contain a master switch, a separator blowdown valve button (to open separator blowdown valves on all units in multiple), a trainline shutoff valve button, and possibly some shutdown indicators. Power for the steam generator motors and controls is obtained from the locomotive's low voltage system through proper fuse or circuit breaker protection. All other equipment for the generator is part of the independent unit, and details covering operation, maintenance, and troubleshooting should be obtained by referring to the instruction manual for the specific equipment.

c. Various safety controls are built into the steam generator wiring system. If the fire fails to light, the low temperature contacts in the *stack switch* remain open and, after a 43 to 47 second time delay, the *outfire relay* contacts open, energizing the *alarm pilot relay* and deenergizing the *line relay*. The *alarm* rings and the generator shuts down. The *stack switch high temperature contacts* open when the temperature of the exhaust gases exceeds 900° F., energizing the *alarm relays* and deenergizing the *line relay*. The contacts must be manually reset after the stack temperature is reduced. The *air switch* contacts are held closed by the pressure in the *atomizing air line*. When the air pressure drops below 40 pounds, spring tension opens the contacts and breaks the circuit through the *fuel solenoid valve*, cutting off the supply of fuel to the spray head. The fire goes out immediately. The motor converter continues in operation until the *line relay coil circuit* is broken. Atomizing air pressure must be stored and the *control switch* turned to "off" or "fill" to reset the *outfire relay*, before the unit can be started again. The *coil blowdown valve switch* is manually operated to break the *line relay coil circuit* when it is open. With the *control switch* turned to "fill" or "run," the *alarm* rings and the *motor converter* will not operate. Under overload conditions, the excessive current passing through the motor into the *motor overload relay coil* will open the relay contacts and break the *line relay circuit*, the *alarm* rings and the unit shuts down. The *control switch* must be turned off to stop the *alarm*. After the overload condition is corrected, the *overload contacts* must be manually reset before the unit can be started. A short in the *control circuit* will blow a control fuse, a short in the *ignition circuit* will blow an ignition fuse, and a short in the *motor converter circuit* will blow a fuse in the *locomotive main control panel*. The *field adjusting resistor* is placed in the *motor field circuit* to permit compensation for a maximum of two volts drop in line voltage because of resistance in the locomotive wiring. It should be adjusted for zero resistance and not used unless necessary. If adjustment is required, run the motor at full line voltage under load conditions until it has reached normal operating temperature. Then, increase the resistance until motor speed is approximately 1,800 rpm. The wiring diagram is shown in figure 68.

113. Fire Alarm

A fire detecting system consists of electric thermostats mounted at appropriate remote points in the locomotive which operate a fire alarm. Excessive temperature closes the circuit through the thermostat, thereby energizing (closing) the relay which operates the fire alarm light and bell. Enginemen should be familiar with the location and use of fire extinguishers, fuel cutoff, and engine stop devices, all of which are manually operated. Carbon dioxide is a nonconductor of electricity which makes it a desirable agency for combating electrical fires. Because of lack of oxygen, personnel must be sure they have access to air to avoid being overcome.

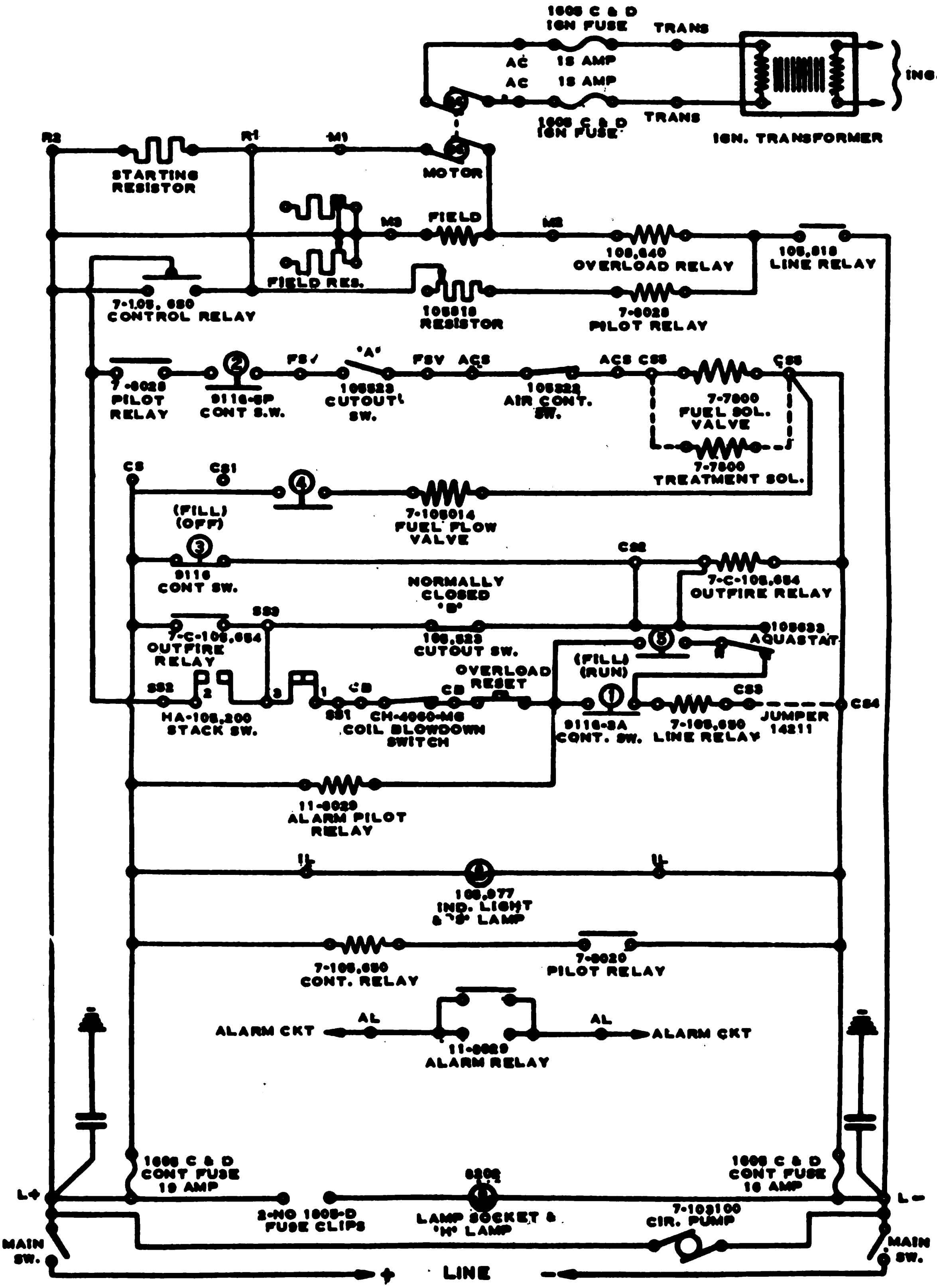
114. Oil-Fired Engine Heaters

a. Oil-fired engine heaters are provided for operation in severe cold weather. It is necessary to warm the cooling, lubricating, and fuel oil systems and batteries before starting the engine if prolonged layover has resulted in congealed fuel oil or lubricating oil. Continued operation of the heaters is often necessary after the engine is started. Special insulation of oil lines, tanks, and compartments is part of such an installation which is often called a winterization system. The heaters use fuel from the main locomotive fuel oil system, but a small tank at the heater is automatically kept full. It may even be necessary to heat this reserve supply of fuel before starting the heaters. After the heaters are operating, they supply heat through a hot water piping system, or an exhaust gas system, to the powerplant and essential auxiliary equipment. An electric motor which obtains its power from the locomotive's auxiliary powerlines drives a fuel pump, water circulating pump, and blower fan. The fuel oil is ignited in the firepot by a continuous electric spark. The equipment does not eliminate the used of draining the cooling system or keeping it filled with an adequate antifreeze solution when the locomotive is shut down. It is also necessary to keep the battery fully charged. Only one attempt can be made to preheat and start the engine. It is, therefore, highly important to be familiar with the equipment and follow the sequence of operations exactly as directed in operating instructions for the specific type of heater.

b. Power for the motor and heater control circuits is obtained from the battery and locomotive auxiliary power system. Heater circuits may be protected by fuses or circuit breakers or both. Thermostatic controls regulate the circulation of water and possibly the setting of radiator shutters. When the temperature in any compartment heated by exhaust gases rises enough to actuate the thermostats in these compartments, the thermostats will close the circuit to a solenoid regulated damper which permits the exhaust gases to discharge to the outside atmosphere.

c. Structural changes involved in proper winterization include removal plates over engine compartment louvers properly hinged for snow removal, additional air filters, weather-stripped doors and hatches, fiberglass cab insulation, and double-glass cab windows.

d. The operation of the model DH-4915 hot water heater is completely automatic after it has been started. The motor runs continuously while the burner cycles on and off. The heater part of the unit consists of two water jackets connected in series. Water is pumped into the outer water jacket and then through the inner water jacket. Heat is furnished by the combustion of diesel fuel oil which is



68. Schematic wiring diagram of steam generator.

sprayed through the fuel spray head into the firepot. Here the fine oil spray mixes with air supplied by the blower and is ignited by a continuous electric spark. The hot gases flow past the inner surface of the inner water jacket, and then around to pass over the outer surface of the inner water jacket and the inner surface of the outside water jacket. A single electric motor drives the blower fan, fuel pump, and water circulating pump. An immersion thermostat keeps the temperature of water returning to the heater within its control range of 110° to 130° F. The output rating of the heater is 150,000 Btu's per hour. The fuel consumption is 1.65 gallons per hour at maximum output. Do not start heater unless system is completely filled with water. To start, place main switch in burner (up) position. (The motor will start and circulate the water and the combustion air. The fuel will be bypassed back to the supply tank through the fuel pump by the action of the fuel solenoid valve.) Rotate the fuel filter handle at least one revolution clockwise. Press the start button. This puts the control circuit in operation. The fire will start unless the water temperature is over the range for which the aquastat is adjusted. If the heater should fail to fire, the outfire control will shut the burner down in approximately 45 seconds. Wait 2 minutes and depress the start button again. If unit still fails to fire, check the troubleshooting section of the appropriate operating instructions. On the DH type unit, if the fire fails to light, it is possible to check the operation by holding the test button down; this overrides the immersion thermostat and the unit will fire. To stop, place the main switch in the off position.

e. In the caterpillar D-397 diesel engines, used on the Baldwin-Lima-Hamilton 60-ton, 500 hp switchers, the No. 1 heater, which supplies heat to the engine cooling system, is fully automatic in operation; but the No. 2 heater, which supplies heat to the auxiliaries, is semiautomatic in its operation.

CHAPTER 12

AIRBRAKES AND ACCESSORIES

115. Air Supply System

Compressed air is used to operate the airbrake system; reverser; electropneumatic contactors; sanders; window wipers; bell; and on some designs a shutter valve, throttle valve, pneumatic control switch, and similar equipment. The main reservoir is kept at a pressure of 125 to 140 pounds. Air is supplied to the brake system from the main reservoir through a feed valve. A 70- to 90-pound control air system is supplied by the main compressor through reducing valves, control air reservoirs, suitable strainers, and check valves (fig. 69). The system includes necessary cutout cocks and gages. If air pressure is too low, the reverser and electropneumatic contactors will not operate and the locomotive will not move.

116. Air Filters

a. A large supply of clean air is required for air compressors. Dirt, grit, or any foreign matter taken into the equipment with the air causes wear and equipment failures. Service is improved and maintenance is reduced by good air filters (fig. 70). The principal requirements in a good air filter are—

(1) Small resistance to the passage of air.
(2) High dust-retaining capacity.
(3) Ease of cleaning.
(4) Ability to operate a long time without cleaning or attention.
(5) Small and compact.
(6) Moderate first costs.
(7) Low operating expense.

b. The oil impingement type filter consists of layers of wire mesh, coated with oil which collects the dust and dirt while the air passes through. Filters may be flat or cylindrical in shape. As dirt collects on the mesh, the filter either becomes clogged or the oil is absorbed, dries out, or otherwise loses its adhesive properties. All these factors lower the effectiveness of the filter, and proper oiling and cleaning should be regularly performed.

c. The two air intake strainers, one for each of the low pressure cylinders, are of the "cartridge" type which permits removal of the strainer element without the necessity of dismounting or disconnecting from the air compressor. Air passing through the strainer unit enters the compressor intake. The strainer element should be cleaned in an alkali-free hydrocarbon solvent, dried, and then dipped and given a lubricating oil bath. After the oil has been drained off, it is ready to be put back into service. Dirt deposited on the metal wire mesh cover may be dislodged by jarring the strainer and by using dry compressed air.

117. Compressors

a. General. The air supply is provided by air compressors which may be engine-driven either directly by belts or through a flexible coupling to the shaft of the main generator (fig. 71). Independent motor-driven installations are found on some locomotives. The major features of various compressors are similar to each other (see para 233 for maintenance procedures). A description of a typical compressor follows.

b. Construction. A typical compressor consists of two low-pressure cylinders and one high-pressure cylinder. The two low-pressure cylinders are the ones at either side and can readily be distinguished from the high-pressure one because of their larger diameter. The three automotive type connecting rods are of forged steel and are identical. They are applied to a common throw of the crankshaft. Each rod has its individual bearing on the shaft. Lubrication for the crankshaft end of the connecting rod is by pressure feed through the drilled crankshaft. The connecting rod is rifle drilled to the wristpin which also is supplied with lubricant under pressure.

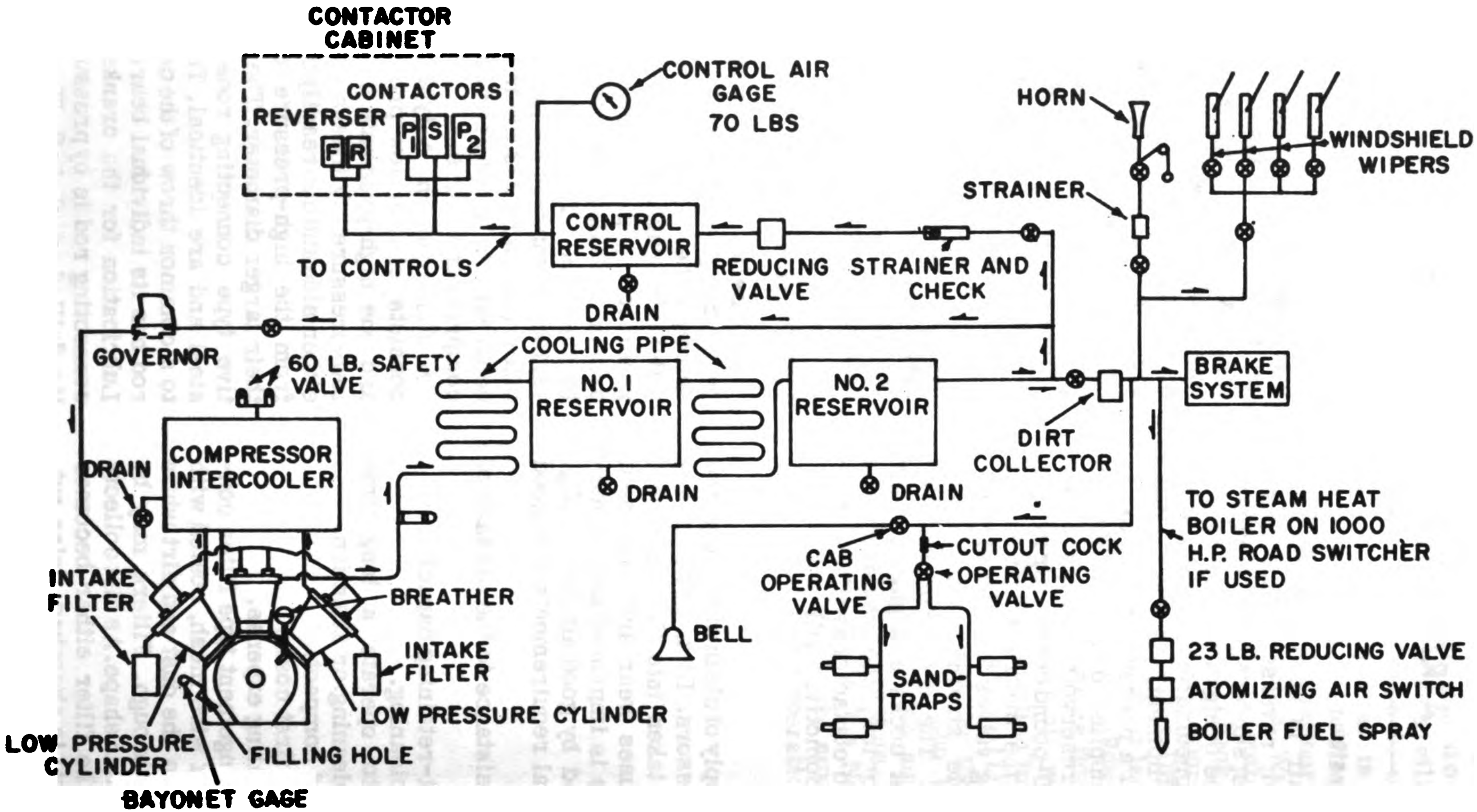


Figure 69. Air piping system diagram.

The cast iron pistons are fitted with four piston rings, two compression rings, and one oil ring above the wristpin and one oil ring below the wristpin. All piston rings should be applied so that the scraping edge is toward the crankcase. Piston wristpins are of the full-floating type and are supported in the connecting rods by bronze bushings. The wristpins are prevented from having excessive end movement by retaining rings which snap in a recess in the piston and thus prevent the wristpins working out against the cylinder wall. The main bearings are the radial ball type, one at each end of the crankshaft. They are lubricated by throwoff from the connecting rod bearings. An oil seal is provided at each end of the crankshaft to prevent oil leakage and also to guard against entrance of dirt. There are two inlet valves and one exhaust valve for each of the low-pressure cylinders and the high-pressure cylinder. They are of the double-washer type and all are located in the compressor head. The compressor crankcase is vented by means of a breather with cap. It has a quantity of copper mesh supported between suitable screens, retained in place by means of a snap ring. The breather is also fitted with a check valve so arranged that any pressure in the crankcase will be relieved to atmosphere, but any tendency for air to flow from the outside of the compressor into the crankcase is prevented. This check valve is felt-sealed for quiet operation.

c. *Intake Strainers*. The two air intake strainers, one for each of the low-pressure cylinders, are of the cartridge type which permit removal of the strainer element without the necessity of dismounting or disconnecting from the air compressor. Air passing through the strainer unit enters the compressor intake.

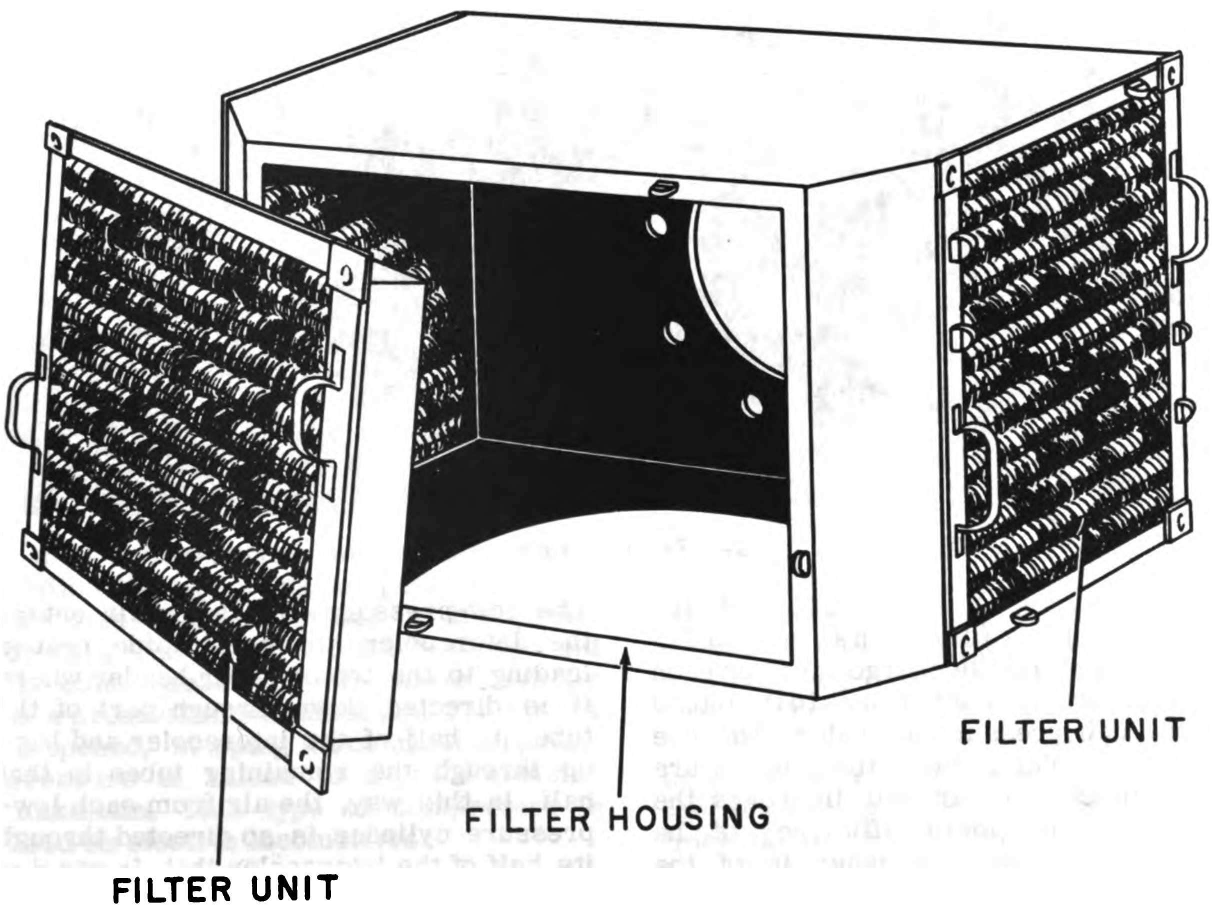


Figure 70. Oil impingement type air filter.

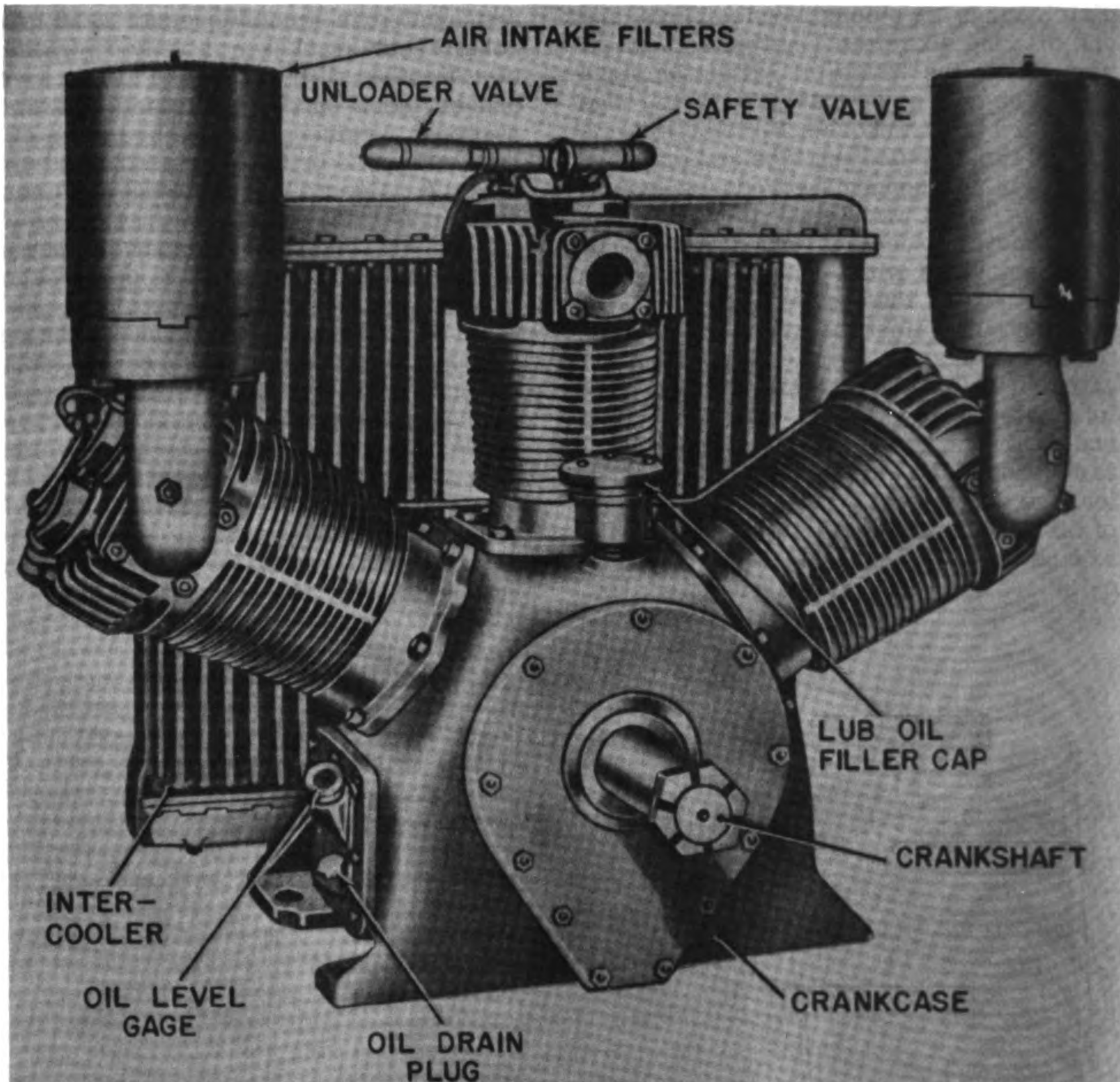


Figure 71. Air compressor.

d. Intercooler. A compressor of the compound type is fitted with an intercooler through which the discharge air from each low-pressure cylinder passes to the intake of the high-pressure cylinder. The use of an intercooler reduces the temperature of the discharge air and improves the volumetric and power efficiency of the compressor. The intercooler is of the radiator type, employing finned copper tubing mounted between cast iron headers. The intercooler is divided in two halves, one for each of the low-pressure cylinders. The low-pressure discharge air enters the intercooler through a side header leading to the top or upper header where it is directed down through part of the tubes in half of the intercooler and back up through the remaining tubes in that half. In this way, the air from each low-pressure cylinder is so directed through its half of the intercooler that, in passing to the high-pressure cylinder, the air has traveled approximately twice the length of the intercooler tube. Suitable baffles are employed to insure that the air follows the path desired. After passing the tubes, the air enters a common passage leading to the intercooler safety valves and to the inlet side of the high-pressure cylinder. One or two safety valves are employed to protect the intercooler against excessive pressure. These safety valves are set to open at 60 psi (relief valves on the MRS-I intercooler are set at 55 psi).

e. *Lubrication.* The compressor has its own pressure lubrication system. Oil is carried in the base which is equipped with a gage, filler and drain connections, filter, and breather. The oiling system is arranged so that oil, under pressure, is circulated by an oil pump. The oil pump is driven by an eccentric at one end of the crankshaft. This pump combines a piston and check valve operating in an oil pump body and is so arranged as to deliver the lubricating oil under pressure to drilled openings in the crankshaft. The oil supplied to the pump is first filtered. The filter consists of a housing, incorporating a fine screen strainer of large area, through which the oil is drawn on its way to the oil pump body. The screen strainer is held in place by a screen retainer which must be removed before the screen can be removed. The oil gage should show approximately 15 psi at 500 rpm and should show some pressure at idling speed. An oil pressure relief valve, mounted in the crankshaft throw toward the intercooler, is provided to protect the oil pump and associated parts against excessive oil pressure.

118. Compressor Control

a. A motor-driven compressor is controlled through a master governor which operates the line switch in the power circuit. The power circuit is closed and the compressor runs when pressure drops to a predetermined minimum. The circuit is opened, stopping the compressor, when pressure is raised to a predetermined maximum. This type of compressor is used on electric locomotives.

b. Because each compressor is directly connected to the engine, the compressor is in continuous operation (although not always pumping air) whenever the engine is running. This requires a load and unload type of control for maintaining reservoir pressure within the desired limits. The inlet valves of the two low-pressure and of the one high-pressure cylinders are equipped with unloaders which are controlled by a governor. They are so arranged that when the compressor has restored the pressure in the reservoir system to the desired point, the compressor will unload and cease to deliver air to the main reservoirs. The tapped opening in the capnut of each of these unloader cylinders connects to a copper pipe header which leads to the compressor governor. When the compressor has built up the desired pressure in the main reservoir, the governor admits main reservoir air through this tapped opening in the capnut onto the face of the unloader valve. This pressure immediately moves the unloader valve in towards the cylinder, carrying with it the intercooler pressure seal valve. This, in turn, acts through the unloader plunger which has a part of the plunger, a head with fingers or prongs on its lower side. These prongs extend through openings in the inlet valve seat. With the pressure admitted as described above, these fingers will push the inlet valves off the seat and the compressor is then unloaded as no compression takes place as long as the inlet valves are thus held open. Complete movement of the unloader valve on which the main reservoir pressure first acted results in its seating and preventing leakage of main reservoir air through the unloader assembly to the atmospheric vent. When the pressure in the main reservoir has dropped to the point where it is desired to cause the compressor to operate, the governor assumes the cut-in position which vents main reservoir air from the face of the unloader valve. The return and unloader springe then move the unloader valve outward, carrying with it the unloader plunger and the fingers (prongs) which unseated the inlet valves. The inlet valves are seated then by the valve springe, and the compressor resumes delivery of air to the main reservoir.

c. The air compressor governor, type NS16, is of the pneumatic double-safety-valve type and consists of two distinct portions, the operating portion and the pipe bracket. Pipe connections to the compressor and to the main reservoir are provided for in the pipe bracket so that the operating portion may be removed for repairs or replacement without breaking any pipe joints. The operating portion casting is marked HP and LP. The adjusting screw in the HP section is used to regulate the point of air compressor cutout or unloading point while the adjusting screw in the LP section is used to regulate the point of air compressor cut-in or loading point. Therefore, it is necessary to set two pressures when adjusting the governor—the high pressure, where the governor unloads the compressor, and the low pressure, where the governor loads the compressor. If all compressors on multiple-unit locomotives load and unload simultaneously, the governor functions with an air-operated switch which controls a magnet valve in each locomotive. The magnet valve controls the flow of main reservoir pressure to the air compressor unloader valves in its unit. The control circuit to the magnet valve is trainlined to all units connected in multiple so that when the pressure is sufficiently low on any unit to load its compressor, all compressors are loaded at the same time. All compressors are thereby required to share the load.

119. Airbrake System

a. *General.* Without sturdy, quick-acting, remote-controlled braking equipment, it would be impossible to operate modern trains. Air has been used to operate the brakes on trains for such a long time, and with such a good record of performance, that the importance of proper maintenance and operation is not initially apparent. However, it is absolutely essential for personnel who have anything to do with train handling, either directly or indirectly, to have a thorough understanding of the basic principles of this highly important part of train control. Engine crews must be able to make required brake tests to insure that the system remains in operating order and operate the brakes to secure the best results under different conditions existing on the track, locomotive, and train. Maintenance men are more concerned with the internal construction of the equipment. Many improvements have been made in designs in order to meet various modern needs, and reference to appropriate manufacturers' instruction manuals is necessary for adequate understanding of any specific installation. The information which follows gives a general basic understanding which has many broad applications. A clear distinction must be made between the following principal types of airbrake systems.

b. *Automatic Airbrake System.* The automatic airbrake system controls both locomotive and train brakes, and consists chiefly of a compressor to supply air, a reservoir for storing an adequate supply of air, a governor to control compressor pumping, duplex pressure gages, brake cylinders whose pistons apply the brakes through mechanical linkage called brake rigging, distributing valve and automatic and independent brake valves to control the flow of air from the reservoir to the brake pipe. Pressure is maintained in the brake pipe the entire time the train is operating, and a reduction in pressure applies the brakes while an increase in pressure releases the brakes. Brakes on the rear cars of long trains respond much sooner with improved automatic equipment than in a straight airbrake system, and there is positive protection against a leaking brake pipe or broken hose connection. Additional equipment on each car in the train consists of an auxiliary reservoir which holds the air for use in the brake cylinders and a trip valve which responds to the changes in train brake pipe pressure in a manner which admits air promptly from the auxiliary reservoirs to the brake cylinders.

c. *Straight Airbrake System.* The straight airbrake system utilizes the air compressor and reservoir on the locomotive to supply air pressure to the brake cylinders of each car in the train. The system is necessarily slow in action compared to the automatic system because pressure must be built up by a passage of air from the locomotive reservoir to the last car in the train.

d. Independent Airbrake System. The independent airbrake system controls the locomotive brakes only by means of a separate valve on the brake pedestal. A decrease in brake pipe pressure applies the brakes, and an increase in brake pipe pressure releases the brakes. The system is not satisfactory for trains of more than a few cars in length, as in shifting cars in industrial plants or work trains, because the car brakes are inoperative which causes rough operation and slow stops.

e. Independent and Automatic Systems. Locomotives have both independent and automatic systems installed on them to attain greater flexibility in control. They have two brake valves at the operator's position called the independent and the automatic brake valves. The independent brake valve controls locomotive brakes only and the automatic brake valve controls the locomotive and train brakes. Locomotive brakes may be applied or released independently of the train brakes or in conjunction with the train brakes. It is not necessary to use more than one brake valve at a time.

f. Vacuum Brake System. MRS road switchers (fig. 97) and other diesel-electric locomotives in the military fleet which are designed for foreign service are equipped (or can be equipped) with vacuum brake valves in order to handle trains in oversea areas where all the rolling stock is equipped with vacuum brake systems. In train vacuum brake operation, the compressed airbrake pipe is cut out and the vacuum brake valve connected. The locomotive and train automatic brakes are then controlled by the vacuum brake valve and the independent brake by the independent brake valve handle (compressed air). Details of the method of operation of vacuum brakes on such locomotives are contained in TM 55-2040.

120. Airbrake Equipment

In addition to the compressor, governor, reservoirs, and brake valves previously mentioned, personnel should be familiar with many other parts of the system. Each part of the system must be individually studied, and only typical examples are given below.

a. Cocks. The use of the various cutout cocks is best understood by the study of actual piping diagrams (or in some instances schematic diagrams). In multiple-unit operation, the brakes of the trailing unit or units are fully operative, but controls are cut out, and the brakes are operated by the engineman on the leading unit by use of the automatic brake valve. Double-heading or pushing operation is much like multiple-unit operation, but the locomotives need not be coupled to each other and the engineman of the subordinate locomotive may find it necessary to release brakes to keep the wheels from overheating when the lead locomotive is applying train brakes. In deadheading operations, the locomotive brakes act like the brakes of a train.

b. Gages. Duplex air gages have two pipe connections and two dial indications. Equalizing reservoir pressure and main reservoir pressure are indicated on one gage and brake pipe pressure and locomotive brake cylinder pressure are indicated by the other gage.

c. Equalizing Reservoir. An equalizing reservoir adds volume to the space above the equalizing piston in the brake valve so that reductions in brake pipe pressure may be properly made during service applications of the brakes.

d. Distributing Valve. A distributing valve, when actuated by the brake valves, permits air to flow to the locomotive brake cylinders, maintains brake cylinder pressure against leakage when brakes are held in applied position, or permits air to exhaust from brake cylinders to atmosphere when releasing brakes.

e. Feed Valve. A feed valve automatically maintains a predetermined air pressure in the brake pipe.

f. Reducing Valve. A reducing valve reduces main reservoir pressure for straight air operation or for air signal system.

g. Quick Release Valve. A quick release valve provides a rapid release of brake cylinder pressure during the release operation.

h. Emergency Brake Valve. This valve, found on some locomotives, is connected to the brake pipe air line. It provides a means of quickly venting the brake pipe pressure through the discharge opening to the atmosphere. It operates like the conductor's emergency valve found in cabooses. A pull cord attached to the operating lever is located in the cab above the fireman's position (left side). When the cord is pulled, the operating lever trips, opening the valve, obtaining an emergency brake valve application. When the cord is released, the valve will reset, preventing further loss of brake pipe air. *This valve should be used only in emergencies where an emergency brake application cannot be quickly obtained from the automatic brake valve.*

121. Airbrake Operation

a. Charging the System. An adequate supply of air is necessary to operate the brake system. Under some conditions, it may take from 5 to 10 minutes to build air pressure up to normal in the brake pipe of a long train and, if a long train has been made up of cars with a depleted air system, it may take 30 minutes to charge the entire system. By placing the reverse lever in the OFF position and advancing the throttle ("rev up" the engines), air may be pumped at a fast rate to reduce the time necessary to charge the system. This can be done while a train is coasting as well as at standstill.

b. Independent and Automatic Brake Valve Positions. The independent brake valve controls the locomotive brakes independently of the train brakes. It is of the self-lapping type. The independent brake valve has two positions, release and brake or service application. The latter spans an operating range which will enable the engineman to secure the desired braking effect. The brake valve handle is kept in release position during movement of the locomotive. Type 6-BL equipment has six positions of the automatic brake valve —

(1) *Release position.* The purpose of this position is to provide a large and direct passage from the main reservoir to the brake pipe. It is used under some circumstances to speed up the release of train brakes. However, its value is limited and many railroads have abandoned its use entirely. If the handle were allowed to remain in this position for any length of time, the brake system would be charged to main reservoir pressure. To avoid this, the handle must be moved to running position. To prevent the engineman from forgetting this, a small port discharges main reservoir air to the atmosphere in release position with sufficient noise to attract attention to the handle position.

(2) *Running position.* This is the proper position of the handle for charging the brake pipe and releasing the train brakes. In this position, a large direct passage connects the feed valve pipe to the brake pipe so that the latter charges up under feed valve control and cannot attain a pressure above that for which the feed valve is adjusted. The equalizing reservoir charges uniformly with the brake pipe, keeping the pressure on the two sides of the equalizing piston equal. The distributing valve release pipe releases air into the atmosphere.

(3) *Service position.* This position gives a gradual reduction of brake pipe pressure to cause a service application.

(4) *Lap position.* This position is used while loading the brakes applied after a service application until it is desired either to make a further

brake pipe reduction or to release them. All ports are closed.

(5) *Holding position.* This position is so named because the locomotive brakes are held applied while the train brakes are being released and their auxiliary reservoirs recharged to feed valve pressure.

(6) *Emergency position.* This position is used when the most prompt and heavy application of the brakes is required. A large and direct communication is made between the brake pipe and atmosphere. This direct passage makes a sudden and heavy discharge of brake pipe air, causing the car brake valves and distributing valve to move to emergency position and give maximum braking force in the shortest possible time. In this position, locomotive brake cylinder pressure is maintained against leakage and main reservoir pressure is permitted to flow into the sandpipe in case air sanders are connected to the brake valve or to the emergency relay valve.

c. Operating Practices. The following general methods of handling brakes do not apply rigidly for all conditions but are included here to broaden the scope of general information for basic study.

(1) When not in use, carry the automatic brake valve in running position and the independent brake valve in release position.

(2) To apply the brakes in service, move the handle of the automatic brake valve to the service position, making the required brake pipe reduction, then back to lap position, which is used for holding all the brakes applied.

(3) It is, as a rule, safest to come to a stop before releasing the brakes on a freight train, especially a long one, rather than attempt to release at low speed. However, if conditions permit the release while in motion, the brake valve handle should be moved to running position to release and recharge the system. If there is a probable need of another application, be sure there is enough pressure to enable the compressor to charge the line before the brakes are needed. A train may overshoot a stop signal or run away on a mountain if charging requirements are not carefully observed.

(4) If, when releasing, it is desired to hold the locomotive brake applied after the train brakes release, move the handle to holding instead of running position, then release the locomotive brake by moving the handle to running position and leaving it there or graduating it off, as circumstances require, by short successive movements between holding and running positions.

(5) To apply the brakes in emergency, move the handle of the automatic brake valve quickly to emergency position and leave it there until the train stops.

(6) When using the independent brake only, the handle of the automatic brake valve should be carried in running position. The independent application may be released by moving the independent brake valve handle to release position. When all brakes are applied automatically, the locomotive brake can be graduated off or released by depressing the independent brake valve handle in release position. The red hand of one air gage will show, at all times, the pressure in the locomotive brake cylinders; this hand should be watched in brake manipulation. Depressing the independent brake valve handle when in release position will quickly release the locomotive brake under any and all conditions. This brake valve has no slow application position, and care should be taken to prevent harsh slack action when handling a long string of cars.

(7) The train brakes should invariably be applied before detaching the

locomotive, holding the train with handbrakes where necessary. Setting the handbrakes is especially important on a grade.

(8) The automatic brake should never be used to hold a locomotive or a train while standing even where the locomotive is not detached for longer than 10 minutes, and not at all if the grade is very steep or the condition of the brake is not good. The safest method is to hold with handbrakes only end keep the auxiliary reservoirs fully charged so as to guard against a start from brakes leaking off, and to be ready to obtain any part of full braking force immediately on starting.

(9) The independent brake is a very important safety feature in this connection, as it will hold a locomotive or a heavy train on a fairly steep grade if, as the automatic brakes are released, the slack is prevented from running in or out (depending on the tendency of the grade) and giving the locomotive a start.

(10) When leaving the locomotive, while doing work about it or when it is standing, always leave the independent brake valve handle in application position.

(11) After an emergency application of the brakes while running over the road due to any causé other then intended by the operating engineman, move the automatic brake valve handle to the lap position to prevent loss of main reservoir pressure. After the train stops, the cause of the application should be located and remedied before proceeding. Before leaving the roundhouse, the engineman should try the brakes with both brake valves and see that no serious leaks exist. The pipes between the distributing valve and the brake valve should be absolutely tight. The safety valve operation and adjustment should be tested at this time and on arrival at terminal.

To determine adjustment of the safety valve, move the automatic brake valve handle to emergency position. After the safety valve opens, return the brake valve handle to lap position and note the pressure at which the safety valve closes. The safety valve should be adjusted to 68 pounds. It is assumed that this test will always be made on the locomotive alone, that is, before the brake pipe is connected to the train.

(12) When two locomotives are coupled together, the brake pipe hose must be coupled between the two locomotives and their angle cocks should be opened. Where there are two or more locomotives in a train, the instructions already given remain unchanged so far as the leading locomotive or the locomotive from which the brakes are being operated is concerned. On the second locomotive, close the brake pipe by setting the cut-out cock to the desired trailing position and place the handles of the automatic brake valve in running position and the independent brake valve in release position. The brake of the second locomotive can then be operated from the first locomotive the same as those in the train. But, if the engineman on the second locomotive finds it necessary, he can prevent the application of the brake on the second locomotive by depressing the independent brake valve handle in release position. Also, if the brake on the second locomotive is applied and there is danger of overheating wheels, or if the wheels should slide, the brake can be released by depressing the independent brake valve handle in release position. The brake can be reapplied later by using the independent brake valve handle in the usual way, provided the handles on the independent and automatic brake valve on the second locomotive

are, as before, left in release and running positions, respectively, after the operation. This does not in any way interfere with the brake on the second locomotive. The pressure in the brake cylinders on the second locomotive should never be thus reduced, except where absolutely necessary.

122. Safety (Deadman) Control

Deadman control is a safety device usually a foot valve which must be depressed at all times when the locomotive is in operation unless a service application of the airbrake (approximately 20-pound brake pipe reduction) is already in force. It safeguards against the incapacitation or negligence of the operator. A release of the deadman pedal (or corresponding manual control) causes a warning whistle to sound for approximately 4 seconds after which the brakes are automatically applied. A brake application can be avoided if the deadman pedal is depressed again within the warning period. Individual installations vary in braking (emergency or service application) and in power interruption. The engine may be returned to idle automatically by a safety control application or it may be necessary for the operator to idle it by the usual movement of the throttle.

PART FOUR

DIESEL-ELECTRIC LOCOMOTIVE

CHAPTER 13

STRUCTURAL FACTORS

123. General Description

a. A diesel-electric locomotive is primarily a powerplant mounted on wheels, with controls whereby the power can be used in the propulsion of railroad vehicles. Electrical equipment has been found to be the most satisfactory method of transmitting power from large internal combustion engines to the driving wheels. The principal task of the electrical transmission system is to receive mechanical energy from the engine, convert it into electrical energy, and transmit it to traction motors which convert the energy back into mechanical energy at the wheels. There are several advantages to this double conversion of energy, such as the ease of transmitting the energy, the precision of the controls, and the flexibility in meeting the power demands.

b. Typical diesel-electric locomotives are shown in figures 72 and 73. The center cab arrangement is normally used when there are two power units on one frame. A power unit consists of a complete engine, generator, and motor system. Each power unit has its own cooling system and air compressor and operates independently, except for the master controller and battery which function with units. Many features of braking, sanding, and similar auxiliaries are similar on all types of locomotives. While locomotives are frequently used interchangeably between several types of service, they are built to meet prevailing requirements in three distinct types of service. Switching service requires high tractive effort and good acceleration in the frequent start, stop, and reversing movements. Freight service requires sustained tractive effort at moderate speeds. Passenger service generally involves less tonnage than freight service, but speeds are higher and auxiliary services, such as steam heat, are furnished by the locomotive. Various requirements are met by changes in gear ratio, truck construction, and accessory equipment.

124. Mechanical Considerations

a. In order to have good tracking characteristics, a locomotive must be able to negotiate sharp yard curves without derailing or spreading the track and must not gallop, nose, or wear the flange and rail excessively on main line service. In general, long locomotives are more stable at high speed than short locomotives but give more trouble on sharp curves. Swivel trucks decrease the rigid wheelbase. Swing bolsters and long center pin spacing improve the riding qualities.

b. The weight of locomotives in common use varies from about 44 tons to 175 tons. Smaller locomotives are usually classed as industrial locomotives. Axle loadings up to 60,000 pounds are standard practice. Axle loading may be kept low by specifying an increased number of axles when the locomotive is under construction. The weight on the driving wheels varies with the total locomotive weight and the number of wheels.

c. Wheel arrangement varies from four-wheel rigid trucks on small industrial locomotives to two swivel trucks of four wheels or six wheels each. Swivel trucks are commonly used on locomotives. Each axle has its own traction motor as a rule. Principal exceptions are the mounting of a single motor on a four-wheel truck with side rod connections between the two pairs of wheels and the mounting of only two motors on a six-wheel truck which leaves two wheels as idling wheels.

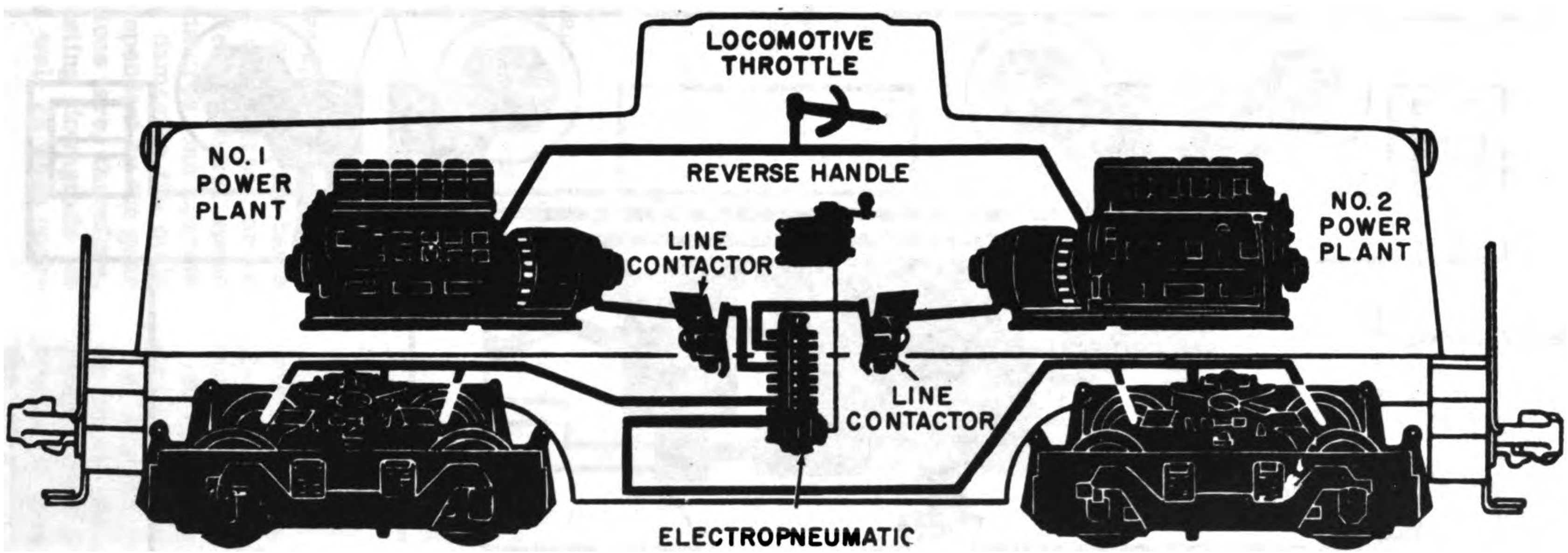


Figure 72. Phantom view of locomotive with center cab.

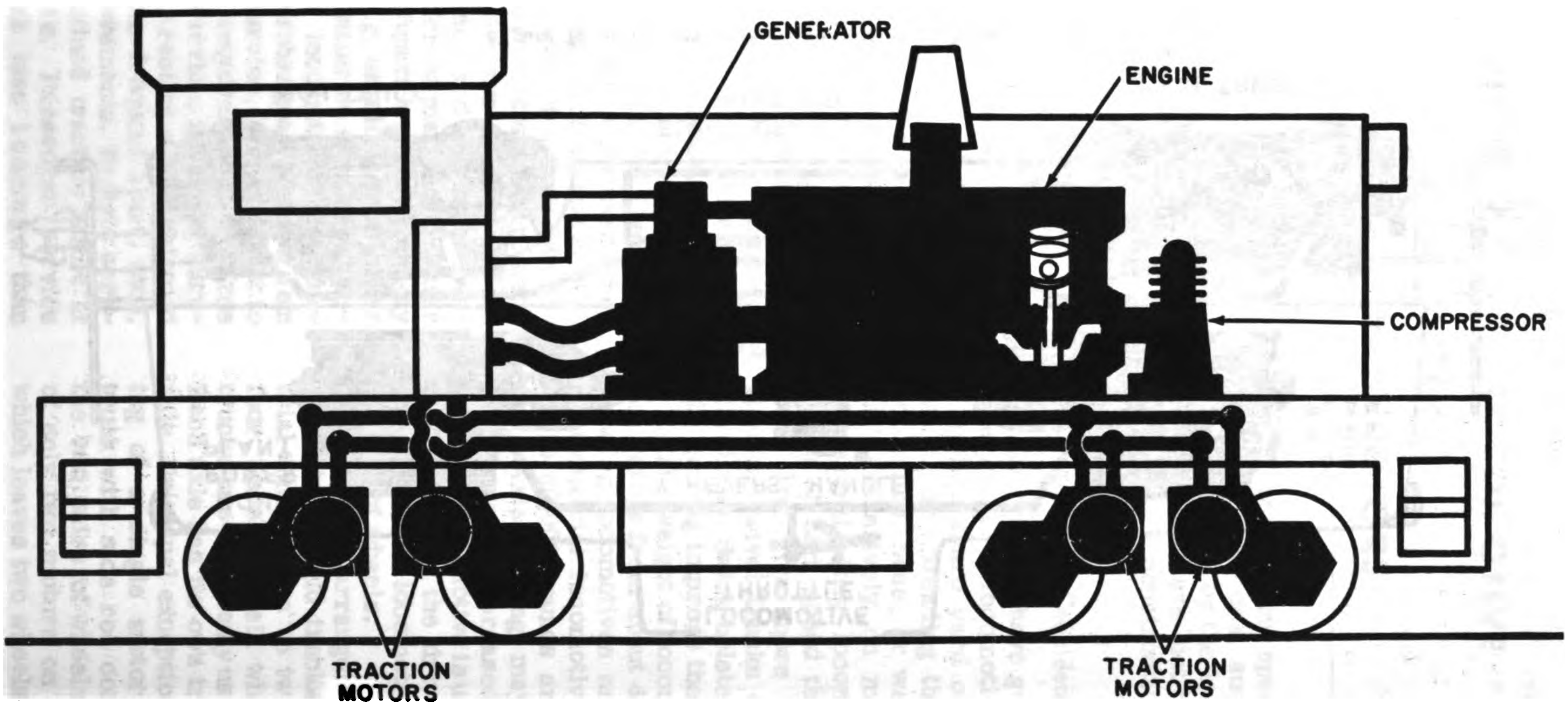


Figure 73. Phantom view of locomotive with end cab.

d. Horsepower varies from about 300 hp to 2,400 hp per locomotive unit. When units are connected semipermanently, units with a controlling cab are called A units, and units without a controlling cab are called B units. The power systems of A and B units are identical, and the operation is equivalent to multiple-unit operation.

125. Gear Ratios

Gear ratio is expressed by two numbers, one being the number of teeth on the axle-mounted gear and the other being the number of teeth on the traction motor pinion. Gear ratio is selected on the basis of the service which the locomotive is to perform. A ratio which keeps motor speed relatively low is used for high speed service. Tractive effort at continuous rating and at specified short-time ratings changes as gear ratio changes. A ratio that requires many revolutions of the motor for comparatively little movement of the locomotive is used for heavy-duty service where power is more important than speed. Intermediate ratios are used for general all-purpose service. The pinion is usually heated and shrunk on the armature shaft. It may be milled and keyed into the shaft on some models. The axle gear is pressed on the axle in the same manner as the wheel. Pinions and gears should be scrapped if a tooth is broken or if the working surface is severely damaged by pitting or spalling (splintering).

126. Speed Limitations

Maximum locomotive speeds are established by the manufacturers on the basis of tracking qualities of the truck or on the basis of allowable peripheral speed at which motor armatures can operate without loosening or damaging the coils and are, therefore, dependent on the gear ratio. Speed limitations are, therefore, applicable when coasting downgrade or when deadheading as well as when operating under power.

127. Arrangement of Equipment

The location of equipment is determined by basic design requirements, operating requirements, servicing requirements, and repair requirements. Radiators and shutters are usually built into the outside walls or roof section for maximum cooling. Locomotive controls are grouped at the operator's position. Power unit controls are grouped together and are mounted in the cab near the locomotive controls but may be in the engineroom of larger locomotives. For adequate servicing, fills and drains for fuel, water and supplies are readily accessible on both sides of the locomotive. Removal for repairs requires working clearance which will permit a maximum of neighboring equipment to remain undisturbed. Many engine parts may be lifted by cranes through roof hatches. Jacking or lifting lugs are provided for supporting the underframe when it is necessary to remove the entire body from the trucks. Typical locations of major items of equipment on a locomotive are shown in figure 74. Operators should be familiar with all fillers and drains. Typical locations are shown in figure 75.

a. Water fills, for the engine cooling system, generally supply all cab heaters, turbochargers, and heat exchanger cooling lines. Add water slowly.

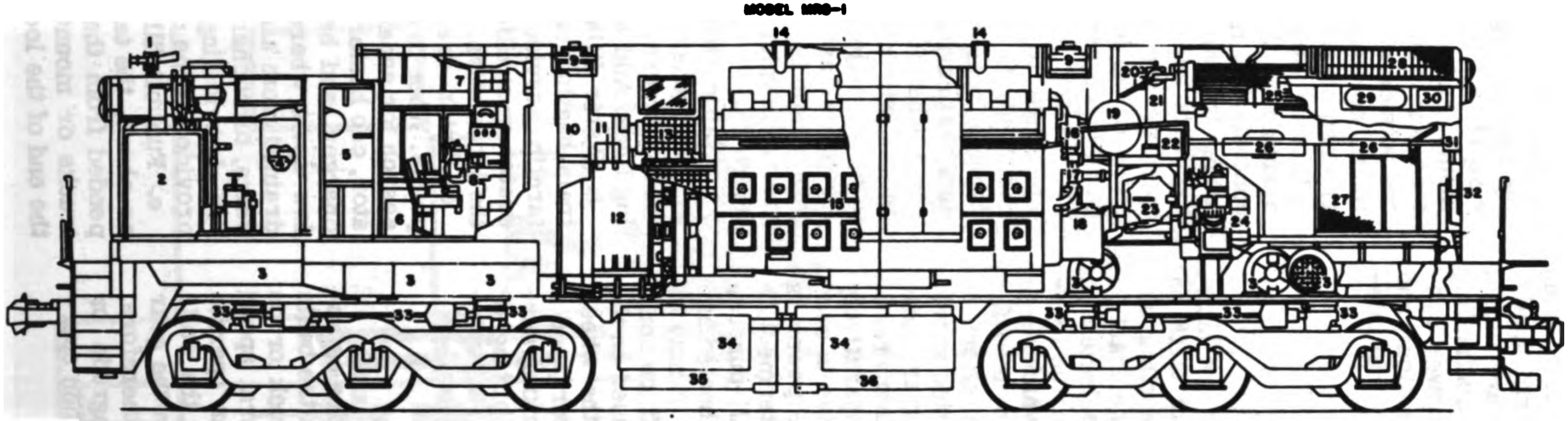
b. Water fills for steam generators for train heating or auxiliary engine heating (arctic service) are on the steam generator or auxiliary water tanks underneath the locomotive.

c. Water drains are located at many points. When draining to prevent freezing, search for separate drains on engine radiator, cab heaters, steam generator, turbocharger, and heat exchanger, as well as low spots where condensed water may be drained from air compressors, air reservoirs, turbocharger, etc.

d. Lubricating oil drains and fills are provided in the diesel engine.

e. Fuel oil fills are usually adjacent to, or above, the tank. The tank may be suspended from the underframe between trucks or mounted on the wheel frame at the end of the locomotive.

UNITED STATES ARMY
120 TON DIESEL ELECTRIC LOCOMOTIVE
MODEL MRS-1



1. HORN
2. STEAM GENERATOR
3. TRACTION MOTOR BLOWER
4. NO.2 HOT WATER HEATER
5. ELECTRICAL CABINET
6. TOOLBOX
7. CAB HEATER
8. ENGINEMAN'S CONTROLS
9. SANDBOX AND FILLER
10. MAIN GENERATOR BLOWER
11. AUXILIARY GENERATOR
12. MAIN GENERATOR & ALTERNATOR
13. ENGINE SCAVENGING AIR BLOWER
14. ENGINE EXHAUST STACK
15. DIESEL ENGINE
16. ENGINE GOVERNOR
17. ENGINE WATER PUMP
18. LUB OIL STRAINERS
19. ENGINE COOLING WATER TANK
20. ENGINE TEMPERATURE SWITCHES
21. LUB OIL COOLER
22. LOAD REGULATOR
23. LUB OIL FILTER
24. AIR COMPRESSOR
25. RADIATOR
26. ENGINE COOLING FAN
27. COOLING FAN AIR INTAKE
28. COOLING FAN SHUTTERS
29. NUMBER BOX
30. CLASSIFICATION LIGHT
31. COOLING FAN CONTACTOR PANEL
32. HAND BRAKE
33. TRACTION MOTOR
34. BATTERY BOX
35. FUEL TANK
36. WATER TANK OR EXTRA FUEL TANK

Figure 74. Arrangement of equipment on a typical diesel-electric locomotive.

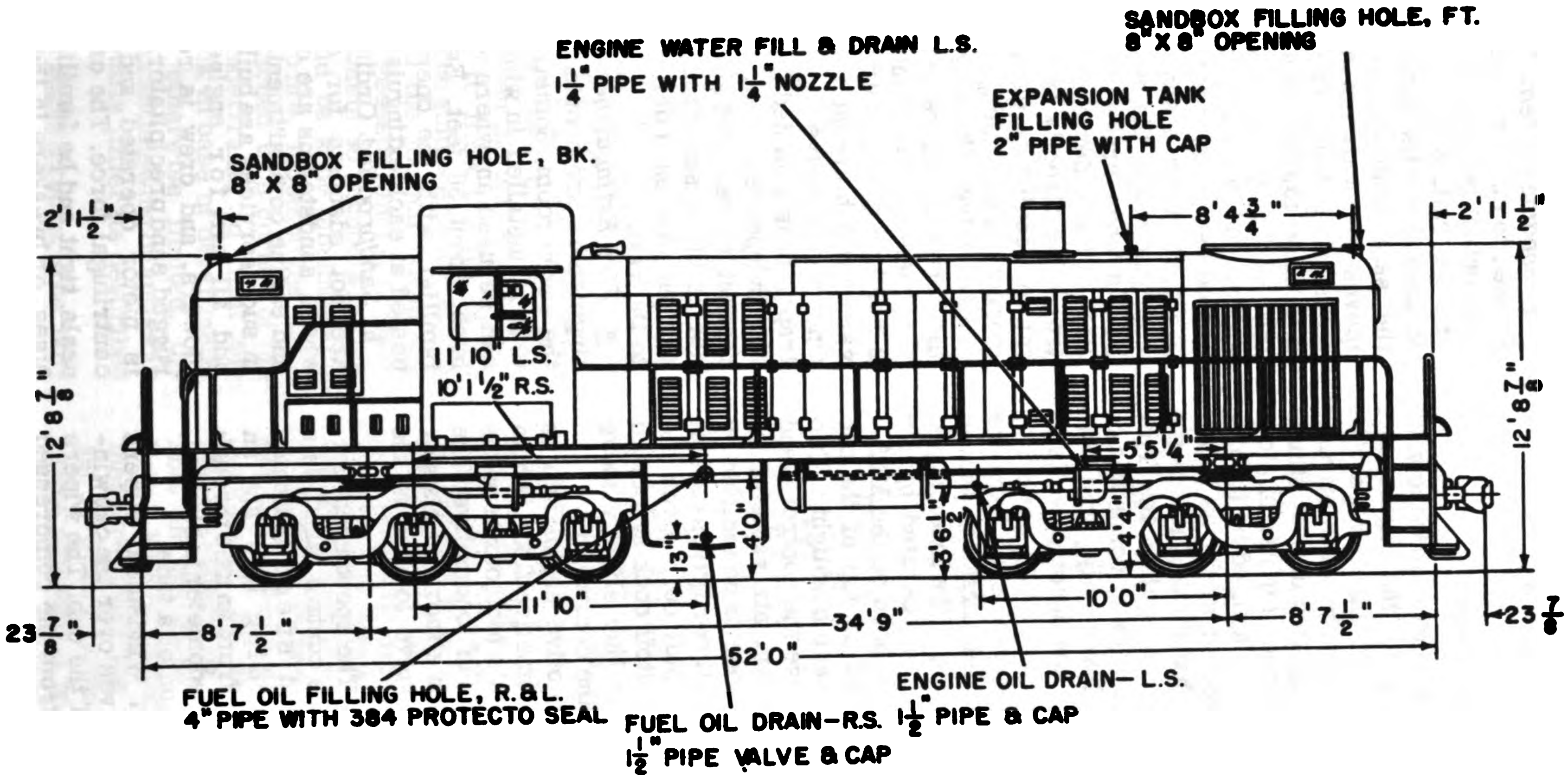


Figure 75. Location of fillers and drains on a typical diesel-electric locomotive.

f. Sandboxes are generally located in the superstructure above the sand traps, and sand flows into the trap by gravity.

128. Locomotive Accessories

a. Handbrake. The handbrake is mounted on the front or rear of the engineroom hood or in the cab and should always be released before moving the locomotive. It is a holding brake, applied only at standstill, and is not intended for use in stopping. The handbrake is applied by turning the handwheel clockwise as far as it will go. To release the handbrake, rotate the wheel counterclockwise against the friction locks. The handbrake is connected to one brake cylinder lever only. Apply the handbrake whenever the locomotive is to left standing by itself for any period of time. Remove the reverse lever from the controller and apply this brake whenever anyone is working around the locomotive.

b. Horn. Horns are operated by air valves. The air chime horn on the MRS-I locomotive is mounted on top of the cab just forward of the rear headlights. Two pull cords located above the control stand operate the double stem air valve which allows a full or soft tone to be emitted by the horn. The front pull cord gives the soft tone while the rear pull cord gives the full tone. The horn shutoff cock is located in the horn valve air line slightly above the floor in front of the controller.

c. Bell. The locomotive signal bell is usually under the locomotive floor behind the pilot or switchman's footboards on the right side of front end of locomotive. The bell is stationary with a movable clapper operated by an air valve located at the engineman's station.

d. Speed Recorder. The speed recorder, located in front of the control stand, is a hydraulically operated speed indicator with a speed recording tape and an odometer. It is driven from an axle through a flexible cable. A speedometer is similar, except for the omission of a tape.

e. Window Wipers. Windshield wipers are controlled by valves over the cab windows on each side of the cab. The wipers are operated by air from the compressed air system and function independently of each other. They should not be run on a dry window as dirt on the glass or blade will scratch the glass.

f. Sanding System. The sanding system is used to deliver sand, when required, at the contact between the tread of the wheel and the rail. Sand is stored in sandboxes located above the sand trap and flows into the sand trap by gravity. Air pressure moves the sand from the sand trap, through the sand delivery pipe, to the rail. There are three major units to a sanding system — the operating device, the control valve, and the sand trap. The operating device can be an independent sander operating valve or a sanding valve which is incorporated in the automatic brake valve handle when brake is used in emergency. Both of these devices can actuate the control valve directly or, where electropneumatic sanding is used, they actuate a magnet valve which, in turn, actuates the control valve. The valve is either marked for forward and reverse direction or, in the case of electropneumatic sanding, a 2-position on-off control energizes magnet valves which are interlocked for direction. One control valve supplies air to all sand traps. It is acutated by air supplied from the independent operating valve or the magnet valve. Sand always covers the air nozzle in the sand trap, and the air moving against this sand delivers a uniform flow to the rail.

g. Fire Extinguisher. Portable fire extinguishers are provided in the cab and in the engineroom. Sometimes a builtin system in installed in which case the nozzle can be used anywhere within range of the hose, about 50 feet. Everyone should be familiar with the operating instructions posted at each extinguisher.

h. Sandproofing. Ordinary air filters are not adequate for desert operations where sandstorms are encountered. Cabs and engine compartments for locomotives in such services are built for tight sealing, and all air for engines, compressors, blowers, and crew is received through a rugged sand precipitator. A typical cleaner is motor operated and removes air by centrifugal force. The crew must keep the seals tight and be familiar with switches, fuses, or breakers in the powerline to the cleaner. All regular air filters are retained in service.

CHAPTER 14
TRUCKS

129. Conventional Trucks

a. *Swivel Trucks.* Swivel trucks are used on all but the smallest types of diesel-electric locomotives (fig. 76). Each truck has a center plate which supports the superstructure and allows the truck to swivel freely on curves. Small locomotives on a short wheelbase, usually of only two axles, may be built with a running gear that is rigid with the cab frame. A truck must carry the weight of the superstructure vertically, must absorb the lateral thrusts, must support the tilting tendency of the locomotive, must traverse uneven track without distortion or excessive stress in any of its members, must carry the brake rigging, and must carry the motors on electrically driven locomotives. Many different types of trucks have been designed to meet a great variety of conditions. The principal types of trucks in locomotives larger than 40 tons are four-wheel rigid trucks, four-wheel swing bolster trucks, and six-wheel swing bolster trucks. In all types, a truck bolster with a center bearing having a renewable plate, mates with the body bolster to carry the superstructure. Side bearings with renewable wear plates are mounted between the underframe and the truck frame to limit the tilt of the superstructure. The guides extending from the frame to hold the journal boxes are called pedestals. Pedestal liners, or wear plates, are renewable to compensate for wear. They should be kept lubricated to reduce wear. Some locomotives have safety chains attached to a corner of the truck and the underframe to limit the swing of the truck in case of derailment. If the swing is otherwise limited, the linkage is called an antislewing or antisway device. Other details differ as described below.

b. *Four-Wheel Rigid Trucks.* The bolster and frame are cast together in rigid trucks. The only lateral motion provision is in the journal boxes. Single coil springs rest in pockets inside the pedestal jaws. Additional support is provided by a spring (typically semielliptical) under the side frame which rests on hangers between equalizing bars extending between the journals. All wheels are drivers, but some small locomotives have only one motor, in which case the motor is geared to one axle and side rods connect the two pairs of wheels.

c. *Four-Wheel Swing Bolster Trucks.* The principal difference between a swing bolster truck and a rigid bolster truck is the independent suspension permitting lateral motion of the bolster with respect to the truck frame. Riding qualities are improved because the bolster absorbs some of the lateral blows between the truck and body. They are better suited to heavy road service. Triple-coil springs and sets of elliptical springs are often used.

d. *Six-Wheel Swing Bolster Trucks.* Six-wheel trucks distribute the locomotive weight more evenly along the rail than do four-wheel trucks. Most of the wheels are driving wheels in large locomotives, but some medium-sized locomotives for light track can obtain enough tractive effort from four driving wheels, in which case the extra pair constitutes idling wheels. A truck with idling wheels is smaller than one with six drivers, since one motor mounting is eliminated. Adjustable brake rigging is provided to take up slack caused by wear of brakeshoes. Compensation for brakeshoe wear and turned wheels is accomplished by either adjusting a hand slack adjuster or changing pins from one hole in the brake levers to another, or both. Brake cylinder piston travel is measured with the locomotive airbrakes set (3-5 in. allowable). Generally, minor brake adjustment on locomotives using the hand slack adjuster may be made while the airbrakes are set. This is done by

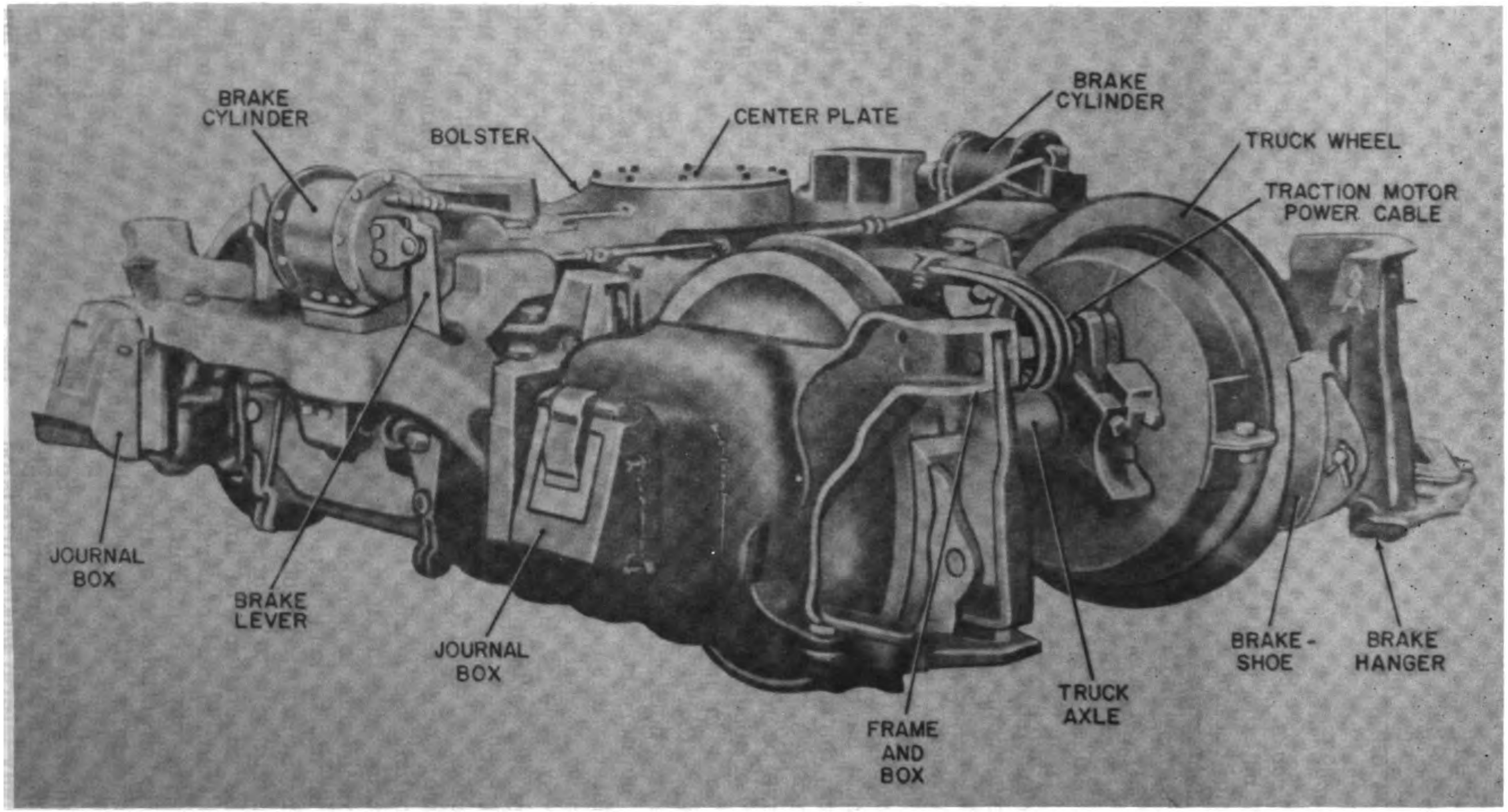


Figure 76. Four-wheel diesel-electric locomotive truck.

closing a cutout cock in the application lines to the brake cylinder, thus releasing the brakes on the cylinder or truck being worked on.

(1) The hand slack adjuster is used to take up slack in the brake rigging caused by brakeshoe wear and to keep the brake cylinder piston travel constant. Brake cylinder piston travel should be adjusted at the maintenance point by replacing worn shoes or changing brake lever pin positions if necessary. Leave the hand slack adjuster as near full travel as possible. Any possible adjustment that may have to be made en route can then be made with the hand slack adjuster, without the necessity of changing pins on the road. Hand slack adjusters with 8-inch travel have enough adjustment to wear a brakeshoe down completely to its condemning limit and still maintain the 2-inch piston travel if the pins and bushings are not badly worn.

(2) The automatic slack adjuster is used in addition to the hand slack adjuster on the six-wheel truck passenger locomotive. The function of this device is to take up automatically any slack in the brake rigging, due to brakeshoe wear, while the locomotive is en route on long sustained high speed and long distance runs with subsequent heavy braking, and also to maintain a constant piston travel throughout the trip.

(3) Brake adjustment on all locomotives should be made when main reservoir air pressure is pumped up. When making adjustments to the brake rigging, release the handbrake and set the independent brake valve in application position, setting locomotive brakes. There is no necessity to apply or release the brakes while adjustments are being made. For safety reasons brake adjustments are made after cutting out the applicable truck with a three way cut-out cock located under the body over each truck.

e. Wheel Set. An assembly of two wheels on an axle is generally considered a "wheel set" in railroad parlance. For diesel-electric locomotives, an axle gear is also mounted on the axle, except in "idler" wheel sets used in six-wheel trucks. The idler wheel is so designated because it mounts no traction motor; its purpose is to help equalize the weight distribution of the locomotive.

f. Axles. Axles are usually solid carbon steel forgings. There are many axle specifications for various services. Where the journal boxes are friction type, provision is made to take lateral thrust by a collar on each end of the axle. Roller bearing type axles have no collar at end of the journal. Axles are manufactured in six classifications, based on journal sizes, designated A to F, or 3-3/4 x 7 inches to 6-1/2 x 12 inches. Only the larger sizes are found in diesel-electric locomotive trucks.

130. Multigage Trucks

a. General. Multigage trucks are designated to permit adjustment of wheel spacing to accommodate diversified use of the locomotive on different track gages. The Military Railway Switcher (MRS) multiple-gage diesel-electric locomotive (fig. 97) has two six-wheel trucks with a traction motor on each axle. Since this truck was designed primarily for military use in various parts of the world, it had to be adaptable for track gages of 4' 8" (standard), 5' 0", 5' 3", and 5' 6". To accommodate the widest wheel gage, the frame is constructed wider than for any other truck used under locomotives. For field operation, wheel sets already assembled will be available for the different gages. Where facilities for wheelwork are available, the standard spacing wheel set can be repressed to the gage required. A change of wheel gage necessitates a change in the brake rigging and sand pipes to conform to wheel spacing. These components are so designed that they can be readily changed. The steps necessary to make these changes are discussed below.

b. Frame. The frame, figure 77, is a steel casting having two side frames connected near the center by two transoms or crossmembers. The transoms have four spring pockets cast on top near the junction with the side frames and spring-loaded wear and stabilizer plates as upright projections at these points. Six brake hanger bosses are cast integrally with the transoms, two on each end of one transom, and one on each end of the other transom. A pocket for a lateral shock absorber is centrally located on top of each transom. Each side frame has three pairs of pedestal jaws and two spring pockets cast integrally. The spring pockets are underneath the side frame between the pedestals.

c. Bolster. The bolster (fig. 78) is an "H" type casting with center casting on top and spring pockets underneath at the four corners. The spring pockets rest on the bolster coil springs which suspend the bolster and car body on the truck. A steel wear bushing is pressed into the center casting. Wear plates are mounted at the four corners of the bolster. The center of each edge of the bolster casting, which rides over the transoms in notched out so that it fits over the lateral shock absorbers in each transom to take up the lateral or sidewise motion of the car body. Wear plates are provided at these points.

d. Equalizers. Four pairs of equalizers are used to connect the journal boxes on the inside and outside of the pedestals. A spring seat is bolted between each pair of equalizers near the outer pedestals. Each of these four seats carries two single coil springs upon which the frame rides.

e. Coil Springs. Four heavy-duty dual coil springs, called bolster springs, are used to transfer the weight of the locomotive between the bolster and the frame. Four pairs of single coil springs carry the frame and ride on spring seats bolted between equalizers.

f. Journal Box. The journal box (fig. 79) is a plain pedestal-type box, consisting of a cast steel housing with a dustproof, spring-closed lid, 6-1/2- x 12-inch journal bearing. A general discussion of friction bearing journal boxes is contained in paragraph 131.

g. Axles. The axle (fig. 80) is tubular and extra long so that it can be used for

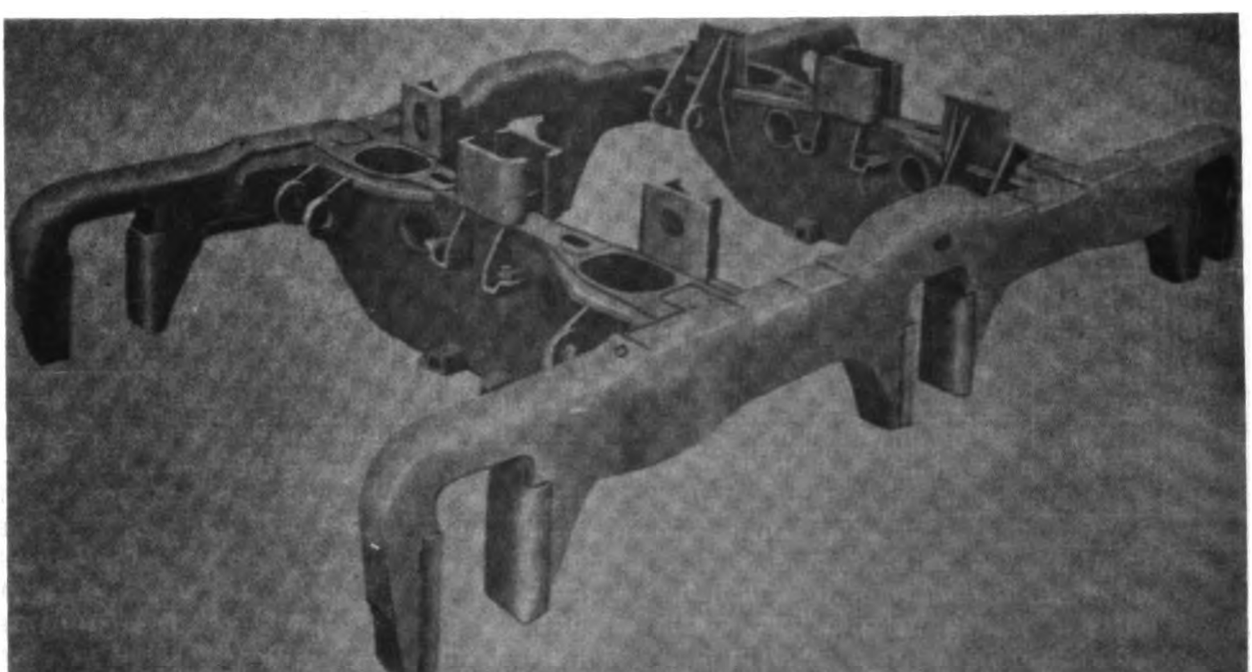


Figure 77. Truck frame.

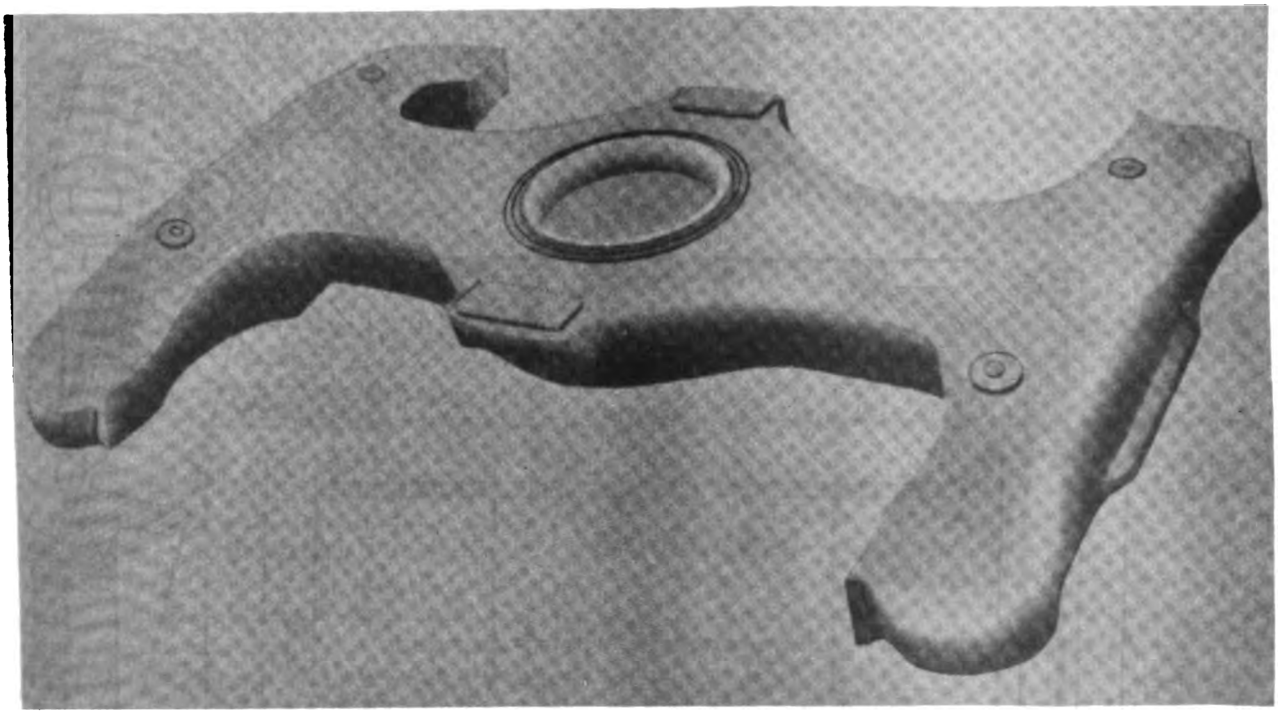


Figure 78. Truck bolster.

wheel spacings of 53-3/8-inch, 56-7/8-inch, 59-7/8-inch, and 62-7/8-inch. The wheel seats are the portions of the axle that have been increased in length to allow the wheels to be pressed onto the different gage widths. Since the journal boxes are friction type, provision is made to take lateral thrust by a collar on each end of the axle. Spacers (fig. 80) are used when a wheel set is changed to a wider gage. Normally, the three spacers are on the outside of the wheel for standard gage. The spacers have three threaded holes which are used to pull the spacers before wheel and axle gear removal. The inner spacer is not threaded all the way through, and it also has a polished surface which must be next to the motor journal bearing when this spacer (or spacers, depending upon gage) is placed on the inside of the wheel. To mount spacers, heat in hot oil (350° F.) and shrink in place. As indicated above, the spacers can be removed by using a puller.

h. Brake Rigging.

(1) The brake rigging on the multigage truck consists of two 10- x 8-inch brake cylinders mounted on each side of the truck frame and attached to two horizontal cylinder levers. The inner ends of these cylinder levers are attached, by means of a flexible clevis, to the top of the two end truck levers. The two horizontal cylinder levers are connected between the ends to an intermediate horizontal lever by means of two pull rods, with the necessary pins. This intermediate horizontal lever is provided with a fulcrum point between its ends, and its inner end is attached by means of a flexible clevis to the top end of the middle truck lever.

(2) The brake cylinders, the horizontal cylinder levers, the intermediate horizontal lever, and the necessary lever guides are mounted on two detachable brake cradles. These cradles are secured to the truck frame by three 1-inch bolts and are kept in position on the frame by a shear lug on the frame at each end of the cradle. These cradles each have twelve 1-1/16-inch holes spaced as shown in figure 81 for

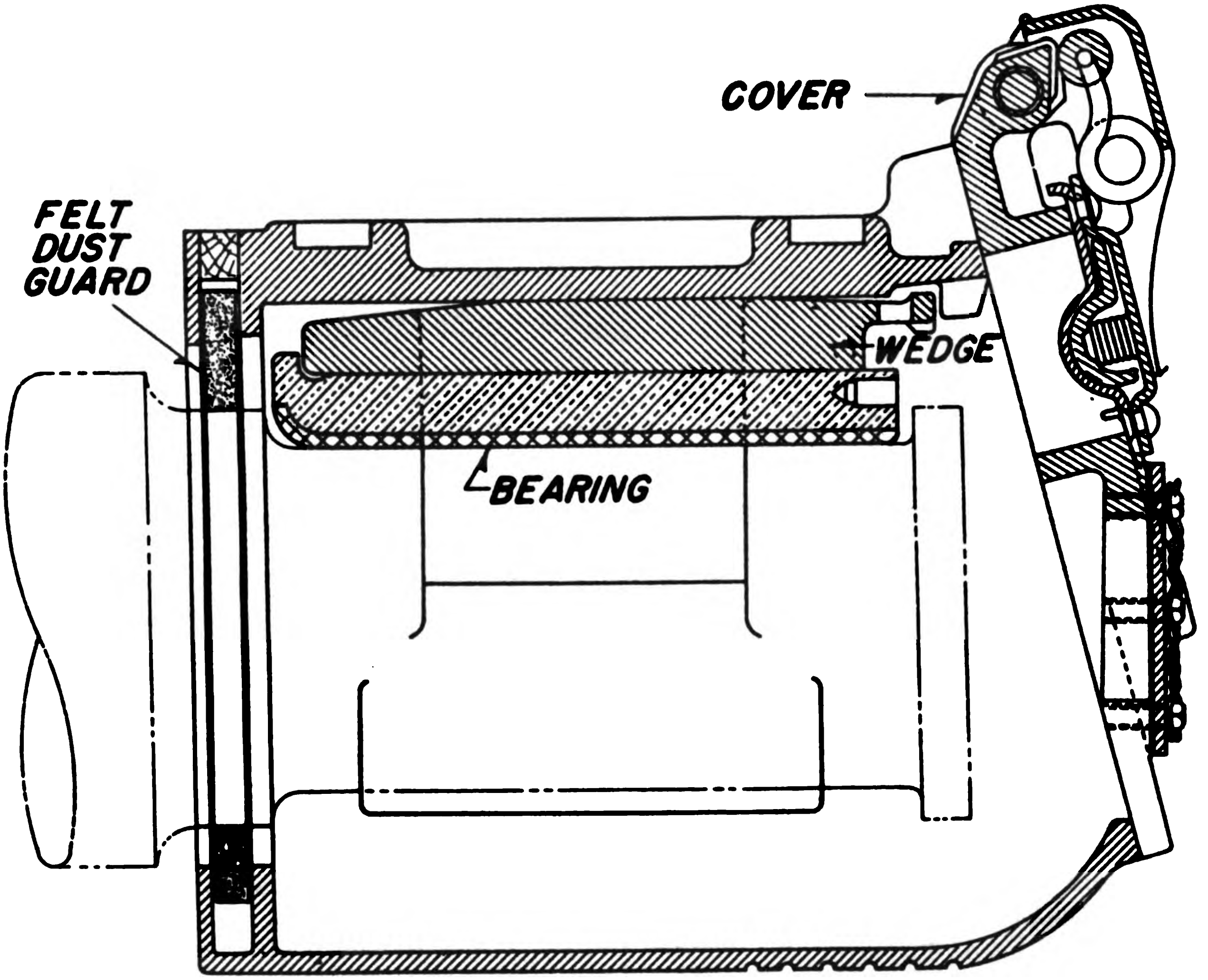


Figure 79. Fricton-type journal box.

the front cradle, and figure 82 for the rear cradle. These holes are designated A, B, C, and D, as shown figures 81 and 82. That portion of the frame which supports each of the cradles is provided with 6 holes tapped to take 1-inch bolts, and is arranged as shown in figure 83 for the frame under the rear cradle. These tapped holes are designated 1 and 2, as shown in figures 83 and 84.

(3) The three truck levers on each side of the truck are, as previously mentioned, connected at their top ends to the horizontal levers by means of a flexible clevis. To the lower ends of the truck levers are attached the brakeheads which hold the brakeshoes. On 4' 8-1/2" gage, nut and spring holding brakeshoe to brake lever are on the "outside." For wider gages, nut and spring must be on the "inside." At a point between the ends, these truck levers are attached to the truck frame by means of a 3/4-inch diameter pin, designated "U" in figure 85. This pin is secured by a 1/2-inch keeper bolt, designated "V" in figure 85. The truck lever is spaced laterally by four spacers, designated "W," "X," "Y," and "Z" in the same figure, which are 2,

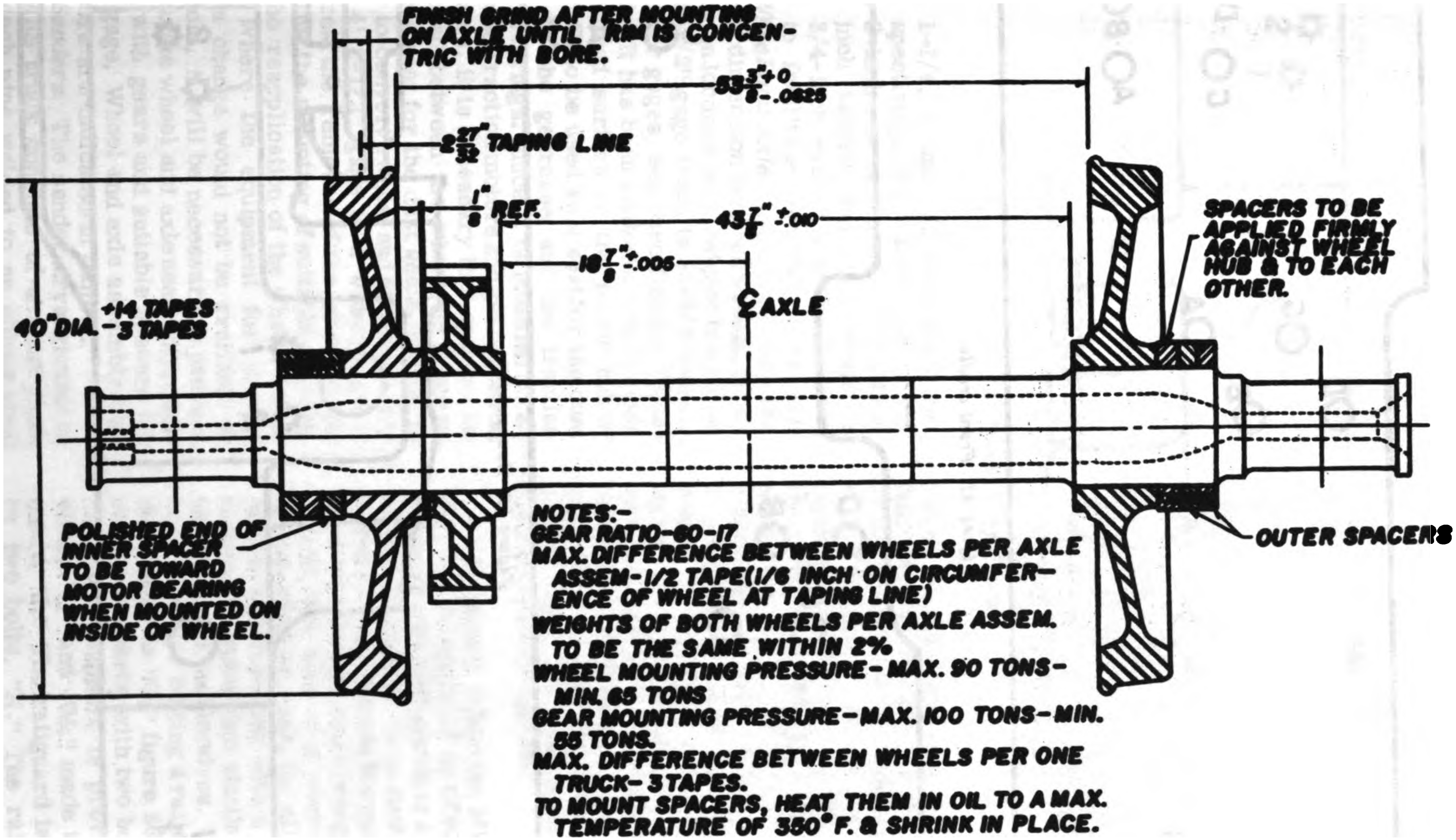


Figure 80. Wheel and axle assembly.

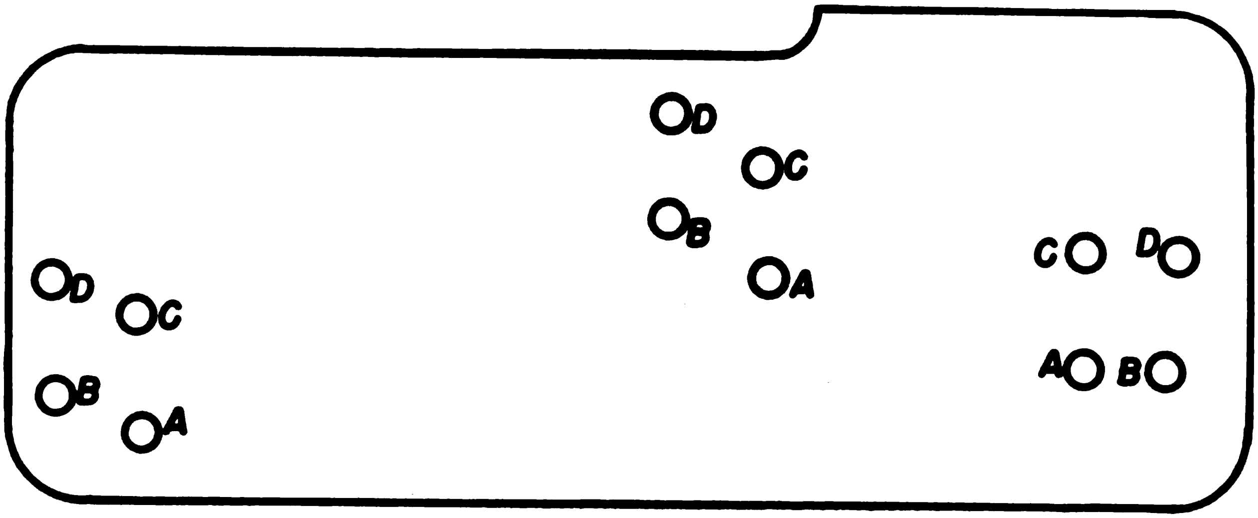


Figure 81. Front cradle

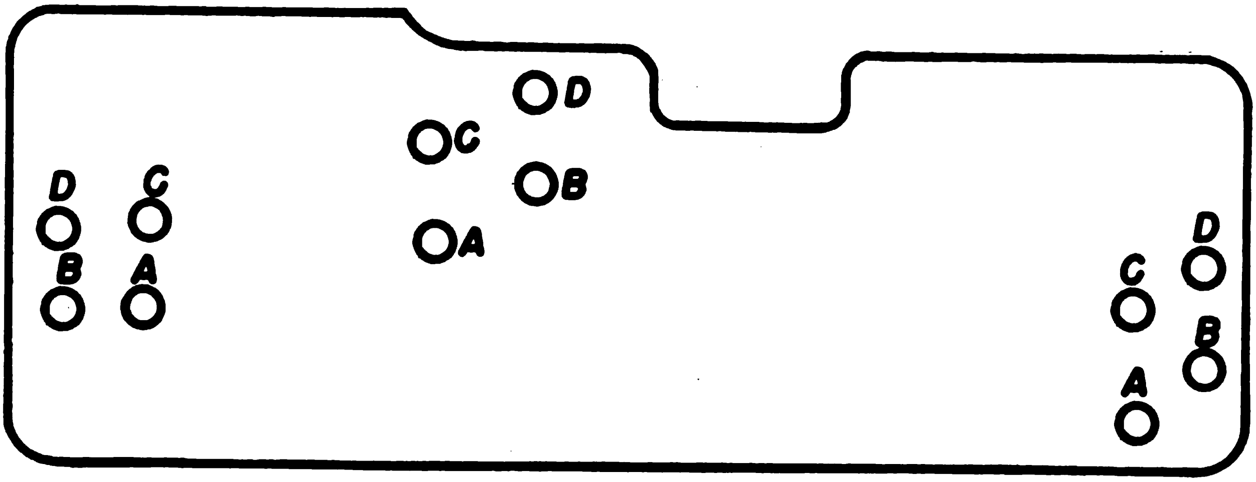


Figure 82. Rear cradle

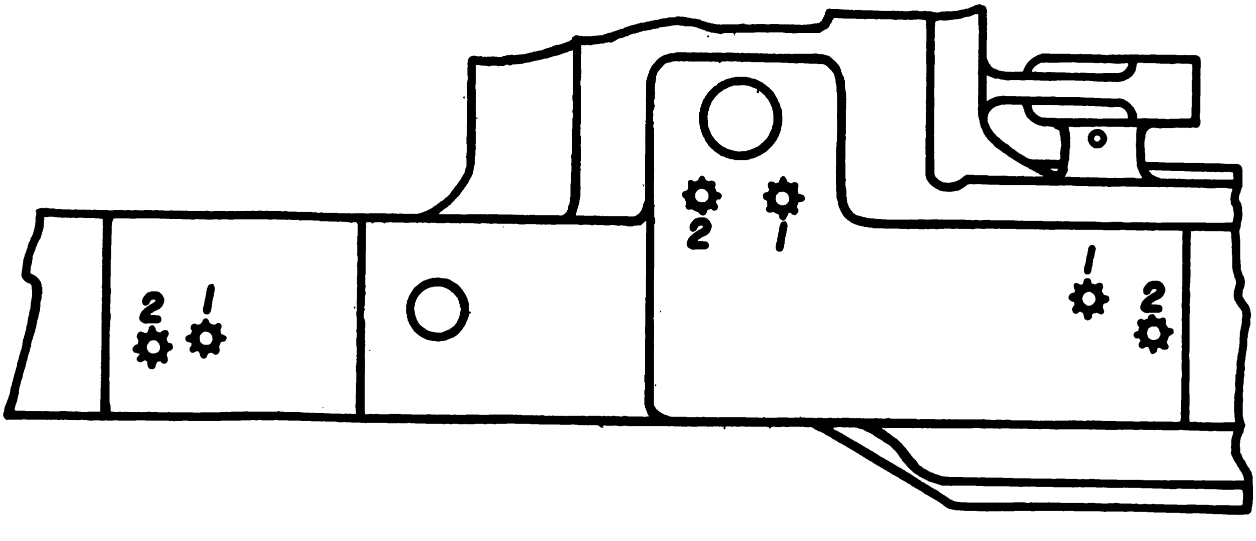


Figure 83. Frame at front cradle.

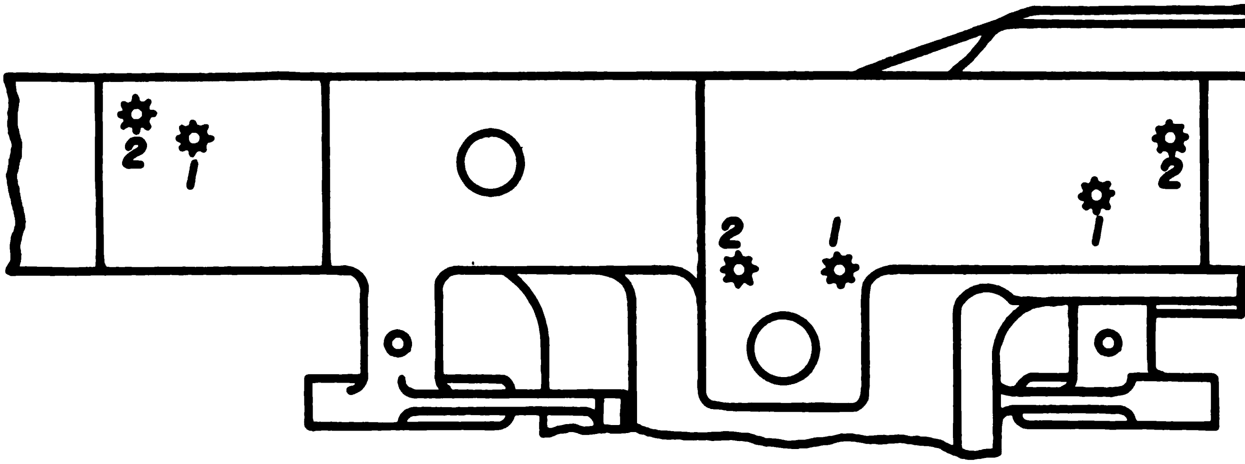


Figure 84. Frame at rear cradle.

1-1/4, 1, and 1/2-inch thick, respectively. The inner end of the 3-inch pin is supplied with a 3/4-inch tapped hole into which a 3/4-inch eyebolt may be inserted to facilitate removal of the pin.

i. Wheel and Axle Assemblies. The standard dimension between wheels, back-to-back on locomotives designed to operate on 4' 8-1/2" gage track is 53-3/8-inches. (For other gages, see Specification Table, table 1.) It has been customary to provide a machined surface on the inside hub of the wheel to be used as a seat for the dust seals in the gearcase and the traction motor bearings. Since it is intended to use the same traction motors and gearcases on all gages, it is necessary that spacers be employed between the wheels in order to obtain a seat for the dust seals. Hence, in order to convert a wheel and axle assembly from 4' 8-1/2" gage to a wider gage, it requires the removal of the wheels from the axle, the mounting of suitable spacers, and the reapplication of the wheels to the axle. Where the equipment for making such a change would not be available in the field, it will be necessary to prepare a separate wheel and axle assembly, complete with gears and suitable spacers for each gage. Wheel and axle assembly part numbers are indicated in table 1.

j. Sanders. The sander arrangement on the MRS truck consists of a short piece of 1-inch pipe welded to an oblong steel block. To the upper end of this pipe is fastened a flexible rubber hose which leads upward to the sanders on the car body. The lower end of this pipe is suspended directly over the rail in front of the wheel and, with new wheels, is 3 inches above the top of the rail. The sandpipe, designated as "A" in figure 86, is held in place on a bracket mounted on the truck frame by two bolts ("E," fig. 86). Three spacers, designated as "B," "C," and "D" are also provided at the sandpipe bracket. Additional boltholes ("F," fig. 86) are provided so that the sandpipe may be raised after the wheels are turned or smaller wheels applied.

k. Railguard. When the MRS locomotive (fig. 98) is operated in CONUS, it will be equipped with footboards or a pilot mounted on the end plate, as is customary in this country. When used in European countries, however, the coupling arrangement will not permit the use of a conventional pilot. Hence, when so used, the pilot will be removed and replaced with a railguard arrangement somewhat similar to that used on European locomotives. Provision has been made for bolting a railguard support, designated as "G," figure 86 above, on the sander brackets with two bolts, shown as "H." This support is provided with two slots, "L" and "M," made to fit the railguard "J." The railguard is held in place by two bolts, "K." The railguard is not

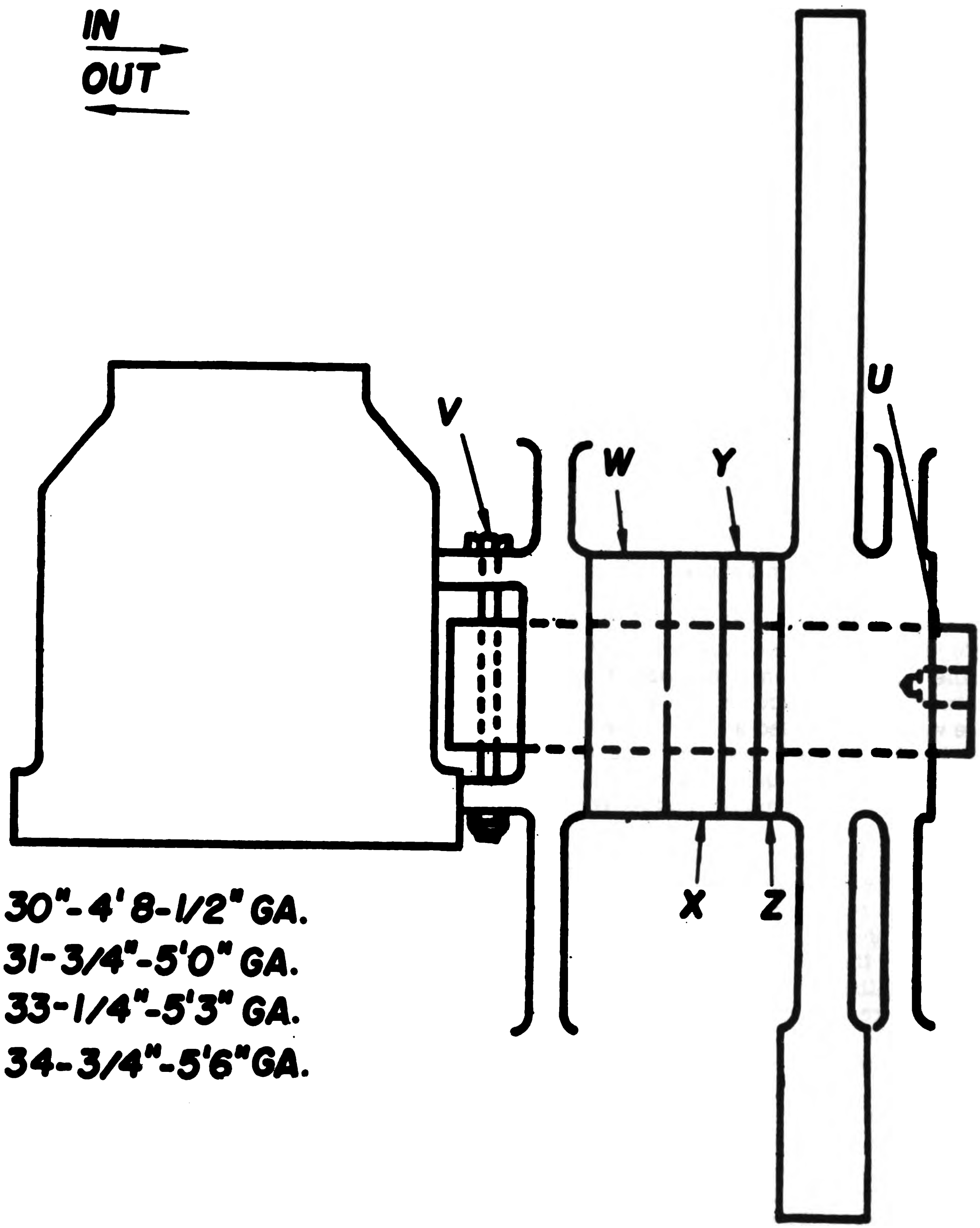


Figure 85. Truck lever pin.

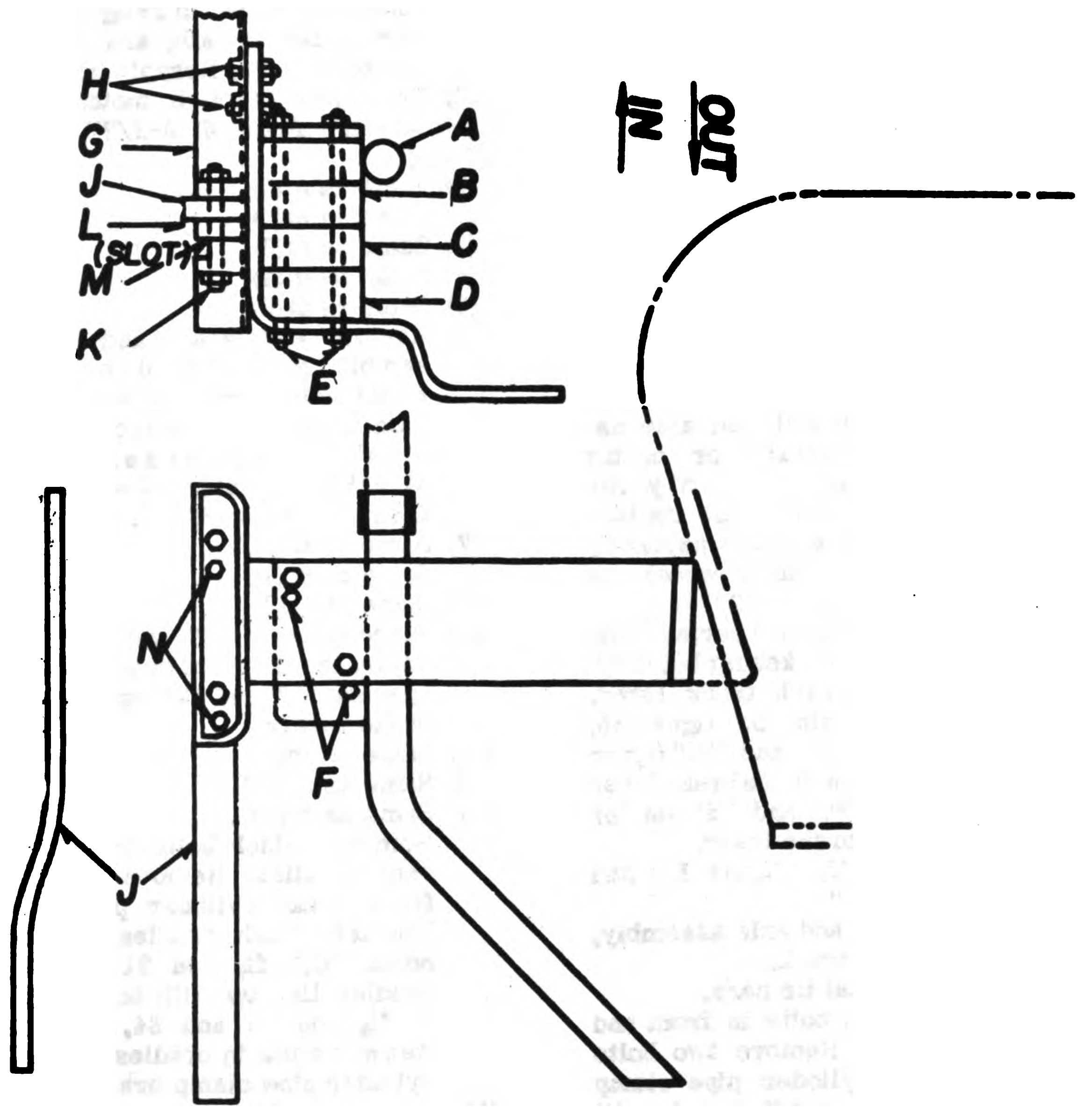


Figure 86. Sander and railguard arrangement.

made straight but is offset 1-1/2 inches, as shown in figure 86, as a provision for wider gage. Extra holes ("N," fig. 86) are also provided so that the railguard may be raised when the wheels are turned or renewed with wheels of smaller diameters.

l. Gage Changing Procedures. The steps indicated below outline, in sequence, the procedures for changing gages on multigage trucks. In all cases, "IN" means toward the centerline of the locomotive; "OUT" means away from the centerline. Procedures in *m*(8), (9), (10), and (11) below must be performed while the motors are out of the truck.

m. To Change From 4' 8-1/2" to 5' 0" Gage.

(1) Remove pedestal tie bars.

(2) Disconnect traction motor lead wires.

(3) Disconnect flexible clevis top of truck levers.

(4) Remove wheel and axle assembly with traction motor still in place on axle. If a drop pit is available,

this may be accomplished by supporting truck frame and equalizers while motor and wheel and axle assembly is lowered out of the truck. If no drop pit is available, then it will be necessary to remove trucks from locomotive, provide suitable supports for the motors and equalizers, and lift the truck frame off of the wheel and axle assemblies.

(5) Place wheel and axle assembly in a suitable fixture to hold motor and remove axle caps and bearings.

(6) Remove end wheel and axle assembly No. 8175150 or center wheel and axle assembly No. 8182772 from motor and replace with end wheel and axle assembly No. 8175151 or center wheel and axle assembly No. 8182774.

(7) Replace bearings and bearing caps.

(8) Remove brake pin keeper bolt "V," figure 85, at each truck lever.

(9) Remove brake pin "U," figure 85.

(10) Place spacers "X" and "Z," figure 85, on the inside of the brake lever and spacers "W" and "Y" on the outside fo the brake lever.

(11) Replace pin "U," figure 85, and keeper bolt "V."

(12) Replace wheel and axle assembly, with motor, in truck.

(13) Reapply pedestal tie bars.

(14) Remove 1-inch bolts in front and rear cradles. Remove two bolts from brake cylinder pipe clamp bracket. Push cradles out until holes (B, figures 81 and 82) in cradles line up with tapped holes (2, figures 83 and 84) in frame. Reapply bolts in cradles and brake cylinder pipe clamp bracket.

(15) Connect flexible clevis between truck levers and horizontal levers.

(16) Remove bolts "E," figure 86, in sander brackets and place spacer "B" inside sander pipe block. Leave spacers "C" and "D" on outside of sander pipe block. Reinstall bolts "E."

(17) Remove railguard bolts "K," figure 86, and move railguard "J" to outside slot "M" in railguard support. Offset in railguard should be turned inward. Reapply bolts "K."

(18) Reconnect traction motor leads.

n. To Change From 4' 8-1/2" Gage to 5' 3" Gage.

(1) Same as *m*(1).

(2) Same as *m*(2).

(3) Same as *m*(3).

(4) Same as *m*(4).

(5) Same as *m*(5).

(6) Remove end wheel and axle assembly No. 8175150 or center wheel/axle assembly No. 8182972 from motor and replace with and wheel and axle assembly No. 8175152 or center wheel and axle assembly No. 8182779.

(7) Same as *m*(7).

(8) Same as *m*(8).

(9) Same as *m*(9).

(10) Place spacers "W" and "X," figure 85, on the inside of brake lever and spacers "Y" and "Z" on outside of brake levers.

(11) Same as *m*(11).

(12) Same as *m*(12).

(13) Same as *m*(13).

(14) Remove 1-inch bolts in front and rear cradles. Remove two bolts from brake cylinder pipe clamp bracket. Push cradles out until holes "C," figures 81 and 82 in cradles line up with tapped holes 1, figures 83 and 84, in frame. Reapply bolts in cradles and brake cylinder pipe clamp bracket.

(15) Same as *m*(15).

(16) Remove bolts "E," figure 86, in sander brackets and place spacers "B" and "C" inside sander pipe block. Leave spacer "D" on outside of sander pipe block. Reinstall bolts "E."

(17) Remove railguard bolts "K," figure 86, and turn railguard "J" so that offset is outward. Replace in slot "L." Reapply bolts "K."

(18) Same as *m*(18).

o. To Change From 4' 8-1/2 Gage to 5' 6" Gage.

(1) Same as *m*(1).

(2) Same as *m*(2).

(3) Same as *m*(3).
(4) Same as *m*(4).
(5) Same as *m*(5).
(6) Remove end wheel and axle assembly No. 8175150 or center wheel and axle assembly No. 8182772 from motor and replace with end wheel and axle assembly No. 8175153 or center wheel and axle assembly No. 8182778.
(7) Same as *m*(7).
(8) Same as *m*(8).
(9) Same as *m*(9).
(10) Place spacers "W," "X," "Y," and "Z," figure 85, on inside of brake lever.
(11) Same as *m*(11).
(12) Same as *m*(12).
(13) Same as *m*(13).
(14) Remove 1-inch bolts in front and rear cradles. Remove two bolts from brake cylinder pipe clamp bracket. Push cradles out until holes "D," figures 81 and 82, in cradles line up with tapped holes 2, figures 83 and 84, in frame. Reapply bolts in cradles and brake cylinder pipe clamp bracket.
(15) Same as *m*(15).
(16) Remove the bolts "E," figure 86, in the sander brackets and place the spacers "B," "C," and "D," figure 36, on the inside of the sander pipe block. Reinstall bolts "E."
(17) Remove railguard bolts "K," figure 86, and move railguard "J" to slot "M." Offset in railguard should be turned outward. Reapply bolts "K."
(18) Same as *m*(18).

p. Specification Table. The table illustrated (table 1) is presented herein as a summary of the positions the various parts should be in for operation of the MRS locomotive (truck) on the various gages.

Table 1. Specification Table

Gage	Wheel spacing	Cradle		Truck lever		Wheel and axle assembly		Sanders		Rail guard	
		Hole in cradle	Hole in frame	Spacers inside	Spacers outside	(end)	(center)	Spacers inside	Spacers outside	Slot	Offset
4'8½ in.	53-3/8 in.	A	1	None	WXYZ	8175150	8182772	None	B,C,D	L	IN
5'0 in.	56-7/8 in.	B	2	X,Z	W,Y	8175151	8182774	B	C,D	M	IN
5'3 in.	59-7/8 in.	C	1	W,X	Y,Z	8175152	8182779	B,C	D	L	OUT
5'6 in.	62-7/8 in.	D	2	WXYZ	None	8175153	8182778	B,C,D	None	M	OUT

131. Journal Box (Friction Bearing)

A journal box consists of a cast steel housing with a dustproof spring-closed lid, wedge, journal bearing, thrust bearing, dust guard, and spring packing waste, in addition to gaskets, lock wire, and bolts. In special cases, a thrust bearing lateral spring pack is added (fig. 79).

a. Channels on each side of the journal box fit over the truck pedestals, holding the journal box in place in the truck frame. A tie bar is bolted across the two lower ends of the pedestals. This serves as a reinforcement for the pedestals and also prevents the journal box from dropping out of the pedestal in case of derailment. The wedge affords a solid contact between the box and the bearing. It has a smooth finish and is easily installed or removed.

b. The journal bearing is a bronze-backed, babbitt, solid type bearing. It rides on the top side of the axle journal with the radius toward the wheel. The thrust bearing, or thrust block as it is sometimes called, is a steel casting with a bronze face. It is located in the front part of the journal box and contacts the end of the axle if lateral thrust is exerted. It also houses a lateral spring and the snubber lateral springs. An oil passage is bored in the recess of the thrust bearing housing to the bearing surface for lubrication which is supplied by oil-soaked cotton or wool waste, or mechanical lubrication devices.

c. The dust guard fits in a slot in the back end of the journal box. When the journal box is assembled on the axle journal, the felt dust guard fits on the shoulder of the axle next to the wheel to prevent oil from leaking out of the box and also to prevent dust and water from entering the box. Oil-soaked spring packing waste or a lubricating device is placed between the bottom of the housing and the axle journal. Oil-soaked cotton or wool waste is also placed in the recess of the thrust bearing to provide lubrication between the thrust bearing and the end face of the axle.

132. Journal Box (Roller Bearing)

Roller bearings consist of heavy cylindrical inner and outer races and two rows of large diameter solid rollers retained in heavy bronze cages. The bearing rollers and races are fabricated from hardened alloy steel. The inner race is shrunk on the axle journal. The wheels may be removed without disturbing the inner race. The rollers are cylindrical with flat ends and are retained in one-piece cast bronze cages. Each bearing contains two rows of rollers which are spaced longitudinally by a floating spacer ring which contacts the ends of the rollers. The outer race is driven into the journal box housing. The rollers are retained in the proper longitudinal position by hardened surfaces on the retainment rings. These retainment surfaces come in contact with the ends of the rollers only.

a. The journal boxes may be fitted with plain or combination front covers. The plain covers have no provision for auxiliary attachments; whereas, the combination covers are fitted for the attachment of speed indicator drives, braking speed generators, overspeed control attachments, or similar devices. The journal box housing is a steel casting bored to receive the outer bearing race, retainment ring, and oil seal bushing (if used), and to center the front cover and retainment ring. The lower portion of the housing forms the oil reservoir and sump. The pedestal ways on the sides of the housing are lined with renewable wear plates welded in place. The top of the housing forms a seat for the subequalizer. Depressions in the housings are provided for the application of heat indicator.

b. The outer retainment ring is an iron casting, the outside of which is turned to fit the inner bore of the housing. It fits between the end of the outer race and a shoulder at the end of the housing bore and is prevented from turning by the engagement of the oil pour spout with bosses cast into the inside of the housing. Grooves in the retainment ring conduct the lubricant from the roller bearing operating cavity to the thrust block. The thrust block is cast from hard bronze and is mounted on the inner side of the front cover. The thrust block is designed for a lateral clearance between its face and the end of the axle to allow the axle to float laterally within the truck. Shim adjustment is provided to maintain any desired lateral clearance between the end of the axle and the thrust block. The thrust block receives the entire lateral thrust of the axle.

c. An oil seal bushing is pressed into the inner end of the housing and provides the oil seal and the inner retainment surface for the roller assemblies. It does not touch the axle; therefore, no wear will occur. An inwardly extending flange surrounds the inner race with small clearance. Oil which passes this flange is flung outwardly by centrifugal force. An annular space is provided in the oil seal bushing to catch this oil and drain it back into the oil reservoir. This prevents any oil from collecting at the underside of the axle. A baffle interrupts any upward surge of oil from the reservoirs at the rear of the housing. The inside diameter of the oil seal bushing shrouds the dust guard diameter of the axle with a close clearance.

133. Flange Oiler

Flange oilers are provided on some equipment operating over numerous sharp curves. Oiling the flange reduces the wear on both the flange and the rail and reduces the tendency of a wheel to ride up or override the rail. Flange oilers can be installed in the track or on the locomotive. Those on the locomotive are mounted on the truck. Lubricant of a specified grade should be fed in limited quantity. The feed stick should ride the correct part of the flange.

PART FIVE

OPERATION OF DIESEL-ELECTRIC LOCOMOTIVES

CHAPTER 15

OPERATING INSTRUCTIONS

134. General

Routine operation of a diesel-electric locomotive is controlled by the throttle, reverse lever, and brake valves. Various instruments, protective devices, and regulating devices contribute to efficient routine operation. A thorough general knowledge of various types of locomotives and a careful observance of prescribed operating procedures are essential to the best operation. Rugged construction will not eliminate the effects of ignorance and abuse. Specific information for individual types is best obtained from the respective operational manuals issued by the manufacturer.

135. Preparation for Service

a. *General.* It is necessary to inspect the locomotive at maintenance terminals as well as at intermediate points following layovers or crew changes. Such an inspection acquaints the operator with the condition of the equipment and supplies. The following procedures are taken before starting the engine:

(1) Check supply of fuel oil, lubricating oil in engine and air compressor, oil in engine governor, engine cooling water, and sand. For preparation under extreme cold weather conditions, see paragraph 114.

(2) Check all lights. (Switches are identified by nameplates.)

(3) Make certain all manually operated valves and electrical switches are in their correct positions. The handle of duplex fuel oil filters, when installed, must be in proper position (para 18*b*).

(4) Check for oil leaks or water leaks. Leaks are more probable on a warm engine under pressure, and subsequent check under such conditions is also advisable.

(5) For multiple-unit operation, be sure that all trainline jumpers and brake pipes are connected properly.

(6) Make certain that rags or tools are not left carelessly near the locomotive, the diesel engine, generator, or other equipment.

(7) Check for loose or dragging parts, worn or missing brakeshoes.

(8) Inspect for visible wheel defects.

(9) Check proper operation of coupler knuckles at both ends of locomotive.

(10) If engine has not run for a prolonged period, test for accumulation of water in the cylinders. Open all cylinder test valves and turn engine a complete revolution with an engine turning jack.

b. *Starting Diesel Engine.* Each engine and its related power unit, being controlled from an individual control panel, must be operating before using locomotive controls. Take the following actions:

(1) Be sure outside battery charging receptacle is not connected to outside powerlines.

(2) See that locomotive controls are in a neutral, or off, position (throttle, reverse lever, etc.).

(3) Close the battery cutout switch in the cabinet and the main control switch at the control stand; also close the fuel pump switch if the motor is not supplied through the control switch.

(4) The auxiliary generator switch is generally open to avoid the load of turning it through an energized field while cranking. Other

switches, such as fan, ground relay, and motor cutout, should be in their normal positions as directed in instruction manuals for individual models.

(5) Press the start button firmly. Press No. 2 start button to start No. 2 engine on locomotives so equipped. Do not hold in for prolonged intervals if engine does not fire, because continued cranking will discharge the battery. Lubricating oil pressure should be normal before releasing the start button, or the low lubricating oil pressure shutdown device, which is bypassed during starting, will stop the engine.

(6) After starting the engine, close the auxiliary generator switch. Check the battery for proper charging by observing battery ammeter. Idle the engine until engine water reaches normal operating temperature.

136. Brake System Inspections

a. While engine is running, the brake system should be checked to make sure that—

(1) Brake cylinders and linkages operate properly.

(2) Air compressor is providing adequate supply of air.

(3) Pressure is regulated properly by compressor governor.

(4) Independent and automatic brake valves operate properly.

(5) Condensate is drained from reservoirs.

(6) Piston travel is properly adjusted.

b. Pump air at a high rate by placing the reverse lever in the OFF position and advancing the throttle until the desired pumping rate is reached. This should be done at standstill when making up a train, or when coasting downgrade to recharge the line. With the reverse lever off, an advanced throttle "revs up" the engine without applying power, and the compressor speed increases as engine speed increases.

137. Inspections During Operation

Operators will inspect the following equipment before moving the locomotive and at appropriate intervals thereafter to insure proper operation.

a. Fuel oil pressure gage.

b. Lubricating oil pressure gage.

c. Turbocharger oil pressure gage.

d. Engine water temperature gage.

e. Main and control air system pressure gages.

f. Horn, bell ringer, sander, and window wipers.

g. Radiator fans, automotive and manually operated radiator shutters.

h. Traction motor blowers (a locomotive must not move a train unless the traction motors are adequately cooled).

i. Battery ammeter (should not show discharge).

j. Water level gage.

k. Engine lubricating oil level.

l. Handle of metal edge lubricating oil strainers.

138. Moving Locomotive Without Train

a. General. Movement of a locomotive without a train (light locomotive) involves certain elementary procedures which warrant discussion and separate consideration from procedures used when moving with a train. The following sequence should be followed by enginemen or operators:

(1) Test airbrakes and release handbrake.

(2) Place the reverser lever in forward or reverse position, depending upon desired direction.

(3) Place foot on foot lever on "deadman control" (para 122), if so equipped, and release airbrakes.

(4) Advance throttle slowly. The first few seconds are consumed by the automatic closing of power circuits, following which the load ammeter should register a flow of current. The throttle may be advanced rapidly for further acceleration. If starting on an upgrade, do not release brakes until the throttle has been opened

sufficiently to prevent the locomotive from drifting backward (para 141).

(5) As speed is increased, manually operated transition equipment should be handled as directed in operating instruction manuals for that specific type of locomotive.

(6) Retard throttle as required to reduce power for slowing down or stopping, then apply brakes.

b. Precautions. Locomotive should never be moved until engineman or operator has assured himself that it is safe to do so, and that no one is in a position to be injured by the movement. Locomotives should never be operated at speeds faster than those speed limits posted in the cab. This restriction applies whether the locomotive is operating on its own power, coasting, or being deadheaded or towed, because the speed of rotation of the traction motors (which are geared directly to the axles) is limited. Excessive speed will loosen armature coils and banding, reduce airgap, and cause rubbing which injures insulation and causes circuits to become defective.

139. Moving Locomotive With Train

Many additional factors are involved in handling trains properly (para 149). Routine procedures, in addition to those in paragraph 138, are summarized below:

a. Couple to the train and connect brake hose.

b. Pump air to charge the trainline.

c. When starting, take slack gradually.

d. Avoid slipping (spinning) the wheels if possible. Temporary slipping corrects itself. Persistent slipping should be corrected by retarding the throttle slightly.

Note. Do not apply sand while wheels are slipping. A sudden grabbing of driving wheels may cause surges of current, flashovers, etc. Sand is used to prevent wheel slip; use it sparingly.

140. Stopping Locomotive

a. Service Stop. Move the throttle to first running position and hold it there until the load ammeter indicates that the current has dropped. This prevents opening the power circuits while heavy current is flowing. Then move the throttle to an idle or off position (not a stop position on controllers which stop the diesel engine in this position). Transition should take place when slowing down as well as when accelerating. The brakes may be applied concurrently with power reduction, but power should be entirely shut off before the stop is completed (see para 157*n*). Do not use the independent brake to stop a heavy train. Release deadman pedal after the brakes have been applied.

b. Emergency Stop. Move the automatic brake valve to emergency position. Power should be shut off. On some locomotives, this is done automatically, but in any event, it is necessary to move the throttle to idle or off position before resuming service.

c. Layover. After stopping, if enginemen leave the cab while diesel engines are running, precautions against unauthorized or accidental movements must be taken. The principal precaution consists of removing the reverse lever. The auxiliary generator field switch may be opened, if desired, thus removing all excitation. Engines may be run at idling speed during layover to avoid too frequent use of the battery for engine starting or to keep engine water and lubricating oil warm in cold weather.

141. Reversing Locomotive

a. Make a service stop. Come to a complete stop before attempting to reverse. Do not move the reverse lever while the locomotive is still in motion. Do not drift in one direction with the reverse lever set in the opposite direction. Electrical equipment may be seriously damaged if this rule is disregarded, because the motors will short circuit the generator due to the lack of a back-emf.

b. Change the reverse lever to the opposite direction.

c. Release the brakes and advance throttle in the normal manner.

142. Cutting Out Traction Motor

If an electrical failure such as short circuit or ground occurs in a traction motor, disconnect it by means of the traction motor, disconnect it by means of the traction motor cutout switch.

a. Idle the engine. Do not cut out motors under load. If several power units are moving in multiple, it is not necessary to retard the throttle. An isolating switch, or engine control switch, is usually provided to idle an engine while throttle is advanced.

b. Open by turning the traction motor cutout switch. See paragraph 83 for types of switches.

c. A load ammeter in the general circuit will then read half normal value and load limits must be adjusted to reflect this 50 percent reduction in current. A load ammeter in one leg of the motor circuit will read full normal value if it is in an unaffected circuit or zero if it is in a cutout circuit.

143. Cutting Out and Restoring Power Unit

a. A faulty power unit may be cut out if it can no longer deliver power for traction but can operate to pump air, charge batteries, and keep the engine water system functioning in cold weather. Idle the diesel engine by setting the isolation switch or engine control switch, whichever is provided. A unit in multiple may be isolated while other units are operating under advanced throttle. It is usually possible to continue multiple-unit operation from an isolated unit, because control circuits continue to function.

b. An isolated unit may be put back into service by merely returning the isolating switch or engine control switch to its normal position.

144. Stopping Diesel Engines

a. General. Diesel engines are stopped by shutting off the fuel supply (para 84). The method of doing this varies with the individual design of the engine. Operators must be familiar with these methods and follow the procedure applicable to the specific locomotive. Care must be exercised to avoid stopping the engine immediately after a hard run as the water circulating pumps will also stop and the water will boil. Idle the engine until the water temperature drops to about 140° F. before stopping it.

b. Normal Stop. Cool the engine at idling speed and then shut off the fuel supply. An engine control switch, stop switch, or a stop position on the throttle will shut off fuel by actrating the engine shutdown valve or governor in certain installations. Open the fuel pump switch if its power circuit was not opened by the stop switch. Open the auxiliary generator switch.

c. Cutout Stop. Certain procedures under *a* above may shut down all engines in multiple-unit connection. If only one engine is to be stopped, use an individual control switch or governor stop button.

d. Emergency Stop. A locomotive without a stop position on the throttle usually has an emergency engine stop switch on the control stand which, when closed, will operate all engine shutdown valves. On some locomotives, opening the main control switch on the control stand will stop the engine. (In the rare event that power to the motors is not shut off when a throttle is retarded to idle, stop the engine.) The fuel cutout pull rings, which are described later, are not used for quick engine stopping.

e. Shutting Down Locomotive. Enginemen will take the following actions:

(1) Stop the engine in the normal manner.
(2) Remove reverse lever.
(3) Set handbrake and release airbrake. Block wheels.
(4) Open battery switch.
(5) In cold weather, take necessary precautions to prevent engine freezeup.

145. Deadheading Locomotives

a. General. The procedures for preparing diesel-electric locomotives out of service for shipment between various

Army areas, activities, installations, and/or commercial repair facilities follow:

b. On Flatcars. Prepare all 23-, 25-, and 45-ton (300 horsepower) locomotives for shipment loaded on commercial flatcars, as follows:

(1) Close or seal all ventilators and cover exhaust stacks.

(2) Close and lock all doors and windows.

(3) In freezing weather conditions, drain entire engine cooling system and steam generator (if so equipped) if antifreeze protection has not been provided.

(4) Remove the two end battery connection leads. Tape and secure the loose ends of these leads.

(5) Place all applicable manuals, accessories, inspection record forms, and data record sheets in the locomotive cab toolbox. In addition, place the applicable parts and tools listed as initial issue items shown in the appropriate manual in the toolbox.

(6) Lock locomotive cab toolbox. Forward keys to the receiving activity.

c. On Own Wheels. Prepare locomotives other than those indicated in *b* above to be shipped dead on own wheels as follows:

(1) In addition to the first six items listed in *b* above, block reverser in neutral and the throttle lever in "idle" position. Open battery and traction motor cutout switches and all other manually operated electrical switches.

(2) Remove pinion gears and apply loose fit dummy bearing spacers on 44-, 45-, and 47-ton (380 hp) and 64-ton diesel-electric locomotives with single or double reduction axle drive.

(3) On 80-ton diesel-electric locomotives equipped with hypoid gears, disengage the intermediate shaft gear from traction motor pinion gear by shifting the intermediate gear shafting, and relocate the shaft spacer collar to the opposite side of the hypoid gear unit housing. Maintain proper lubricating oil level. MRS 120-ton locomotives should be placed at rear of train with traction motor brushes and pinion gears in place and reverser drum centered and locked in position.

(4) Maintain required lubricating oil level in the traction motor support bearings. Check for proper condition and position of wick lubricators.

(5) Provide adequate lubrication to reduction gearcase.

(6) Lubricate all mechanical moving parts, such as brake pins, levers, etc. Check condition of brakeshoes and airhoses; renew as required.

(7) Inspect position and condition of journal bearinge, wedges, and packing. Tuck in all loose ends or strands of packing. Be certain journal repack date conforms to Army requirements. Provide additional lubrication to all journal boxes.

(8) Remove the brushes from all traction motors.

(9) Generally, prepare all airbrake systems on diesel-electric locomotives being hauled dead on own wheels as follows:

(a) Reduce the adjustment of the safety valve on the distributing valve to 23 pounds.

(b) Place the automatic brake valve handle in running position and the independent brake valve in release position. For additional protection, either clamp or wire the handles.

(c) Close the doubleheading cock (when equipped) and open the dead engine cock to "dead" position.

(d) Set each airbrake cylinder piston travel at 5 inches.

(e) Open both angle cocks.

(10) Procedure for setting "dead engine" on 6-SL brake systems equipped with doubleheading features in as follows:

(a) Couple together the brake pipe hose; open the brake pipe hose angle cocks.

(b) Place handles of both brake valves in running position.

(c) Set the N-1-A brake application valve K-3 rotair valve in dead position.

(d) Open the dead engine cock on the 6-DKR distributing valve.

(e) Plug the equalizing discharge valve vent. This will require the removal of the equalizing discharge fitting and use of a plug in its place. The locomotive brake will then operate like that of a car in the train.

(f) When a locomotive has been in use as a "live" engine prior to being set up as a dead engine, the main reservoir pressure should be reduced to 20 pounds below brake pipe pressure.

(g) When it is desirable to keep the maximum braking power of a locomotive lower than standard, reduce the adjustment of the safety valve on the distributing valve as indicated in (9) (a) above.

(11) Speed restrictions should be held to 35 miles per hour. MRS 120-ton locomotives may be towed at 50 miles per hour.

(12) When locomotives are prepared as previously outlined, messenger service is not required on the locomotive or locomotives being shipped as freight on their own wheels. If available and desired, sulfur heat pad or stink bombs may be placed on the journal bearing and/or traction motor support bearings in order to indicate hotspots or hotboxes. The train crew should be advised when these safety items have been applied.

146. Operating as Pusher or Doubleheader

In pusher or doubleheader service, power is controlled on each locomotive independently by a separate operator, but service brake applications are made by the leading locomotive only. However, the independent brake valve can be used so that the noncontrolling locomotive can release its own brakes only to avoid sliding or overheating its wheels. See instructions for individual types of brake equipment for correct settings of rotair valves, dead engine cock, and doubleheading cock. Doubleheading differs from multiple-unit operation in that the locomotives need not be of the same type and each locomotive has its own operator.

147. Connecting Units in Multiple

Multiple-unit equipment previously discussed in paragraph 86 is provided for the purpose of operating two or more coupled locomotives as one locomotive from one cab. Not all locomotives with multiple-unit equipment (fig. 60) can be connected in multiple. Individual operating instructions for specific locomotives should be strictly observed in this respect. Only the general objectives can be discussed here. Controls for the throttle, transition, and brakes must be similar on connected locomotives. The reverse lever is removed from trailing units in order to deactivate the electrical controller. The control switch is opened in trailing units because the electrical jumpers between units connect the related circuits. The doubleheading cock on the brake pedestal is placed in trailing position. The air system is otherwise kept fully operative, and the battery switch is kept closed in trailing units. If engine is not running, it must be started at its own control panel. If both engines are running when locomotives are coupled, there is an interval when some circuits may be connected to two power sources (depending on individual designs). Undesirable currents may flow during this interval until the control switch of the trailing unit is opened, but it is usually practical to connect units in this manner without stopping the engine on the trailing unit during the coupling operations.

148. Changing Operating Ends

When an operator moves controls to

another cab, control of both the power system and air system must be established (cut in) at the new station and cut out at the station being deactivated. In general, a service application is made on the brake system, the reverse lever handle is removed, cocks are set as directed in airbrake instructions, all control stand switches are opened, and the opposite action is taken at the new station. To avoid stopping the diesel engine during the changeover, it may be practical to delay opening the control switch (and perhaps the fuel pump switch) at the old station until the circuits have been established through the new station.

149. Miscellaneous

a. *Running Through Water.* Under absolutely no circumstances should a locomotive pass through water which is deep enough to touch the bottom of the traction motors. If it is necessary to run through water of less depth, proceed at very slow speed (2 or 3 miles per hour) to avoid splashing the motors.

b. *Crossing Other Tracks.* When crossing other tracks, reduce the throttle to the fifth notch or equivalent to avoid excessive jarring which, under a heavy load, may cuase pitting of the commutators. Keep the throttle at this position until the locomotive and all trailing units have traversed the crossing.

c. *Rerailing Locomotive.* Do not apply power to derailed driving wheels. A traction motor, or any series motor, will be seriously damaged if power is applied when unloaded, which is the condition existing when derailed wheels spin freely. It is best to move the derailed locomotive with another pusher. However, if power can be kept off the derailed wheels by opening the proper traction motor cutout switch, or by isolating a power unit on two-unit locomotives, power may be applied to the motors remaining in service in an attempt to rerail the locomotive.

d. *Resetting Engine Overspeed Trip.* Normally, an overspeed trip mechanism is provided as a safety feature to stop the diesel engine when its speed becomes excessive. All types shut off the fuel, some by a trip shaft or fuel control shaft extending the length of the engine to cutt off the fuel injectors, and others by dropping out a clutch in the governor. The alarm bell and indicator lights come on when the engine is stopped. The device is usually at one end of the camshaft and is tripped by the centrifugal force of flyweights acting against a spring which holds the tripping lever. It must be reset by hand, using a lever which is either mounted on the housing (fig. 87) or is inserted in a reset slot. Some types use a reset button. The resetting procedure should be apparent on sight. (Control switches related to engine starting should be set at the same time as directed in the operating instructions for the specific locomotive.)

e. *Recovery After Emergency or Penalty Brake Application.* Following an emergency brake application, there is a loss of air pressure and frequently an interlocking of electrical controls. The brake system must recover and interlocking must be disengaged. The procedure for most installations is —

(1) Place automatic brake valve in lap position.
(2) Return throttle to idle position.
(3) Place foot on safety control (deadman) pedal, if installed.
(4) Allow application pipe to build up. In about 12 seconds, an audible release of the application portion indicates that the line is charged. On locomotives having an indicator light connected to a pneumatic control switch or power cutoff switch, the light goes out when the equipment has reset.
(5) Return brake valve to running position.

f. *Handling Long Trains.* The three main factors in handling a long train are throttle, braking, and slack action plus a knowledge of the route over which it is operating. Improper handling can readily result in a broken coupler. Complete information must be obtained locally from printed regulations, verbal information, or actual experience. Only a few typical circumstances can be given here to emphasize the importance of a thorough knowledge of such matters.

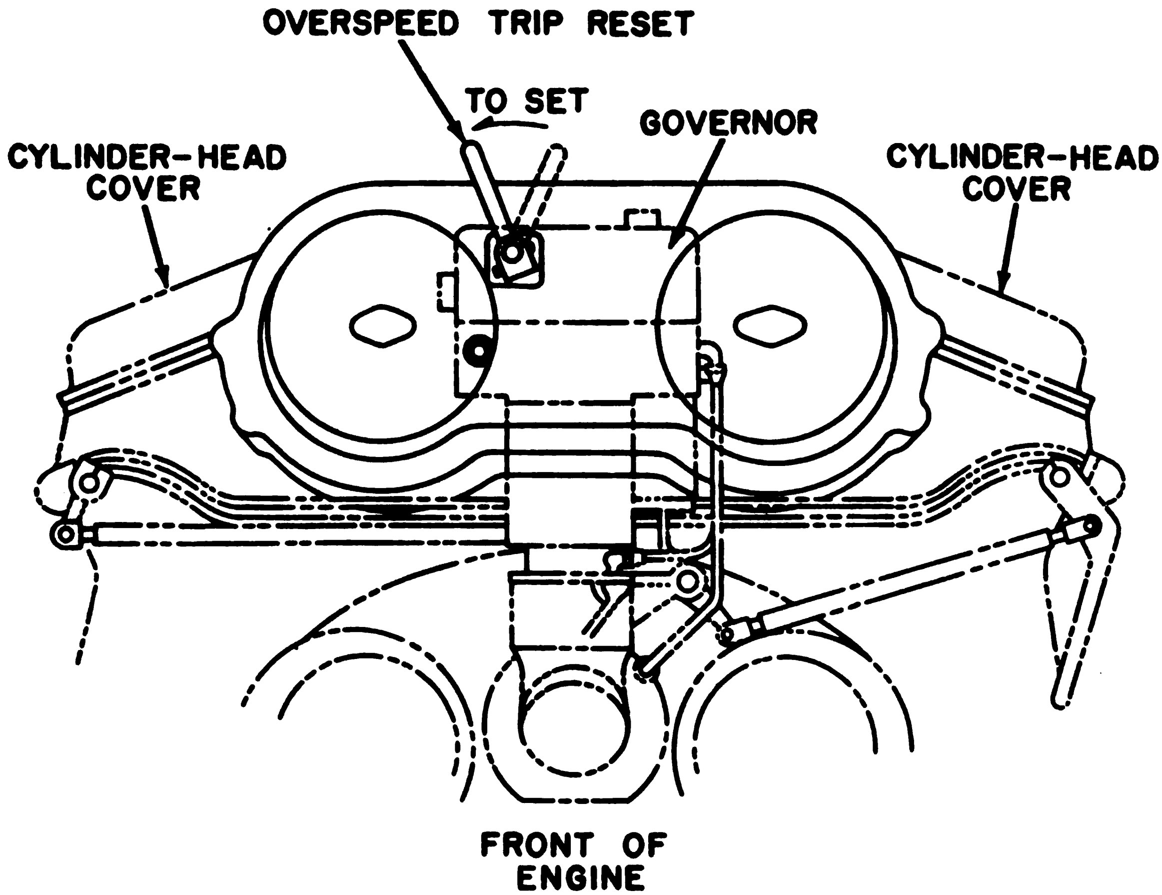


Figure 87. Resetting overspeed trip.

g. Starting Train. Starting a train depends not only on the class of locomotive being used but also on the type, length, weight, and the amount of slack (free play at couplings) in the train in addition to grade and weather conditions. It is important that the airbrakes be completely released before attempting to start the train. On a 100-car train having average uniformly distributed leakage, as much as 9 minutes may be needed to completely release the brakes. It requires approximately 30 minutes (with 130 pounds main reservoir pressure) to completely charge a depleted air system on a similar 100-car train. Although it will generally be unnecessary to bunch slack in starting, there will be cases where it is wise to do so. A tonnage train should be started in as low a throttle position as possible, bearing in mind that the speed of the locomotive must be kept at a minimum until the train has been stretched. Sometimes it is advisable to reduce the throttle a notch the moment the locomotive begins to move in order to prevent stretching the slack too quickly. The engineman must be the judge of the acceleration and the conditions under which the train is being started. When the locomotive has moved far enough to completely stretch the train, the throttle may be advanced, but should not be advanced so quickly that slipping results. It is never necessary to move the throttle hastily except in an emergency. The throttle should be opened with a steady motion but gradually enough to move the load without slipping the wheels.

h. Slack Action. Avoid quick runout of the head end to avoid breaking a coupler. Quick runout can be caused by releasing the head end to free rolling while the rear is still braking. This is especially likely if the independent brake has been used. If a rear end helper cuts off from the train at the top of a grade without stopping the train, care is necessary to avoid rough slack adjustment. Always adjust slack gradually whether in or out. When not adjusting slack, keep the train stretched, except when deliberately bunching for a stop or other special circumstances.

i. Terminal Brake Test. A terminal brake test consists of a thorough inspection of brakes on newly made up trains after brake pipe has been charged. Make a continuous service reduction of brake pipe pressure of about 15 pounds and hold (lap). Brake pipe pressure gage should show that leakage will not exceed 5 pounds per minute. If this condition is satisfactory, make an additional reduction to a total of 20 pounds. The crew then walks the length of the train to see that all brakes are applied (all cocks must be set so that all reservoirs charge and hence all brake cylinders respond). Piston travel is also checked visually for each cylinder. Signal is then given to release the brakes from the locomotive, and the crew walks the length of the train to see that all brakes release, all retainers are down (that is, not holding brakes) and all handbrakes are released. The train is now ready to operate, but running brake tests are made by slight application and release en route immediately after leaving terminal. Running brake test is also made prior to certain downgrade operations.

j. Brake Pipe Pressure. The feed valve may be set to give various brake pipe pressures desired for freight or passenger service. Regulations sometimes specify that normal pressure for smooth braking over rolling terrain will be increased for additional braking on certain downgrades. When locomotives are interchanged between freight and passenger service, reset the feed valves to give standard brake pipe pressure for the service in which they are operating.

k. Brake Pipe Charging. See paragraph 136 for quick pumping. The train should not be stopped on a grade unless —

(1) It is certain the trainline can be fully charged and all brakes fully released before the speed of the train has been reduced to less than 10 mph.

(2) Retainers will hold the train while charging.

(3) Cars are equipped with a type AB control valve which is sensitive to quick pressure changes in the brake pipe, even at low brake pipe pressures, which will respond to an emergency application if brakes are needed before normal pressure is built up.

(4) Brakes are kept applied on a moving freight until stopped when —

- *(a)* Forward end is on downgrade and rear end on level or ascending grade.
- *(b)* There is a curve on the rear end acting as a brake.
- *(c)* Loaded cars are on front and empty cars on rear of train.
- *(d)* Excessive brake pipe leakage has developed en route. All of these conditions are equivalent to extra braking on the rear end, and a release would probably permit a quick runout of the head end of sufficient force to part the train.

l. Retainers. It may be necessary to release brakes while running if brake pipe leakage causes too great a trainline reduction; or if an intermediate level grade or upgrade on a long mountain descent would cause the train to stop if brakes were not released; or to recharge the auxiliary reservoirs so they do not fall below predetermined pressures for that run. Retaining valves are provided on cars to retain braking effort while charging. They are set on certain cars to keep the brakes applied on these cars and prevent the train from running away while the trainline is being recharged (it is necessary to release in order to recharge). The number of cars on which the retainers are set varies with the grade and the tonnage of the train. Information must be obtained from local operating rules governing movements on a specific grade. Some retainers provide for a gradual release as well as an absolute holding action.

m. Braking With Power. If braking while power is applied, remember that for any given throttle position the drawbar pull rapidly increases as the train speed decreases. This pull might become great enough to part the train unless the throttle is reduced as the train speed drops. The pull of the locomotive is indicated by the amperage on the load meter. The engineman can maintain a constant pull on the train during a slowdown by maintaining a steady amperage on the load meter. This is accomplished by reducing the throttle a notch whenever the amperage starts to increase. The independent brakes should be kept fully released during power braking, and the throttle must be in the idle position before coming to a stop.

n. Brake Pipe Reductions Prior to Release. After stopping a long train, trainline air pressure may vary sufficiently to lack the required differential to release the brakes on the rear of the train. It is, therefore, advisable to make a 15-pound reduction on an 80-car train, a 20-pound reduction on a 120-car train, and a 25-pound reduction on longer trains in order to insure subsequent release of the rear end brakes. A broken coupler may be caused by brakes holding the rear.

o. Defective Brake Cutout. Defective train brakes may be cut out, if necessary, on not more than one car in seven. On freight cars, close the cutout cock in the brake pipe branch pipe and drain the reservoirs on the car. On passenger cars, close the cutout cock in both the brake pipe branch pipe and the brake cylinder pipe.

p. Mixed Train Restrictions. Mixed trains of both freight and passenger cars are usually restricted to freight train speed and freight train brake pipe pressure. Passenger equipment is generally placed next to the locomotive if heat and water raising equipment is kept operating. The graduated release feature should be set for direct release. Some freight cars are equipped for passenger service without any adjustments.

150. Operating Difficulties

a. General. When faults develop which require departure from routine operation, the crew should determine whether they can continue to operate and whether they can correct the trouble (as discussed in *b* below). A thorough understanding of this manual should enable the crew to check equipment without further instructions, but many faults occur so seldom that the following summary of special procedures may be useful.

b. Low Oil Pressure Alarm. Low oil pressure indication is given on all engine shutdowns and it is, therefore, necessary to determine whether there is any other reason for an engine shutdown. Since the same alarm bell rings for all alarm indicators (except wheel slip), the crew should first observe indicator lights to determine whether another device, such as a water temperature switch or ground relay, has stopped the engine. If several units are connected for multiple-unit operation, the bells ring on all units, but the indicator lights come on only for the faulty unit. Low oil pressure on a single unit must be corrected in order to operate. When units are connected in multiple, the operating unit may continue to operate after the faulty unit is isolated, provided load limits as described in paragraph 76 are observed.

c. Water Temperature Alarm. The crew must know whether the protective system (para 94) stops an engine, idles an engine, or merely gives an alarm. If several units are connected for multiple-unit operation, the bells ring on all units, but the indicator lights come on only for the faulty unit. If the locomotive has a means of setting the shutters manually, or if the automatic regulation of fan motors can be bypassed (usually by a so-called manual position of a fan end shutter switch) operation may be resumed. Water temperature, under such circumstances, may not be in the usual operating range but may be within a safe operating range. If the crew cannot bring water temperature down to a safe operating range, the unit must be shut down or isolated.

d. Ground Alarm. Press the ground relay reset button at the lit ground indicator light to attempt to resume service if the ground was a temporary condition. If the ground indication persists and it is necessary to use the unit, open the ground relay cutout switch. Such operation is for emergency use only, and the information in paragraph 95 should be followed exactly when this situation arises. If the ground is thought to be in a traction motor, cut the motor out of the circuit (para 83).

e. Wheel Slip Indication. Power is automatically decreased when wheels slip and then restored when slipping stops. It is not necessary to reduce the throttle because of momentary wheel slipping. Repeated slipping under poor rail conditions requires a reduced throttle. The proper use of sand will minimize wheel slippage. Sand should be used to *prevent*, but not to overcome, wheel slippage.

151. Troubleshooting

a. General. Operating difficulties which cannot be offset by alternative operating methods described in paragraph 150 require further observation of trouble symptoms to determine whether minor remedies will make it possible to operate. The most prevalent troubles are open circuit breakers, burned out fuses, dirty or clogged oil or air lines, leaks, defective interlocks, and loose or broken electrical connections. For methods of correcting operating difficulties, refer to specific troubleshooting directions applicable to respective models of locomotives. Some failures which develop during operation, including difficulties in starting, are caused by careless departure from operating routine instead of defective equipment. The following list includes those failures most common on diesel-electric locomotives. The usual causes of these failures are also indicated. The list can be used only as a general guide, since specifications for each piece of equipment vary. The operation or maintenance manual which applies to the equipment in question should be referred to before taking corrective action.

b. Engine Does Not Turn Over.
- (1) Battery and control switches may be open; close them.
- (2) Battery or control fuses may be blown.
- (3) Battery may be down; recharge.
- (4) Electric connections may be poor.
- (5) Engine start switch may be defective.
- (6) Engine heat may be too low for starting (start hot water heaters).

c. Engine Turns Over But Does Not Fire.
- (1) Check fuel supply.
- (2) Fuel lines may be broken or clogged; governor may be inoperative.
- (3) Fuel lines may be airbound. If so, prime them.
- (4) Fuel filter may be plogged. If so, clean it.
- (5) Emergency fuel shutoff may be closed.
- (6) Fuel pump not running; check circuit.
- (7) Water may be in fuel.

d. Locomotive Does Not Move With Engine Running and Throttle Open.
- (1) Brakes may not be released.
- (2) Battery and control switches may be open (close).
- (3) Electric connections may be poor.
- (4) Reverse lever may be in neutral (move to proper position).

e. Locomotive Moves Very Slowly.
- (1) Drag may be too heavy; cut off cars.
- (2) Brakes may not be fully released. (Bleed line.)
- (3) Main generators may not be delivering full power.

f. Locomotive Remains in Low Speed.
- (1) The traction motor is not making transition.
- (2) All traction motors are not operating.

g. Locomotive Moved With Throttle Off. Throttle valve is stuck open. Close by hand or open control switch and apply brakes.

h. Engine Stops.
- (1) Fuel supply is exhausted; refill tank.
- (2) Fuel line is broken or fouled; replace.
- (3) Fuel filter is plugged.

(4) Low lubricating oil pressure.
(5) Bar engine over to see that it is not blocked by an obstruction.
(6) There is a faulty governor or throttle linkage.
(7) Governor is inoperative; check fuel racks.

i. Engine Overspeeds.
(1) There is a faulty governor.
(2) Improper fuel pump rack setting.
(3) Low overspeed trip setting.

j. Engine Overheats.
(1) Water is low. Check for leaks and refill faulty water pump; replace.
(2) Radiator is plugged or dirty.
(3) Lubricating oil not cooling properly.
(4) Fan belts are slipping; renew.
(5) Heat exchanger (lubricating oil cooler) is plugged.
(6) Shutters closed or not functioning; check operation.
(7) Engine overloaded.
(8) Water hose collapsed; replace.

k. Engine Races Before Picking Up Load. Main generator field is defective. Excitation fails to build up properly.

l. Battery Does Not Charge.
(1) Blown battery or charging generator fuse; renew.
(2) Faulty electric circuits.
(3) Generator brushes faulty; clean.

m. Air Pressure Does Not Build Up.
(1) Main reservoir drain valve open; close.
(2) Brake pipe angle cock open; close.
(3) Pilot valve stuck open; close.
(4) Unloader valve stuck open.
(5) Compressor belts slip or are broken; replace.
(6) Faulty compressor; repair.

n. Air Pressure Builds Up Slowly.
(1) Long train requires longer time to charge.
(2) Compressor belts are slipping.
(3) Unloader valve stuck open; close.
(4) Broken pipe or loose fittings.
(5) Faulty governor.

o. Brakes Reapply After Regular Release.
(1) Brake pipe is overcharged. Make partial brake application and return handle to running position.
(2) Faulty feed valve; replace.

p. Brakes Hold After Release Application. Brake pipe undercharged or faulty distributing valve.

q. Low Braking Power.
(1) Too much brake cylinder piston travel; adjust.
(2) Faulty piston.
(3) Worn brakeshoes; replace.
(4) Low brake cylinder pressure.
(5) Broken brake cylinder pipe; renew.

r. Brake Cylinder Pressure Too High. Feed valve stuck or distributing valve sticks.

s. Sander Does Not Operate.
(1) Wet or dirty sand. Clean out trap and refill box with clean, dry sand.
(2) Kinked hose or pockets in hose. Clean out and straighten hose.
(3) Blocked sandpipe. Clean out pipe.
(4) Broken sander; replace.

t. Broken Brake Pipes. Many brake pipe troubles are similar on all types of brakes, but reference must be made to individual diagrams for full servicing work. Typical description for 6-BL brakes follows:

(1) *Main reservoir pipes.* If the main reservoir pipe breaks between the reservoir and the brake valve pedestal in such a way that it cannot be repaired, the locomotive brake cannot be applied by either brake valve.

(2) *Main reservoir branch pipes.* If the the branch pipe from the main reservoir pipe to the distributing valve breaks between the main reservoir pipe and the cutout cock, plug the main reservoir side of the break and close the branch pipe cutout cock. The locomotive brake is then inoperative. The train brakes can be operated in the usual manner.

(3) *Brake pipe.* If the brake pipe branch to the distributing valve is broken, plug the end leading from the brake pipe. The train brakes may then be operated in the usual manner, but the locomotive brake cannot be operated by the automatic brake balve. The locomotive brake can be operated by the inde-

pendent brake valve in the ordinary way except that the independent brake valve must be depressed, in release, to release it. If the break is ahead of the branch pipe to the distributing valve and the branch pipe to the brake valve, the branch pipe side of the break may be plugged without affecting brake operation. If the break occurs between the branch pipe to the distributing valve and the branch to the automatic brake valve, plug the distributing valve side of the pipe and close the brake pipe cutout cock. It will be impossible to apply and release the brakes by the automatic brake valve, but they may be applied and released by the independent brake valve.

(4) *Brake cylinder pipe.* A broken brake cylinder pipe permits main reservoir air to escape when the brake is applied. This may cause the release of one or more of the locomotive brake cylinders, depending upon where the break occurs. If the break cannot be repaired, close the cutout cock in the pipe leading to the broken pipe. If the break occurs next to the distributing valve reservoir, close the cutout cock of the main reservoir supply pipe to the distributing valve. The locomotive brakes cannot be applied, but the train brakes can be operated normally.

(5) *Application cylinder pipe.* If the application cylinder pipe breaks, plug the pipe on the distributing valve side of the break. The locomotive brake cannot be applied with the independent brake valve, and the emergency maintaining feature is lost; the locomotive brake can, however, be applied as usual by the automatic brake valve and released by that valve in running position.

(6) *Distributing valve release pipe.* If the release pipe breaks, the holding feature is lost and it is impossible to keep the locomotive brake fully applied with the independent brake valve unless the opening from the distributing valve side of the brake is closed. Closing of this break should not be done except possibly in switching service where the independent brake valve is mostly used. Then, it is necessary to keep the independent brake valve handle in release position at all times when it is desired to release the locomotive brake. On road locomotives, the distributing valve side of the brake should be left open and the brakes controlled by the automatic brake valve until repairs can be made.

(7) *Equalizing reservoir pipe.* In case of breakage of the equalizing reservoir pipe, plug this pipe at the brake valve and also plug the brake pipe service exhaust. Then, to apply the brakes, move the handle of the automatic brake valve gradually toward emergency position, making the desired brake pipe service reduction gradual and diect. Then return the handle gradually to lap position.

(8) *Safety control pipe.* In case of a brake between the safety control cutout cock and the N-1-A brake application valve, and there is no overspeed control or train control on the locomotive, move the cock on the application portion cover to OUT position. Otherwise, plug the break on the application valve side. The brakes may be operated normally, but safety control is nullified.

(9) *Application pipe (No. 10).* If the break occurs on the branch to the safety control volume reservoir, plug the break on the application pipe side. In this case, only the safety control warning time period is lost. If the break occurs elsewhere, the cock on the application portion cover of the N-1-A brake application valve may be moved to out position. This nullifies all control applications.

(10) *No. 8 pipe.* If this pipe breaks, plug

the broken pipe on the application valve side. The brakes may be operated normally, but the feature that requires lapping of the automatic brake valve handle to release the brakes after a control application is lost. Also, during a safety control application, the application valve will cycle.

(11) *Equalizing pipe.* Regardless of the location of the break, plug the break on the distributing valve side, set the transfer valve operating cock on any units operated in multiple-unit control to lead position, and close all equalizing pipe end connection cocks. The brakes will operate normally except that independent brake valve control of a trailing unit will be lost.

(12) *Transfer valve operating pipe.* If this pipe breaks, turn the transfer valve operating cock to lead position or leave it in that position. The brakes will operate normally except that, if the locomotive is operated as a trailing unit, independent brake valve control of brakes on that unit will be lost.

(13) *Main reservoir equalizing pipe (trainlined on multiple-unit arrangement only).* If this pipe breaks between the main reservoir and the No. 15 connection of the three-position brake pipe cutout cock or N-1-A brake application valve, the break must be repaired. Otherwise, there will be no pressure to keep either type of brake pipe cutout cock seated. If it breaks in any other location on a unit between the the end connection cutout cocks, plug the main reservoir side of the break and close all main reservoir end connection cutout cocks. If the break occurs on an end connection between units, close all end connection cutout cocks. If it is necessary to close any of these cutout cocks on units equipped with compressor governor synchronization, the governor system must be set to permit the governor on each unit to control its compressor independently. This is imperative to avoid excessive main reservoir pressure on the trailing unit. The brakes will operate normally, but the main reservoir supply of air for train braking will be limited to that of the lead unit system.

CHAPTER 16
LOCOMOTIVE APPLICATION

152. Application Problems

The selection of the proper type and size of locomotive for a particular operation, or group of operations, requires detailed study of many variable factors involved in train movements. These factors are briefly described here for general information. A thorough understanding of them is needed by experienced personnel who are responsible for related decisions. Many days of calculation by experienced transportation men are required to determine power requirements or make tonnage ratings for specific motive power. In Army operation where capacity movements, schedules, and operating routines are uncertain and often governed by expediency, approximate ratings may be made temporarily in shorter time. However, heavy tonnage which would load a locomotive beyond its short-time ratings must be avoided in making up trains or in operating trains when faulty equipment requires cutting out en route part of the locomotive's power equipment. Significant factors affecting the application problem are discussed separately in paragraphs 153 through 159. Some factors are normally uniform in the United States but must necessarily be included in any study of universal applications.

153. Track

a. *Gages.* The need for proper matching of wheel spacing to track gage should not be overlooked. In foreign countries, many different track gages exist. The multigage truck is provided for such situations, but changing locomotive gage requires time and shop facilities. A multigage locomotive is depicted in figure 97.

b. *Weight of Rails.* Allowable axle loading varies with the weight of rail, speed of operation, and other factors. Rails weighing 60 pounds per yard or less will handle about 500 pounds of axle load (2 wheels) per pound of rail weight (that is, about 30,000-pound axle loading for 60-pound rail, 25,000-pound axle loading for 50-pound rail). As rails become heavier, the allowable axle loading increases to an approximate value of 700 pounds per pound of rail for 90-pound rails (that is, 63,000 pounds).

c. *Condition.* The spacing of ties, the type of ballast, standards of maintenance, general condition of tie plates, rail joints, and other items affecting rail alinement are factors to be considered in applying engineering data to locomotive applications.

154. Operating Limitations

a. *Bridges.* If standard operating practices are not known, information should be obtained from Corps of Engineers reconnaissance or other reliable sources concerning the limitations in capacity and speed with which trains may be safely operated over a bridge. In oversea areas, considerable reinforcement and strengthening of bridge members may be required before the heavier Army locomotives can be used.

b. *Clearances.* The overall height and width of locomotives and overhand at curves should be determined if there is any question about tunnels or other fixed structures constituting an obstruction to the movement of trains. U. S. built motive power and rolling stock will generally require wider clearances than that found in oversea areas.

c. *Curvature.* Curved track offers more resistance to train movement than straight track. Resistance increases with the degree of curvature and must be taken into consideration in studying power requirements. Sharp curves may also cause derailments or damage to couplers if the wrong type of locomotive is dispatched. A 1-degree curve is one in which 100 feet of track is 1/360 of a complete circle. Curve resistance varies with trucks, banking of track, etc. A value of 1 pound per ton of train weight per degree of curvature is used in calculating train movements.

d. Speed Limits. Many conditions of track and traffic impose speed limitations below the maximum capabilities of the locomotive. The characteristics of the load and its duration affect the study of motive power applications. *For example,* a speed limit approaching an upgrade (due to a sharp curve) will create a load for a locomotive on the grade which differs considerably from the load for the same train on a corresponding grade approached at higher speed. Speed limitations apply while any portion of the train is in the restricted zone, even though the locomotive has reached a straight, unrestricted section of track.

e. Types of Couplers. Couplers in the United States are standard AAR types, 34-1/2 inches high, with springs in the draft gear to absorb some of the shocks. They swing enough to permit free movement around curves. Couplers in most foreign countries differ greatly from the American couplers. Locomotives must have couplers which conform to the rolling stock utilized. All U. S. Army foreign service type diesel-electric locomotives are designed to use Willison (41 inch height) couplers.

f. Types of Brakes. Vacuum brake systems are used in some foreign countries. A proper exhauster and brake application valve must be part of locomotive equipment in such service. Compressed air systems are described in paragraph 119.

155. Profile

a. The profile gives the elevation of the track at all points, from which can be obtained the rise or fall between points. Portions of track having a consistent general trend of rise or fall are grouped for analysis, and the slope of any section is expressed as the percent grade. Any traffic movement upgrade naturally requires extra power which must be considered when determining locomotive applications. The grade which limits the size of train that can be moved by a given locomotive is called the ruling grade of a section or division. The actual grade is the rate of uniform rise or fall of a track and is calculated by dividing the difference in elevation between two points by the distance between the points. It is expressed in percent. A 2-percent grade means there is a difference of 2 feet elevation in a 100-foot length of track. If the actual grade varies slightly in adjacent sections, an average grade for all sections may be used in studying train movement. The selection of points between which the average grade is suitable for use in train calculations is a matter of judgment and experience.

b. Grade resistance is calculated at 20 pounds per ton for each percent of grade. A ton (2,000 pounds) must be raised 1 foot for each 100 feet traveled on a 1-percent grade. If the grade is 2 percent, the train is raised 2 feet and the grade resistance is 40 pounds per ton. If the grade is 0.50 percent, the train is raised 1/2 foot and the grade resistance is 10 pounds per ton. On a downgrade, gravity helps move the train and a corresponding negative figure is used in the calculations. When the negative downgrade resistance balances the other forces retarding the train, it will coast at constant speed without power. When the negative downgrade resistance exceeds the other forces retarding the train, it will coast at increasing speed and require an application of brakes when maximum allowable speed is reached.

156. Types of Service

There are three types of railway train service; passenger, freight, and switching. Passenger service, such as ambulance trains, may require a steam generator on the locomotive for train heating. High gear ratio is preferable in passenger service, and the braking system should have a rotair valve for adjusting braking power to the type and length of train. In light switching service, track conditions may require a light locomotive and low gear ratio with high starting tractive effort. Independent brake applications are often sufficient if only a few cars are being moved, and it is impractical to connect airhose. Long trains should not be stopped with the independent brake. Road freight service generally uses equipment designed for intermediate speed. Helper service and humping service are special applications of the above three groups of service. Structural changes are required in insulation for operation in severely cold territory, in filtering during operation in extremely dusty surroundings in mines and mills, and in desert operations. The many basic similarities between different designs permit interchangeable use of locomotives, but when a locomotive is assigned to a different service, it must be operated under restrictions described elsewhere in this manual, or it must be modified in gearing, braking, etc., in the shops.

157. Train Resistance

Train resistance is the sum of the forces which oppose the motion of a train at constant speed on straight level track in still air. It is made up of rolling friction, journal friction, and normal air resistance. Many formulas have been devised for calculating the resistance values of different types of trains. Resistance value varies with the speed of the train, the type of bearings, and the axle loading. Extremely cold weather increases journal friction. The Davis formulas are most widely used and can be found in numerous railroad textbooks. However, the entire family of curves derived from these formulas narrows down to an approximate value of 5 pounds per ton of train weight for speeds below 30 miles per hour. Above 30 miles per hour, the resistance will vary from 6 to 12, and even more, pounds per ton of train weight. It is a significant factor in the speed which a given locomotive can attain with a given train. These factors are studied in detail in regular railroad operation where costs and competitive schedules are important. The elementary analysis in paragraph 158, plus observations from experience, will serve most of the requirements in the Army.

158. Train Acceleration

a. The power required to accelerate a train at a rate of 1 mile per hour per second is about 100 pounds per ton. Freight trains usually accelerate at about 0.1 to 0.2 mile per hour per second, and a power requirement of 10 pounds to 20 pounds per ton of train weight is a reasonable value.

b. Accelerating rates are often confusing. If a passenger train increases its speed from standstill to 20 miles per hour in 20 seconds, it increases its speed 1 mile per hour during each second of time. In 30 seconds, it would be traveling 30 miles per hour. If a freight train requires 80 seconds to reach 20 miles per hour, its accelerating rate is 1/4 mile per hour per second. It is essential to express acceleration as a change in speed per unit of time (feet per second per second or miles per hour per second).

c. The adhesion, or coefficient of friction, between the driving wheels and the rails determines the maximum tractive effort that can be exerted without slipping the wheels. If two surfaces are pressed together, it requires force to slide one along the other. There is usually a definite relationship between the sliding force required and the pressing force existing between two surfaces. The ratio of sliding force over pressing force is called the coefficient of friction or adhesion. Various tests have been made to determine the coefficient of friction between train wheels and steel rails, the force pressing the two together being the weight on the points of contact. A consistent set of tests of a wide variety of electric locomotives, over a long period of years, show starting adhesive values varying from 48 percent downward. It has been found that on a clean dry rail, a factor of 30 percent is usually obtainable at start and a factor of 20 to 25 percent is normal on a wet rail if sand is used. However, as the train speed rises, various factors tend to reduce the weight on drivers momentarily and thereby allow driving wheels to slip. The maximum useful adhesive value decreases as the train speed increases.

159. Train Movement

Train movements require power to overcome grade resistance (para 155), curve resistance (para 154c), and train resistance (para 157), plus the power required to accelerate the train from standstill or from intermediate slowdowns en route. After it has been determined what size train can be started on the ruling grade by a given locomotive, it must be established whether the locomotive will be traveling at a speed within the continuous load rating after the short-time ratings have been used up to the available overload capacity. It is also necessary to know what other grades are encountered and the time spent on these grades. A detailed study called a speed-time-distance calculation is required. The complete calculation is very involved. Table 2 shows typical selected entries from such a calculation, the purpose here being to convey an idea of the relative importance of grade resistance, curve resistance, train resistance, and acceleration at various speeds. The time spent and the distance traversed at each stop are not shown. The values that are shown are for a given speed, and the time and distance calculations must apply from one speed to another speed. The various steps of speed must be assumed at intervals sufficiently close so that the various tractive effort and resistance values remain approximately constant during that step. The significant facts shown in table 2 are—

a. The tractive effort of the locomotive decreases as speed increases (as shown in any locomotive tractive effort curve)—column 3.

b. The train resistance increases as speed increases—column 6.

c. The net tractive effort available for acceleration is greatest at low speeds—column 8.

d. The train reaches a balancing speed (constant speed) at line 3a where all available tractive effort is used to overcome the various resistances to train movement.

e. The train resistance is a greater percentage of the total as speed increases. If at line 3b the grade is assumed to change from 0.3 percent to 0.15 percent, a tractive effort of 5175 becomes available for further acceleration. The average rate of acceleration is then shown to be 0.14 mph per second, and in line 5, the balancing speed is again reached for the new conditions. On level track or straight track, a still higher balancing speed would be reached. Any subsequent increase in grade or curvature will reduce the train speed. It can be seen that train movement is a constant adjustment to a balance between many continually varying forces. The use of speed-time-distance calculations for steam locomotives is largely a study of schedule performance and an assurance against stalling on heavy grades. The study for diesel-electric locomotives takes on an additional significant factor with respect to the extent and duration of overloads. If it is necessary to study locomotive application by test operations, most satisfactory results and regulations are obtained if the basic factors of an engineering calculation are understood. (Additional columns in table 2 would be the average acceleration between any two lines, the time spent in accelerating between the selected speed values in column 2, and the distance traversed in that interval. These figures actually occupy an intermediate, or in-between, line in the calculation. If tables are seen with all entries mads on a straight line for sake of convenience, the analysis is, nevertheless, understood to apply to the respective blocks as just described.)

Table 2. Typical Data for Speed-Time-Distance Calculations for a Train of 1,725 Tons

0.3% grade to line 3a, 0.15% grade after line 3a, one degree curve								
1	2	3	4	5	6	7	8	9
	Speed (miles per hour)	Total tractive effort	Grade resistance	Resistance			Tractive effort for acceleration	Rate of acceleration (mph per second)
				Curve	Train	Total		
1	6	62,500	10,350	1,725	8,070	20,145	42,355	.246
2	17.5	27,000	10,350	1,725	8,880	20,955	6,045	.037
3a	21.5	21,625	10,350	1,725	9,550	21,625	0	0
3b	21.5	21,625	5,175	1,725	9,550	16,450	*5,175	
4	23	19,000	5,175	1,725	9,700	16,600	2,400	.014
5	24.5	16,890	5,175	1,725	9,990	16,890	0	0

Column 8 is column 3 minus column 7.
Column 9 is column 8 divided by train tonnage, divided by 100 (para 158a).
*Available at the instant the grade changes. The approximate average tractive effort and rate of acceleration between 21.5 mph and 24.5 mph is shown in line 4.

PART SIX

INSPECTION AND MAINTENANCE

CHAPTER 17

REGULATIONS GOVERNING INSPECTION AND TESTING

Section I. BRAKE EQUIPMENT

160. General

Before starting each trip, enginemen will ascertain that the locomotive brakes are in safe and suitable condition for service, the air compressor or compressors are in condition to provide an ample supply of air for the service in which the locomotive is placed, the devices for regulating all pressures are properly performing their functions, the brake valves work properly in all positions, and the water has been drained from the airbrake system.

161. Safety Valves

a. The main reservoir system of each unit will be equipped with at least one safety valve, the capacity of which will be sufficient to prevent accumulation of more than 10 pounds pressure psi above the maximum working air pressure fixed by the chief officer of the unit operating the locomotive.

b. A suitable governor will be provided that will stop and start the air compressor within 5 pounds above or below the pressure fixed.

c. The compressor governor, when used in connection with the automatice airbrake system, will be so adjusted that the compressor will start when the main reservoir pressure is not less than 15 pounds above the maximum brake pipe pressure fixed by the railway equipment superintendent of the theater. It will not stop the compressor until the reservoir pressure has increased not less than 10 pounds.

d. Compressor or compressors must be tested for capacity by orifice test as often as conditions require and not less frequently than once each 3-month period.

(1) The diameter of orifice, speed of compressors, and minimum main reservoir air pressures to be maintained during test of compressors in common use are shown in table 3.

Table 3. Mechanically Operated Air Compressors

Type compressor	Compressor (c) or motor (m) speed (rpm)	Diameter of test orifice (inches)	Minimum main reservoir air pressure (pounds)
Gardner-Denver:			
ABE	600 (c)	13/64	58
ADX	600 (c)	13/64	57
WXE	600 (c)	1/4	74
WXO	600 (c)	9/32	74
WXG	600 (c)	23/64	74
ADS	900 (c)	1/8	96
ABO	600 (c)	13/64	72
ABX	600 (c)	13/64	57
ADR-9001	500 (c)	# .9 drill	59
ACM-1000	500 (c)	3/32	60

Table 3. Mechanically Operated Air Compressors—Continued.

Type compressor	Compressor (c) or motor (m) speed (rpm)	Diameter of test orifice (inches)	Minimum main reservoir air pressure (pounds)
General Electric:			
CP-4	200 (c)	9/32	64
CP-35	1,000 (m)	15/64	107
CP-127	1,450 (m)	#41 drill	65
CP-130	1,470 (m)	#24 drill	65
CP-32-A	360 (c)	13/64	115
CP-32-D	360 (c)	13/64	115
CP-36	235 (c)	#28 drill	104
CP-39-A	313 (c)	15/64	118
7CPA39A1	258 (c)	15/64	95
Westinghouse:			
3-CD and 3-CDB	400 (c)	17/64	77
3-CDC	400 (c)	17/64	53
2-CDA	400 (c)	#12 drill	77
D-2-F	200 (c)	#36 drill	86
DH-20	273 (c)	#41 drill	86
DH-25	200 (c)	#36 drill	86
XQ-27	100 (c)	#34 drill	86

(2) Consult manufacturer's specifications for orifice tests of air compressors not listed in table 3.

(3) Test specifications indicated above must be used for altitudes to and including 1,000 feet. For altitudes over 1,000 feet, amount of air pressure shown may be reduced 4 percent for each 1,000 feet increase in altitude.

e. The minimum capacity of any compressor permitted in service will be approximately 80 percent of the capacity of the compressor when new.

f. Air pressure regulating devices must be adjusted for the following pressures:

(1) Minimum brake pipe air pressure, 70 pounds.

(2) Minimum differential between brake pipe and main reservoir air pressures, with brake valve in running position, 15 pounds.

(3) Safety valve for straight airbrake, 40 to 55 pounds.

(4) Safety valve for LT, ET, No. 8-EL, No. 14-EL, No. 6-DS, No. 6-BL, and No. 6-SL equipment, 40 to 68 pounds.

(5) Safety valve for HSC and No. 24-RL equipment, 40 to 75 pounds.

(6) Reducing valve for independent or straight airbrake, 30 to 50 pounds.

(7) Self-lapping portion for electro-pneumatic brake (minimum full application pressure), 65 pounds.

(8) Self-lapping portion for independent airbrake (full application pressure), 30 to 50 pounds.

(9) Reducing valve for air signal, 40 to 60 pounds.

(10) Reducing valve for high speed brake (minimum), 50 pounds.

162. Hydrostatic Test of Main Reservoirs

Every main reservoir will be subjected to hydrostatic pressure of not less than 25 percent above fixed maximum working pressure. A report will be made on DD Form 1336 (Monthly Inspection and Repair Report of Locomotives and Locomotive Cranes Other Than Steam) (fig. 93) at least once every 12 months. The entire surface of each main reservoir will be hammer tested each time the locomotive is shopped for general repairs. This must be done at least once every 18 months, and a report made on DD Form 1336. This test will be made while the reservoir is empty.

163. Air Gages

Air gages will be so located that they may be read conveniently by the engineman from his customary position in the cab. Air gages will be tested at least once every 3 months or whenever any irregularity is reported. They will be compared with an accurate deadweight tester or test gage constructed for the purpose of testing gages. Air gages found incorrect will be repaired before they are returned to service.

164. Cleaning

Distributing or control valves, reducing valves, triple valves, transfer valves, straight-air doublecheck valves, brake pipe vent valves, and dirt collectors will be cleaned and maintained as often as conditions require. This should be done at least once every 6 months. The date of testing or cleaning and the initials of the shop or station at which the work is done will be stenciled legibly in a conspicuous place on the parts or placed on a card displayed under glass in the cab of each locomotive.

165. Foundation Brake Gear

a. *General.* The foundation brake gear will be maintained to the standard for the locomotive. Levers, rods, brake beams, hangers, and pins will be of ample strength and will not be fouled in any way which will affect the proper operation of the brake. All pins will be properly secured in place with cotters, split keys, or nuts. Brakeshoes will be properly fastened in place and kept approximately in line with the tread of the wheel.

b. *Piston Travel.* Minimum brake cylinder piston travel will be sufficient to provide brakeshoe clearance when the brakes are released. Maximum brake cylinder piston travel, when locomotive is standing, must not exceed the following:

(1) Driving wheel brake, 6 inches.
(2) Swivel type truck brake with brakes on more than one truck operated by one brake cylinder, 7 inches.
(3) Swivel type truck brake equipped with one brake cylinder, 8 inches.
(4) Swivel type truck brake equipped with two or more brake cylinders, 6 inches.

166. Main Reservoir Leakage

Leakage from main air reservoir and related piping must not exceed an average of 3 pounds per minute in a test of 3 minutes duration, made after the pressure is reduced 40 percent below the maximum pressure. Brake pipe leakage must not exceed 5 pounds per minute. With a full service application from maximum brake pipe pressure and with communication to the brake cylinders closed, the brakes must remain applied not less then 5 minutes.

Section II. DRAWGEAR AND RUNNING GEAR

167. Drawgear and Connections

a. Drawgear between units of any locomotive and connections between trucks will be of ample strength and will be maintained in a safe and suitable condition for service.

b. Provisions will be made for securing drawbar pins and pins of articulated connection. A plate or stirrup will be provided under the lower end of all drawbar pins and articulated connection pins which will prevent the pin from falling out of place in case of breakage.

c. Drawbars and pins, when used between units of any locomotive, will be removed as often as conditions may require or at least once every 6 months. When used between trucks, they will be removed each time the locomotive is shopped for general or echelon repairs or at least once every 18 months. When drawbars and pins are removed, they and their connections will be inspected carefully for defects. Date of the last inspection will be stamped legibly on the heads of the pins and drawbars.

d. Lost motion is articulated connections will be kept to a minimum and will not exceed 1/4 inch at each pin. Pins of articulated connections between units of any locomotive will be removed at least once every 6 months and pins of articulated connections between trucks will be removed at least once every 18 months. When articulated connection pins are removed, they will be inspected carefully for defects. Date of last removal and inspection will be stamped legibly on the heads of the pins.

e. When drawbars are used between units of any locomotive, chafing irons or spring buffers that permit proper curving will be properly attached to each unit. They will be maintained in condition to permit free movement laterally and vertically. Lost motion between chafing irons will be kept to a minimum but must not exceed 1/2 inch. Buffer springs will be applied with not less than 3/4 inch compression and will at all times be under sufficient compression to keep the chafing faces in proper alinement and contact; chafing irons or spring buffers will not be required for drawbars designed and constructed for the purpose of taking buffing stresses. When such drawbars are used, the lost motion will be kept to a minimum and will not exceed 1/4 inch at either end.

f. Drawgear between units of any locomotive consisting of automatic couplers with friction or spring draft gear will be maintained in such condition that the lost motion in each draft gear assemblage not absorbed by the springs or friction devices will not exceed 1/2 inch.

g. Drawgear between units of any locomotive, consisting of automatic couplers without friction or spring draft gear, will have lost motion kept to a minimum and lost motion between coupler and coupler pocket will not exceed 1/4 inch in each assemblage. If the couplers are attached by means of pivot pins, the pins will be removed and inspected at least once every 6 months. The date of the last inspection of pins will be stamped ligibly on the heads of pins and all prior dates obliterated.

h. Draft gear and attachments of locomotives will be of ample strength, securely attached, and maintained in a safe and suitable condition for service including couplers and all operating gear. Standard couplers measuring 5-1/8 inches or more between point of knuckle and guard arm will not be continued in service.

168. Running Gear

a. Axles. Driving and truck axles with any of the following defects will be continued in service:

(1) Cracked or bent axles, or cut journals that cannot be made to run cool without turning.
(2) Seamy journals in steel axles.
(3) Transverse seams in iron axles or any seams in iron axles causing journals to run hot.
(4) Driving and truck axles unsafe on account of usage, accident, or derailment.
(5) Driving or truck axles more than 1/2 inch under original diameter.

b. Gear Guards.

(1) Exposed gears will be provided with safe and suitable guards.
(2) Gears or pinions with any of the following defects will not be continued in service:
   (a) Gears or pinions loose on shaft.
   (b) Gears or pinons broken, cracked, or with badly worn teeth.
   (c) Broken or defective rim fastenings.
   (d) Gears or pinions out of alinement or improperly meshed.
   (e) Split gears with loose or missing bolts.

c. Lateral Motion. The total lateral motion between the hubs of the wheels and boxes on any pair of wheels will not exceed the following limits:

(1) Truck wheels, 1 inch.
(2) Driving wheels (more than one pair of wheels), 3/4 inch.
(3) The lateral motion will in all instances be kept within such limits that the driving wheels, rods, crankpins, or armatures will not interfere with other parts of the locomotive.

d. Frames and Parts. Frames, deck plates, tailpieces, pedestals, and braces will be maintained in safe and suitable condition for service and will be cleaned and inspected thoroughly each time the locomotive is in shop for general or echelon repairs.

e. Spring Rigging:

(1) Springs and equalizers will be arranged to insure the proper distribution of weight and to cushion shocks to the various wheels. They will be maintained approximately level.

(2) Springs or spring rigging with any of the following defects will be renewed or repaired properly:

(a) Top leaf broken, or two leaves in top half, or any three leaves in spring broken. (The long side of spring is considered the top.)

(b) Springs with leaves working in band.

(c) Broken coil springs.

(d) Broken, cracked, or badly worn driving-box saddle equalizer, hanger, bolt, gib, or pin.

f. Trucks.

(1) Truck center plates will fit properly, and the male center plate will extend into the female center plate not less than 3/4 inch, except on motor trucks constructed to transmit tractive effort through center plate or center pin. The male center plate must extend into the female center plate not less than 1-1/2 inches and the center plates will be fastened and maintained securely. When trucks are removed for any reason, female center plates will be cleaned of any accumulated scale and lubricated with lard stick grease before replacing trucks.

(2) Center pins with substantial head, key, or nut at each end, or other suitable means that will hold the carrying bolster on the truck will be provided. All centering devices will be maintained properly.

(3) A suitable safety chain of minimum consistent length will be provided at each corner of all four-wheel and six-wheel trucks, except where construction prevents truck sluing in case of derailment.

(4) All parts of trucks will have sufficient clearance to prevent them from seriously interfering with any other part of the locomotive.

(5) Truck bolsters will be maintained approximately level.

(6) Suitable means for securing radius bar pins in place will be provided. Inverted radius bar pins will be held in place by plate or stirrup.

(7) Trucks with any of the following defects will not be continued in service:

(a) Cracked arch bar.

(b) Loose column, pedestal, or journal box bolt.

(c) Cracked or broken frame, unless properly repaired.

(d) Loose tie bar.

(e) Broken or defective motor suspension lug, spring, bar, or bolt.

(f) Broken or cracked center casting.

(g) Cracked or broken equalizer, hanger, gib, or pin.

(8) Motor suspension lugs or bars will be of ample strength and provisions made to prevent nose-supported motors from falling in case of failure of motor supports.

g. Side Bearings.

(1) Side bearings will be fastened securely in place. Friction side bearings with springs designed to carry weight will not be continued in service with more than 25 percent of the springs broken in any one nest.

(2) Friction side bearings unless designed to carry weight will not be run in contact. Maximum clearance of side bearings will not exceed 1/4 inch on each side or a total of 1/2 inch on both sides. When more than two side bearings are used under the same rigid superstructure, the clearance on one pair of side bearings will not exceed 1/4 inch on each side or a total of 1/2 inch on

both sides. The other side bearings under the same rigid superstructure may have 1/2 inch clearance on each side or a total of 1 inch on both sides. These clearances apply where the spread of the side bearings is 50 inches or less. Where the spread is greater, the side bearing clearance may be increased in proportion. Side bearing clearances may be modified if investigation shows that operating conditions and construction warrant such modification.

h. Clearance Above Top of Rail. No part or appliance of locomotive, except the wheels, will be less than 2-1/2 inches above the top of rail.

Section III. WHEELS

169. Wheels Tight on Axle

a. Wheels will be pressed securely on axles, except wheels and axles of special design and construction where other proper and safe means are provided for holding the wheels on the axles. Wheel mounting pressures are listed in table 4, (para 229). Prick-punching, shimming wheel fit, or driving pins in ends of axles will not be permitted.

b. When wheels or tires are applied or turned, the diameter of the wheels on the same axle will not vary more than 3/32 inch. When all wheels or tires are turned or new wheels applied in rod-connected driving-wheelbases, the diameter of such wheels will be within 3/32 inch of the average diameter of the other wheels in the same driving-wheelbase.

c. Wheels used on standard gage track will be out of gage if the inside gage of flanges, measured on base line, is less than 53 inches or more than 53-1/2 inches.

d. Counterbalance, when used, will be maintained in safe and suitable condition for service.

e. On locomotives used in road service, the minimum height of flange measured from tread will be 1 inch. On switching locomotives, the minimum height will be 7/8 inch, except where construction does not permit the full height of flange on all driving wheels in any rigid wheelbase. In such exceptions, the height of flange on at least two pairs of drivers will be not less than 1 inch for road locomotives and not less than 7/8 inch for switching locomotives. The others may have flanges with minimum height of 5/8 inch. Where plain tires or 5/8-inch flanges are used on front or rear drivers, trucks will be provided for safely guiding the locomotive (fig. 88 ④).

f. The maximum taper for tread of driving wheels from throat of flange to outside of wheel for locomotives used in road service will be 1/4 inch. On locomotives used in switching service, the taper will be 5/16 inch. The maximum taper for tread of truck wheels from throat of flange to outside of wheel will be 5/16 inch.

g. The minimum width of wheels for driving and truck wheels of standard gage locomotives will be 5-1/2 inches for flanged tires and 6 inches for plain tires. The minimum width of tires for driving and truck wheels for narrow gage locomotives will be 5 inches for flanged tires and 5-1/2 inches for plain tires.

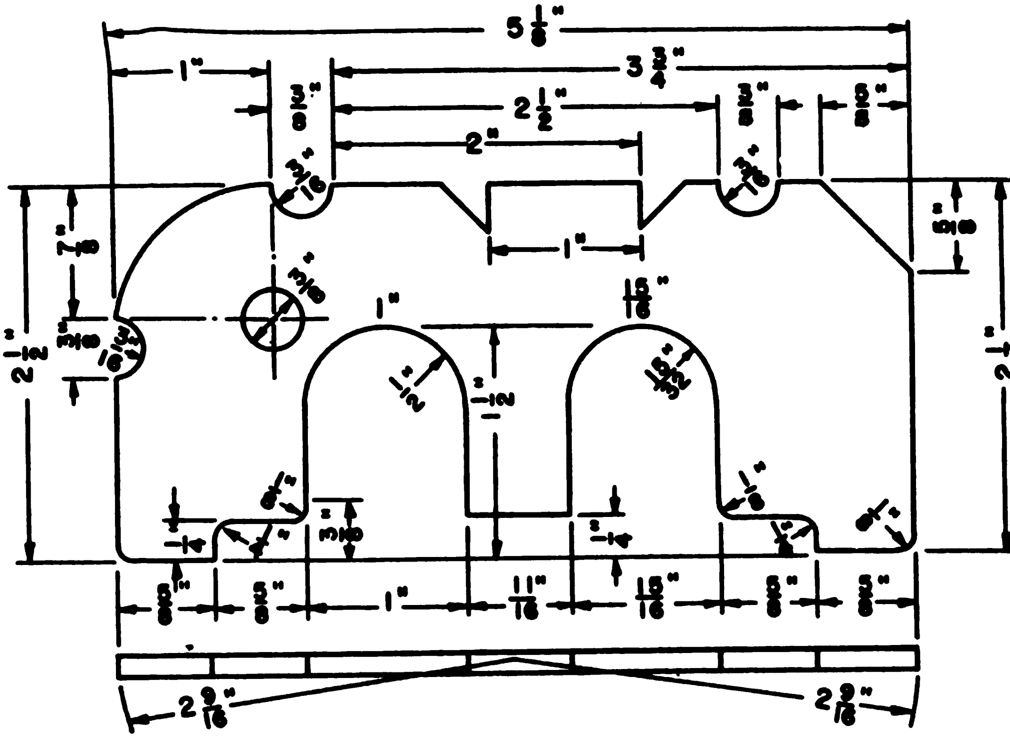
h. The limits prescribed in *c*, *e*, and *g* above may be modified if, upon application to the commanding officer, investigation shows that conditions warrant such modification.

170. Wheel Defects

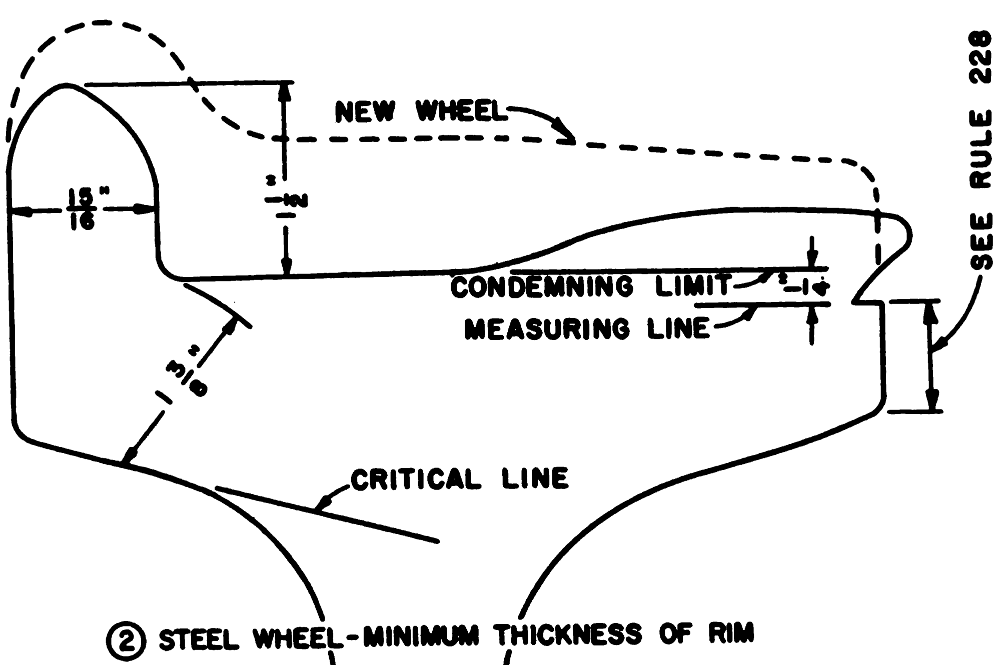
Wheels with any of the following defects will not be continued in service. (Defects listed are in accordance with provisions of the Association of American Railroads Wheel and Axle Manual, the standard railway reference on this subject.)

a. Slid flat, when the flat spot is 2-1/2 inches or over in length or if there are two or more adjoining spots each 2 inches or over in length.

b. Broken or chipped flange, if the chip



① WHEEL GAGE



② STEEL WHEEL-MINIMUM THICKNESS OF RIM

Figure 88. Method of gaging wheels.

exceeds 1-1/2 inches in length and 1/2 inch in width.

c. Broken rim, if the tread measured from the flange at a point 5/8 inch above the tread is less than 3-8/4 inches in width.

d. Wheels with defective treads on account of cracks, or shelled-out spots 2-1/2 inches or over, or so numerous as to endanger the safety of the wheel.

e. Any seam running lengthwise and within the limit of 3-8/4 inches from the flange.

f. Wheels with flanges having a flat vertical surface extending 1 inch or more from the tread or flanges 15/16 inch thick or less, gaged at a point 3/8 inch above the tread, will not be continued in service. Cast iron or cast steel wheels on axles with journals 5 by 9 inches or over will not be continued in service with flanges having flat vertical surfaces extending 7/8 inch or more from the tread or flange 1 inch thick or less gaged at a point 3/8 inch above tread.

g. Wheels with tread worn hollow 5/16 inch on locomotives used in road service or 3/8 inch on locomotives used in switching service.

h. Wheel cracked outward from the wheel fit, cracked tread, cracked plate, one or more cracked brackets, or wheel loose on axle.

i. Loose, broken, or defective retaining rings, tires, or bolts.

j. Flanges more than 1 1/2 inches from tread to top of flange.

k. Thickness of tires less than that shown in paragraph 171*a*.

l. Wheels or tires out of gage.

m. Rolled steel wheels 1 3/8 inches or less in thickness through throat of flange or 1 inch or less in thickness at rim when used in road service; or 1 1/8 inches or less in thickness through throat of flange or 3/4 inch or less in thickness at rim when used in switching service (fig. 88②).

n. The limits shown in *m* above may be modified if, upon application to the commanding officer, investigation shows that conditions warrant such modifications.

171. Minimum Tire Thickness

a. Minimum thickness for driving wheel tires on standard and narrow gage locomotives is 1 inch when used in road service and 3/4 inch when used in yard service. Wheels will not be reapplied to axle when tire thickness, after turning, is less than 1/4 inch above minimum (fig. 88②).

b. The thickness of tires may be modified if the commanding officer approves and investigation shows that conditions warrant such modifications.

Section IV. CABS, LIGHTS, WHISTLES, BELLS, SANDERS, AND SIGNALS

172. Cabs

a. The word "cab" as used in these rules and instructions means that portion of the superstructure utilized for housing the enginemen and parts of the locomotive and through which a passageway is provided for the use of the enginemen.

b. Cabs and superstructures will be attached securely and braced. Cab windows will be located and maintained so that the enginemen will have a clear view of track and signals from their usual and proper positions in the cab.

c. Front cab doors or windows which are in line of enginemen's vision when they look ahead from their usual and proper positions in the cab will be equipped with an appliance that will clean the outside of the windows over sufficient space to provide a clear view of track and signals ahead. They may be equipped with a window which is hinged at the top and is so placed in the glass of each of the doors or windows that it can be closed or opened and fastened in desired position in the cab. Hinged windows will be 5 inches high, and the lower edge will be without obstruction and as nearly as possible in line with the engineman's vision when he is seated in the cab.

d. Deck plates and floors of cab passageways and compartments will be kept free from accumulations of oil, waste, or any obstructions that create unnecessary hazards. Deck plates and metal floors will be roughened properly or other provisions made to afford secure footing.

e. Floors of enginemen's compartments will be constructed of, or covered with, heat-insulating material.

f. Enginemen's compartments will be provided with heating arrangements that will maintain therein a temperature of not less than 50° F. Temperature will be taken at substantially the center of the compartment under normal winter weather conditions, under the running conditions of the locomotive, and with doors and windows closed.

g. Aprons or cover plates, when used between units or compartments, will be of proper length and width to insure safety. They will be hinged or fastened securely and roughened, or other provisions will be made to afford secure footing.

173. Lights

a. Headlights.

(1) Each locomotive in road service between sunset and sunrise will be equipped with a headlight of sufficient illumination to permit a person in the cab of the locomotive to see, in a clear atmosphere, a dark man-sized object at least 800 feet in front of the headlight. Such a headlight will be maintained in good condition.

(2) Each locomotive which regularly is required to run backward for portions of its trip will be equipped with a rear headlight which meets the requirements of (1) above.

(3) Such a headlight, as described in (1) and (2) above, will be provided with a device whereby the light may be dimmed at stations and in yards or when meeting trains.

(4) When two or more locomotives are used in the same train, the leading locomotive only will be required to display a headlight.

(5) Each locomotive used in yard service between sunset and sunrise will have two lights, one located in front of the locomotive and one on the rear. Each headlight will be of sufficient power to enable a person in the cab of the locomotive, under the conditions set forth in (1) above, to see a dark object such as there described for a distance of at least 300 feet ahead and in front of such a headlight. Such headlights will be maintained in good condition.

b. Classification or Marker Lights. Each locomotive will be provided with such classification and marker lamps as may be required. When such lamps are used, they will be maintained in good working order; classification lights will be lighted electrically.

c. Cab Lights.

(1) Each locomotive unit will have cab lights which will provide sufficient illumination of the control instruments, meters, and gages to enable the enginemen to make accurate readings from their usual and proper positions in the cab. These lights will be located, constructed, and maintained so that light will shine only on those parts requiring illumination. A light will be conveniently located to enable the personnel operating the locomotive to read the train orders and timetables easily. It will be so constructed that it may be quickly shielded or extinguished.

(2) Cab passageways and compartments will have adequate illumination. When persons are required to pass from one cab to another, the platform or passageway between them will be illuminated.

(3) Lights will be located, constructed, or shielded so that the light will not interfere with enginemen's vision of track and signals.

(4) All lights may be supplied entirely from storage batteries if desired. Where lights are not supplied from storage batteries, there will be two

or more lighting circuits for providing illumination required by (1), (2), and (3) above. Battery containers will be properly vented.

d. Blackout Operations. When operating under tactical conditions or in prescribed blackout areas, all locomotive lights will be hooded or disconnected, as directed by local commanders.

174. Whistles, Bells, Sanders and Train Signal

a. Whistle. Each locomotive will be provided with a suitable whistle or its equivalent, located so that it may be operated conveniently by the engineman from his customary position in the cab.

b. Sanders. Each locomotive unit will be equipped with proper sanding apparatus. Sandpipes must be fastened securely and arranged to deliver the sand on the rails in front of the wheel contact. Sanders will be tested before each trip.

c. Headlights, Sandboxes, Bells, and Whistles. Headlights, sandboxes, bells, and whistles, will be located in safe and accessible places. Where locomotives are equipped with overhead current collectors, headlights and sandboxes will be located, constructed, and arranged so that they may be given the necessary repairs and attention without requiring a person to mount the roof or become exposed to contact with parts carrying high-tension electric current.

d. Train Air-Signal System. The train air-signal system will be tested before each trip and maintained in safe and suitable condition for service.

Section V. ELECTRICAL EQUIPMENT

175. General

a. Current-Carrying Parts. All current-carrying parts connected to circuits with potential of more than 150 volts will be isolated, insulated, or guarded against accidental contact.

b. Doors and Cover Plates Marked Danger. All doors and cover plates guarding high-tension equipment will be securely fastened in place and kept marked with the word DANGER and will state the normal voltage carried by the parts so protected.

c. Rheostats and Grid Resistors. All rheostats and grid resistors will be maintained free of accumulations of dirt or extraneous matter.

d. Insulation Inspection. A careful inspection of all visible insulation and electrical connections will be made not less than once every month and all defects repaired.

176. Hand-Operated Switches

a. All hand-operated switches which may be operated while under load, carrying currents with a potential of more than 150 volts, will be inclosed in a cabinet or properly covered and be operative from the outside; means will be provided also to show whether switches are open or closed. Switches which may not be operated while under load will be guarded against accidental contact and kept plainly marked with the words "must not be operated under load" and state the voltage carried.

b. Circuit breakers, contactors, and fuses will be maintained in safe and suitable condition for service and will be so located or guarded that persons may not be injured by their operation.

c. Oil-type circuit breakers will be maintained in safe and suitable condition.

177. Jumpers

a. Jumpers or cable connections between locomotives or units will not be allowed to hang with one end free. Chains or hooks for fastening loose ends will be provided.

b. Cable connections between units and all jumpers will be cleaned, inspected, and tested as often as conditions require to maintain them in a safe and suitable condition for service, but not less than once every 3 months. Each jumper carrying current having a potential of 600 volts or more will be tested by immersing the cable portion in water and subjecting each conductor with another and with the water, to a difference in potential of not less than 1-3/4 times the normal working voltage and for not less than 1 minute. Date and place of inspection and test will be stenciled legibly on the jumper or stamped on a metal tag attached securely to jumper.

c. Cable connections between units and jumpers with any of the following defects will not be continued in service: broken or badly chafed insulations; broken or defective plugs, receptacles, or terminals; broken or protruding strands of wire; and jumpers of improper length.

178. Motors and Generators

Motors and generators will be fastened securely in place. Axle collars will be maintained tight on the axle. Axle bearing and armature bearing caps will be bolted securely in place. Motors or generators with any of the following defects will not be continued in service: broken and loose or excessively worn bearings; excessive sparking or flashing over a commutator; defective collector ring, brush holder, yoke, or insulator; loose or broken armature coil bands or wedges; and short-circuited armature or field coil.

179. Voltmeters and Ammeters

All voltmeters and ammeters on units receiving power from an outside source will be tested whenever any irregularity is reported and at least once every 6 months. Voltmeters and ammeters on units driven from power generated within the unit will be tested whenever any irregularity is reported and at least once every 12 months. Meter readings more than 5 percent in error will be corrected.

180. Insulation Dielectric Test

An insulation dielectric test of not less than 1 minute duration will be applied not less than once every year to all circuits and parts carrying current with potential of more than 150 volts. The voltage applied to circuits other than motor or generator windings will be not less than 75 percent above the normal working voltage; the voltage applied to windings will be not less than 50 percent above the normal working voltage. A careful examination will be made of any weakness indicated; all defects will be remedied before the locomotive is returned to service.

Section VI. INTERNAL COMBUSTION EQUIPMENT

181. Fuel Tanks and Piping

a. General. Fuel tanks and related piping will be maintained free of leaks. When fuel is fed from tank by gravity or pressure, a safety cutout valve will be provided in the fuel line adjacent to the supply tank. This valve will close automatically when tripped and can be operated by hand from inside and outside the cab. Fuel tanks and related piping will be grounded electrically.

b. Filling and Venting. Fuel reservoirs will be arranged so they can be filled and vented only from outside the cab or other compartments. Vent pipes will not discharge on the roof nor on or between the rails. A gage which will indicate properly the level of fuel in fuel reservoirs will be provided for each reservoir or series of reservoirs connected and filled from a common source; gages will be located so that they are visible to the person filling the reservoir or reservoirs.

182. Exhaust Gases

Exhaust gases will be released entirely outside of cab or other compartments. Pipes carrying hot gases and exposed moving parts of mechanism liable to cause personal injury will be isolated or guarded against personal contact.

183. General

The officer in charge of locomotive maintenance shops or facilities is responsible for maintaining all daily, monthly, semiannual, and annual report forms. He checks to see if they are properly completed, signed, and certified to, as applicable, and posted or filed as required. Appropriate forms will be requisitioned through normal supply channels from Adjutant General publication centers by installations within and outside CONUS (see AR 310-1 and DA Pam 310-2). Samples of certain forms are illustrated and discussed in following paragraphs. It will be noted that certain of these forms, DD Forms 863, 864 and 865, are no longer required for Army use. The required information, taken from inspection checklists in the manuals applicable to the particular locomotive, will be recorded on DA Forms of the 2400 series in accordance with TM 38-750 (see para 188).

184. Accident Reports

If an accident causing serious injury or death results from failure from any cause of a locomotive or unit or any of its parts, or from contact with an electrically energized part of an appurtenance of such part, the unit which operates such a locomotive will transmit report of such accident immediately to the transportation railway group headquarters in the theater of operations or to the appropriate Army headquarters in the continental United States. This report will give specific information as to the nature of the accident, the place where the accident occurred, and the location where the locomotive or unit may be inspected. DA Form 285 (Accident Report) (not shown herein), letter, or electrical means will be used as appropriate.

185. DD Form 865 (Daily Assignment Worksheet for Locomotives and Locomotive Cranes) (Not required for Army Installations)

This form (fig. 89) will be completed by the individual in charge of maintaining the equipment and will be retained on file at the installation where the equipment is operated. In order that the mechanical record of the equipment be accessible at all times, completed forms will be clipped at the left edge in a file folder. This record will accompany the equipment if it is transferred to another installation or sent to a depot maintenance shop for repairs. Attention is especially directed to the reverse side of DD Form 865. Only such data as the date repairs are made, job order number, and a brief description of repairs will be recorded here. The job order and parts requisitions will be kept as a permanent record and may be referred to if a more complete description of the parts and nature of repairs is necessary. Standard applicable service job order forms will be used in connection with the repair of the equipment.

186. Inspection Worksheets

a. *DD Form 862 (Daily Inspection Worksheet for Diesel-Electric Locomotives).* This form (fig. 90) will be completed by the operator and maintenance personnel of the using unit.

(1) Each locomotive will be inspected by the operator after each day's work. If any defects are found, they will be reported on this form.

(2) This form will show the number of the locomotive, hours in operation, date and place of inspection, and the signature of the road inspector and/or operator.

(3) The form is then given to the maintainer who checks all the items listed on his section of

DAILY ASSIGNMENT WORKSHEET FOR LOCOMOTIVES AND LOCOMOTIVE CRANES	INSTALLATION: Fort Eustis, Va.	MONTH: November
	TYPE: D/E Loco USA #1819	YEAR: 1964

1. DAY OF MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS
2. OPERATIONAL HOURS - DAILY	12	8	8	2	0	0	0	0																								
3. EQUIPMENT REPAIR HOURS	1	0	2	0	0	0	8	8																								
4. SUPPLIES - QUANTITIES BY DATE: a. LOCO OR FUEL (Gallons) [X] DIESEL [ ] GASOLINE (Tons) [ ] COAL	300	0	250	0	0	0	0	370																								
b. LUBE OIL (1) NUMBER 1 ENGINE	0	0	5	0	0	0	0	5																								
b. LUBE OIL (2) NUMBER 2 ENGINE	-	-	-	-	-	-	-	-																								
b. LUBE OIL (3) NUMBER 1 AIR COMPRESSOR	0	0	0	0	0	0	0	10																								
b. LUBE OIL (4) NUMBER 2 AIR COMPRESSOR	-	-	-	-	-	-	-	-																								
c. FILTER ELEMENTS (Clean or replace) (Specify on reverse side, filter cleaned or replaced on date indicated)	-	-	OL	-	-	-	-	OL																								
(1) FUEL OIL NUMBER 1 ENGINE	300	0	250	0	0	0	0	370																								
(1) FUEL OIL NUMBER 2 ENGINE	-	-	-	-	-	-	-	-																								
(2) LUBE OIL NUMBER 1 ENGINE	0	0	5	0	0	0	0	5																								
(2) LUBE OIL NUMBER 2 ENGINE	-	-	-	-	-	-	-	-																								
d. ANTI-FREEZE (Gallons)	0	0	0	0	0	0	0	0																								
e. WATER TREATMENT COMPOUND (Pounds) NUMBER 1 ENGINE	0	0	0	0	0	0	0	0																								
e. WATER TREATMENT COMPOUND (Pounds) NUMBER 2 ENGINE	-	-	-	-	-	-	-	-																								
f. GREASE (Pounds)	-	-	10	-	-	-	-	15																								
g. JOURNAL LUBRICANT (1) GREASE (Pounds)	-	-	-	-	-	-	-	-																								
g. JOURNAL LUBRICANT (2) CAR OIL (Gallons)	1	-	-	1	-	-	-	1																								
g. JOURNAL LUBRICANT (3) WASTE (Pounds)	0	0	0	0	0	0	0	0																								
h. VALVE OIL (Gallons)	0	0	0	0	0	0	0	0																								
i. SAND (Pounds)	0	0	20	0	0	0	0	25																								

5. INSPECTIONS	a. MONTHLY		b. QUARTERLY (Steam only)		c. SEMI ANNUAL		d. ANNUAL	
	DUE DATE	DATE COMPLETED	DUE DATE	DATE COMPLETED	DUE DATE	DATE COMPLETED	DUE DATE	DATE COMPLETED
	7 Nov 64	8 Nov 64	NA	NA	7 Mar 65	--	7 Sept 65	--

6. REMARKS

7-8 November- Monthly Inspection, see DD Form 863.

DD FORM 1 AUG 60 865 — REPLACES DD AGO FORM 99-119, 1 JAN 49, WHICH IS OBSOLETE.

Figure 89. DD Form 865 (Daily Assignment Worksheet for Locomotives and Locomotive Cranes).

DATE	JOB ORDER NUMBER	RECORD OF REPAIRS	COSTS				
		DESCRIPTION OF REPAIRS	ORGANIZATIONAL MAINTENANCE		FIELD MAINTENANCE		TOTALS
			LABOR $	MATERIEL $	LABOR $	MATERIEL $	$
3 Nov 64	10717	Replace sender valve	--	1.50	--	--	1.50
7 Nov 64	10802	Replace wind shield wiper	--	7.25	--	--	7.25
	10803	Install new cab heater element	--	2.15	--	--	2.15
	10804	Replace fuel filter elements	--	3.00	--	--	3.00

Figure 89—Continued.

DAILY INSPECTION WORKSHEET FOR DIESEL ELECTRIC LOCOMOTIVES	LOCOMOTIVE NUMBER	OPERATING HOURS	DATE
	USA 1819	8	3 Nov 64
	INSTALLATION: Fort Eustis, Virginia		

INSTRUCTIONS

Mechanical deficiencies encountered during operation will be recorded by equipment Operator, in the "A - Operators Report" portion of form. The remaining items will be completed by qualified maintenance personnel. Check each item "OK" or "Defective". Maintainer initials and dates to the right of item marked "Defective" to signify necessary repairs were accomplished.

Items which are not applicable to the equipment being inspected should be marked "N/A". In the remark column enter additional work or other qualifying data, such as: Repairs required beyond the scope of organization maintenance. For details in repairs, maintenance and inspection, use the applicable manuals for each model and type of equipment.

A - OPERATORS REPORT

ITEM NUMBER	REPAIRS NEEDED (*Reported by Road Inspector or Operator*)	CORRECTED (*Mechanic's Initial*)
1	Left front windshield wiper does not operate	JMG
2	Locomotive does not make transition automatically	JMG

1. CLEAN LOCOMOTIVE	2. LUBE OIL PRESSURE		3. WATER PRESSURE		4. BATTERY AMMETER		5. LOAD METER	
	NUMBER 1	NUMBER 2	NUMBER 1	NUMBER 2	NUMBER 1	NUMBER 2	NUMBER 1	NUMBER 2
☒ YES	35	--	--	--	Charge	--	800	--
☐ NO	6. MAIN RESERVOIR PRESSURE: 140#		7. EQUALIZING RESERVOIR PRESSURE: 70#		8. BRAKE PIPE PRESSURE: 70#		9. CONTROL AIR PRESSURE: 90#	

SIGNATURE OF ROAD INSPECTOR	SIGNATURE OF OPERATOR
	J. R. Jones, PFC

B - MAINTAINER'S REPORT DATE 4 Nov 64

ITEMS	OK	DEFECTIVE	CORRECTED (*Mechanic's Initial*)	ITEMS	OK	DEFECTIVE	CORRECTED (*Mechanic's Initial*)
1. LUBRICATE COMPLETE LOCOMOTIVE IN ACCORDANCE WITH APPLICABLE DA LUBRICATION ORDER	X			4. BRAKE EQUIPMENT, SANDERS, SHUTTERS, ETC.	X		
2. CHECK AND REPLENISH:				5. COOLING FAN AND DRIVE	X		
a. WATER SUPPLY	X			6. COUPLERS, LOCKS AND LEVERS	X		
b. FUEL		X	JMG	7. BRAKE RIGGING AND PINS	X		
c. BATTERY WATER	X			8. BRAKE SHOES AND BRAKE CYLINDER PISTON TRAVEL	X		
d. SAND	X			9. CAB HEATER AND STANDBY HEATER	X		
e. WHEEL FLANGE LUBRICATOR	NA			10. FOOTBOARDS, DOORS, GRAB IRONS & SAFETY DEVICES	X		
3. HORN, BELL, LIGHTS AND WINDSHIELD WIPERS		X	JMG	11. LOOSE ELECTRICAL WIRES		X	JMG

DD FORM 1 AUG 56 862 REPLACES DD FORM 70, 1 OCT 49, WHICH IS OBSOLETE.

Figure 90. DD Form 862 (Daily Inspection Worksheet for Diesel-Electric Locomotives).

ITEMS	CHECK ONE OK	CHECK ONE DEFEC-TIVE	CORRECTED (Mechanic's Initial)	ITEMS	CHECK ONE OK	CHECK ONE DEFEC-TIVE	CORRECTED (Mechanic's Initial)
B - MAINTAINER'S REPORT (Continued)							
12. LOOSE BOLTS, NUTS AND PINS	X			d. INTAKE AND EXHAUST SYSTEM	X		
13. ALL HOSES AND BELTS	X			15. WHEELS AND JOURNALS	X		
14. LEAKS:				16. DRAIN MOISTURE FROM AIR RESERVOIRS & INTERCOOLERS	X		
a. FUEL AND LUBE SYSTEMS	X			17. DRAIN AIR BOXES AND CHECK OPERATION OF CRANKCASE EXHAUSTER	X		
b. COOLING SYSTEM	X			18. CHECK FOR UNUSUAL NOISES	X		
c. AIR SYSTEM	X			19. CHECK ENGINE WARM UP	X		

C - ADDITIONAL WORK OR OTHER QUALIFYING DATA

REMARKS

NONE

D - AUTHENTICATION

SIGNATURE OF INSPECTOR	SIGNATURE OF FOREMAN
James O. Smith, SP2	Frank Johnson Capt T.C.

GPO 864583 U.S. GOVERNMENT PRINTING OFFICE: 1966 O—355330

Figure 90—Continued.

the form as to whether they were reported good, fair, or bad.

(4) The mechanic receives the form and makes the necessary repairs on those items checked as defective. When each item has been repaired, he puts his initials in the space provided to show that the correction has been made.

(5) If it has been found impossible to make the needed repairs on an item, or any qualifying data is desired, this is written in the section titled "additional work or other qualifying data."

(6) Space is provided for the signature of the inspector or foreman authenticating the report.

b. ***DD Form 863 (Monthly and Semiannual Inspection Worksheet for Diesel-Electric Locomotives).** The monthly and semiannual inspections will be performed by the most technically qualified maintenance personnel of using organizations. The form (fig. 91) for these inspections is divided into six sections from A to F denoting the specific items to be checked.

(1) *Section A, mechanical,* requires inspection of wheels and truck details, couplers and draft gear, and the condition of the horn, bell, window wiper, sander, heater, handbrakes, fan, and fan drive, etc.

(2) *Section B, engine,* requires a complete inspection of engine lubricating oil, fuel oil intake, and cooling systems in conjunction with all bearings, piston assemblies, and governor and throttle linkage.

(3) *Section C, airbrakes,* requires a complete inspection of the compressor and its operation, air gages, brake details, and air reservoirs.

(4) *Section D, electrical,* requires a complete inspection of the lighting system, battery, rotating electrical equipment, and control circuits.

(5) *Section E* consists of a thorough check of the steam generator.

(6) *Section F* requires the inspection of fire extinguishers and lubrication system and a test run of the locomotive.

c. **DD Form 864 (Annual Inspection Worksheet for Diesel-Electric Locomotives).* The annual inspection will be performed by qualified and authorized maintenance personnel. The form (fig. 92) for annual inspections is similar to that described in *b* above. The locomotive and all of its accessories are given detailed and thorough inspections. All gages are tested and calibrated, and all fuel injectors cleaned and tested. Measurements are taken of the crankshaft thrust clearance, coupler heights, and footboard heights.

d. *DD Form 1336 (Monthly Inspection and Repair Report of Locomotives and Locomotive Cranes Other Than Steam).* The monthly inspection and repair report (fig. 93) will be performed by qualified and authorized personnel and certified to by the officer in charge of the maintenance facility. The form indicates an inspection of all parts and appurtenances of the unit; repairs made, if any; and defects not properly repaired, if any. Spaces are provided for the signatures of four inspectors in that several branches of a maintenance shop are represented in the inspection. The reverse side of the form is for noting any defects not properly repaired, a dateline indicating length of time unit was out of service, and a deposition sworn before an adjutant or notary public in which the inspectors certify to the accuracy of the inspection and tests conducted by them.

e. *DA Form 1325-Series (Depot Maintenance Inspection Worksheets for Diesel-Electric Locomotives).* These forms are to be used by the depot maintenance shops (Rail) in performance of depot maintenance. The above worksheet is subdivided as follows, to cover the various types of work performed:

(1) DA Form 1325 (Depot Maintenance Inspection Worksheets for Diesel-Electric Locomotives—Section A—Engine and Details).

*Not required for Army installations.

*Not required for Army installations.

MONTHLY AND SEMI-ANNUAL INSPECTION WORKSHEET FOR DIESEL ELECTRIC LOCOMOTIVES	LOCOMOTIVE NUMBER (USA)	DATE STARTED	DATE COMPLETED
	#1819	7 Nov 64	8 Nov 64

INSTRUCTIONS

Check each item "OK" or "Defective". Maintainer initials and dates to the right of the items marked "Defective", and signify necessary repairs were accomplished. Items which are not applicable to the equipment being inspected should be marked "N/A". In "REMARKS" column enter additional work and other qualifying data such as: Repairs required beyond the scope of Organization Maintenance. For details in repairs, maintenance and inspection, use the applicable manuals on each type and model of equipment.

ITEMS	MONTHLY OK	MONTHLY DEFECTIVE	SEMI-ANNUAL OK	SEMI-ANNUAL DEFECTIVE	CORRECTED (Date and Initial)
A - MECHANICAL					
1. WHEELS AND TRUCK DETAILS					
a. JOURNALS, BEARINGS AND WEDGES, WHEELS	X				
b. JOURNAL PACKING, THRUST PLATE AND BOLTS	X				
c. WHEEL FLANGES	X				
d. SIDE ROD BUSHINGS					
2. COUPLERS AND DRAFT GEAR					
a. COUPLER MECHANISM	X				
b. GAUGE KNUCKLE					
c. DRAFT GEAR, CARRIERS, ETC.					
3. INSPECT FOOT BOARDS, HAND RAILS, STEPS, SAFETY APPLIANCES	X				
4. INSPECT CAB, HOOD, DOORS, WINDOWS, PLATFORM, ETC.	X				
5. CHECK OPERATION OR CONDITION OF:					
a. HORN	X				
b. BELL	X				
c. WINDOW WIPER	X				
d. SANDER EQUIPMENT		X			8/11 Jmk
e. CAB HEATER		X			8/11 Jmk
f. SHUTTERS AND SHUTTER MECHANISM	X				
g. FAN AND FAN DRIVE	X				
h. HAND BRAKES	X				
i. HOSE AND HOSE CLAMPS	X				
j. BELTS AND PULLEYS	X				
k. T.M. BLOWERS AND DUCTS	X				
6. DRAIN WATER AND SLUDGE FROM FUEL TANKS	X				
B - ENGINE					
7. INSPECT FOR LEAKS:					
a. FUEL SYSTEM	X				
b. LUBE SYSTEM	X				
c. COOLING SYSTEM	X				
d. CYLINDER HEADS, CRANKCASE INSPECTION PLATES AND COVERS	X				
e. EXHAUST AND INTAKE SYSTEMS	X				

ITEMS	MONTHLY OK	MONTHLY DEFECTIVE	SEMI-ANNUAL OK	SEMI-ANNUAL DEFECTIVE	CORRECTED (Date and Initial)
8. CHECK COOLING WATER LEVEL					
a. TEST ANTI-FREEZE	X				
b. COMPARATOR TEST WATER TREATMENT	X				
9. CLEAN AND CHECK:					
a. FUEL STRAINERS AND FILTERS		X			8/11 Jmk
b. LUBE OIL STRAINERS AND FILTERS	X				
c. AIR INTAKE FILTERS	X				
d. CRANKCASE BREATHERS	X				
e. TURBO-FILTERS	NA				
f. AIR BOXES	X				
10. CHECK PRESSURES					
a. LUBE OIL	X				
b. FUEL OIL	X				
11. CHECK					
a. ENGINE SPEEDS IDLE 175 FULL 800	X				
b. FUEL INJECTION PUMP TIMING AND RACK SETTING					
c. INTAKE AND EXHAUST VALVES AND MECHANISM	X				
(1) TAPPET OR LASH ADJUSTER CLEARANCE		X			8/11 Jmk
(2) LUBRICATION, LEAKS, STICKING VALVES AND BROKEN SPRINGS	X				
d. GOVERNOR AND THROTTLE LINKAGE					
12. MAIN AND CONNECTING ROD BEARINGS (When accessible)					
13. CHECK TIGHTNESS OF ENGINE BASE BOLTS					
14. VISUALLY INSPECT PISTONS RINGS AND CYLINDERS (When accessible)					
C - AIR BRAKES					
15. INSPECT COMPRESSOR					
a. COUPLING	X				
b. CLEAN AIR INTAKE FILTERS	X				
16. CHECK COMPRESSOR OPER.					
a. UNLOADING VALVES	X				
(1) CUTS-IN 120 LBS	X				
(2) CUTS-OUT 140 LBS	X				
b. ORIFICE TEST					

DD FORM 1 AUG 60 863 — REPLACES DD FORM 71, 1 OCT 49, DD FORM 72, 1 SEP 49 AND DD FORM 73, 1 OCT 49, WHICH ARE OBSOLETE.

Figure 91. DD Form 863 (Monthly and Semiannual Inspection Worksheet for Diesel-Electric Locomotives).

ITEMS	MONTHLY OK	MONTHLY DEFECTIVE	SEMI-ANNUAL OK	SEMI-ANNUAL DEFECTIVE	CORRECTED (Date and Initial)
C – AIR BRAKES (Continued)					
17. CHECK AIR PRESSURE SETTINGS AND OPERATION OF AIR GAUGES	X				
18. CHECK AIR SYSTEM FOR LEAKS	X				
19. DRAIN MOISTURE FROM RESERVOIRS AND INTERCOOLERS	X				
20. CHECK BRAKE DETAILS:					
a. RODS, LEVERS AND PINS	X				
b. AIR HOSE AND COUPLINGS	X				
c. HAND BRAKE AND CHAIN	X				
d. BRAKE SHOES AND KEYS	X				
e. BRAKE CYLINDER AND PISTON TRAVEL		X			8/11 [illegible]
f. CLEAN DIRT COLLECTORS, STRAINER, ETC					
D – ELECTRICAL					
21. CHECK LIGHTS AND LIGHTING SYSTEM	X				
22. CHECK BATTERY:					
a. LEVEL OF SOLUTION	X				
b. SPECIFIC GRAVITY	X				
c. WASH OFF BATTERY	X				
d. CLEAN AND LUBRICATE TERMINALS	X				
23. ALL ROTATING ELECTRICAL EQUIPMENT					
a. VISUALLY CHECK CONDITION CLEAN AND BLOW-OUT	X				
(1) COMMUTATORS AND ARMATURES	X				
(2) STRING BANDS	X				
(3) BRUSHES AND PIGTAILS	X				
(4) BRUSH-HOLDERS	X				
(5) INSULATORS, FIELD COILS AND INSULATION	X				
b. INSPECT AND CHECK					
(1) FOR PROPER DRIVE GEAR LUBRICATION	X				
(2) INSPECTION COVERS ARE TIGHT AND CLEAN	X				
(3) MOTOR NOSE SUSPENSION					
(4) FOR PROPER TH SUPPORT BEARING LUBRICATION					
24. CONTROL CIRCUITS					
a. CHECK CONDITION, OPERATION AND CLEAN CONTACT SURFACES	X				
(1) THROTTLE CONTACTS	X				
(2) AIR OPERATED CONTACTORS	X				
(3) REVERSER	X				
(4) RELAYS	X				
(5) RESISTORS					
b. CHECK ALL CONNECTIONS FOR TIGHTNESS					
c. CHECK FUSES AND KNIFE SWITCHES	X				
E – STEAM GENERATOR					
25. STAND-BY HEATERS NOTE: REFER TO APPROPRIATE MAINTENANCE MANUALS	X				
F – GENERAL					
26. CHECK FIRE EXTINGUISHERS	X				
27. CLEAN ENGINES AND COMPARTMENTS	X				
28. LUBRICATE LOCOMOTIVE IN ACCORDANCE WITH APPLICABLE DA LUBRICATION ORDER	X				
29. TEST RUN LOCOMOTIVE	X				
30. REPLACE CAB CARD	X				

G – REMARKS *(Use extra sheet, if more space is needed)*

NONE

H – SIGNATURES

INSPECTED BY (Mechanic) Jean M. Gray	FOREMAN Robert G. [illegible] C.W.O.
INSTALLATION Fort Eustis, Va.	TRANSPORTATION OFFICER [illegible] Maj T.C.

U. S. GOVERNMENT PRINTING OFFICE [illegible] O—355380

Figure 91—Continued.

ANNUAL INSPECTION WORKSHEET FOR DIESEL ELECTRIC LOCOMOTIVES

LOCO ROAD NUMBER (USA)	DATE STARTED	DATE ENDED
1819	7 Sept 64	9 Sept 64
INSTALLATION: Fort Eustis, Virginia		

INSTRUCTIONS

Check each item "OK" or "Defective". Maintainer initials and dates to the right of items marked "Defective", to signify necessary repairs were accomplished. Items which are not applicable to the equipment being inspected should be marked "N/A". In "Remark" column enter additional work and other qualifying data such as: Repairs required beyond the scope of Field Maintenance.

ITEMS	OK	DEFECTIVE	CORRECTED (Date and Initial)
A - MECHANICAL			
1. WHEELS AND TRUCK DETAILS:			
a. SIDE ROD BUSHINGS	NA		
b. PEDESTAL LINERS AND SHOES	X		
c. JOURNAL BOX LIDS AND PINS	X		
d. JOURNALS, BEARINGS AND WEDGES	X		
e. REPACK JOURNAL BOX AND STENCIL	X		
f. SPRINGS AND SPRING RIGGING	X		
g. AXLE THRUST PLATES AND BOLTS (Axle Lateral)	X		
h. CENTER CASTINGS	X		
i. WHEEL FLANGE LUBRICATORS	NA		
j. INSPECT AND GAUGE WHEELS	X		
2. RECORD AND/OR ADJUST:			
a. COUPLER HEIGHTS			
(1) FRONT (34½) INCHES	X		
(2) REAR (34½) INCHES	X		
b. GAUGE COUPLER KNUCKLE	X		
c. UNCOUPLING MECHANISM, DRAFT GEARS AND CARRIERS	X		
d. FOOT BOARD HEIGHTS			
(1) RF (11) INCHES	X		
(2) RR (11½) INCHES	X		
(3) LF (11) INCHES	X		
(4) LR (11½) INCHES	X		
3. INSPECT:			
a. HANDRAILS, STEPS AND GRAB IRONS	X		
b. CAB, HOOD, DOORS AND PLATFORMS	X		

ITEMS	OK	DEFECTIVE	CORRECTED (Date and Initial)
A - MECHANICAL (Continued)			
k. WINDOWS AND WEATHER-STRIPPING	X		
4. CHECK OPERATION OR CONDITION OF:			
a. T.M. BLOWERS AND AIR DUCTS		X	8/9 [illegible]
b. WINDOW WIPERS	X		
c. BELL AND HORN	X		
d. CAB HEATER		X	8/9 [illegible]
e. HANDBRAKE	X		
f. FAN AND FAN DRIVE	X		
g. SHUTTER AND SHUTTER MECHANISM	X		
h. ALL HOSES AND CLAMPS	X		
i. ALL BELTS AND PULLEYS	X		
j. RADIATORS AND OIL COOLERS	X		
5. CHECK SANDER EQUIPMENT, ALIGNMENT AND LEAKS		X	8/9 [illegible]
6. DRAIN WATER AND SLUDGE FROM FUEL TANKS	X		
7. CHECK AND CLEAN LOCO INTERIOR AND EXTERIOR: PAINT AND STENCILLING	X		
B - ENGINE			
8. INSPECT FOR LEAKS:			
a. FUEL SYSTEM		X	
b. LUBE SYSTEM	X		
c. COOLING SYSTEM	X		
d. TURBO-CHARGER OR AIR BLOWERS	X		
e. CYLINDER HEADS, BLOCKS AND CRANKCASE	X		
f. INTAKE AND EXHAUST SYSTEM	X		
9. CLEAN AND CHECK:			
a. FUEL STRAINERS AND FILTERS		X	8/9 [illegible]

DD FORM 1 AUG 60 864   REPLACES DD FORM 76, 1 OCT 49, WHICH IS OBSOLETE.

ITEMS	OK	DEFECTIVE	CORRECTED (Date and Initial)
B - ENGINE (Continued)			
b. CRANKCASE BREATHER AND/OR EXHAUSTER	X		
c. AIR INTAKE FILTERS AND SILENCERS		X	8/9 acw
d. LUBE OIL STRAINERS AND FILTERS		X	8/9 acw
e. TURBO-CHARGER FILTERS	NA		
f. HYDRAULIC LASH ADJUSTERS	NA		
10. COOLING WATER LEVEL			
a. TEST ANTI-FREEZE	X		-20°
b. COMPARATOR TEST WATER TREATMENT	NA		
11. CLEAN, TEST FUEL INJECTORS, NOZZLES AND PUMPS	X		
12. INSPECT AND CHECK:			
a. FUEL TRIPS	X		
b. OVERSPEED TRIP	X		
c. GOVERNOR SETTING	X		
d. RECORD ENGINE SPEEDS IDLE (350) RPM FULL (1000) RPM	X		
e. LOW OIL PRESSURE SHUTDOWN	X		
f. FUEL INJECTION PUMP OR INJECTOR TIMING AND RACK SETTING		X	8/9 [illegible]
g. VALVE TIMING:			
(1) ADJUST TAPPET OR LASH ADJUSTER CLEARANCE		X	8/9 [illegible]
(2) CHECK FOR PROPER LUBRICATION, LEAKS, STICKING VALVES & BROKEN SPRINGS	X		
h. TEMPERATURE REGULATORS AND/OR THERMOSTATS	X		
13. CHECK ALL INSPECTION PLATE AND COVER GASKETS		X	8/9 [illegible]
14. RECORD TURBO-CHARGER SPEEDS IDLE ( ) RPM FULL ( ) RPM	NA		
15. RECORD PYROMETER READINGS #1 ____ #2 ____ #3 ____ #4 ____ #5 ____ #6 ____	NA		

ITEMS	OK	DEFECTIVE	CORRECTED (Date and Initial)
B - ENGINE (Continued)			
15. RECORD PYROMETER READINGS (Continued) #7 ____ #8 ____ #9 ____ #10 ____ #11 ____ #12 ____ #13 ____ #14 ____ #15 ____ #16 ____	NA		
16. RECORD PRESSURES:			
a. FUEL GAUGE (45) LBS	X		
b. LUBE GAUGE (40) LBS	X		
c. DEAD WEIGHT TESTS - GAUGES		X	8/9 acw
d. CYLINDER COMPRESSION TEST (Lbs per sq. inch) Right / Left: #1 418, #2 425; #3 425, #4 436; #5 419, #6 420; #7 425, #8 420; #9 425, #10 419; #11 419, #12 420; #13 ____, #14 ____; #15 ____, #16 ____			
17. HEADS, PISTONS AND CYLINDERS (When conditions and the above tests warrant)			
a. REMOVE AND INSPECT CYLINDER HEADS	X		
b. PISTONS AND RINGS	X		
c. CHECK CYLINDER LINERS FOR WEAR	X		
18. RECORD CRANKSHAFT THRUST CLEARANCE	X		
19. CHECK ALL CYLINDER HEAD UNITS FOR PROPER TORQUE		X	8/9 acw

2

Figure 92. DD Form 864 (Annual Inspection Worksheet for Diesel-Electric Locomotives).

ITEMS	CHECK ONE: OK	CHECK ONE: DEFECTIVE	CORRECTED (Date and Initial)
B - ENGINE (Continued)			
20. CHECK ENGINE BASE BOLTS FOR TIGHTNESS	X		
21. SCRAPE CARBON AND CLEAN:			
a. AIR BOXES (When accessible)	NA		
b. EXHAUST COMPARTMENT (When accessible)	NA		
C - AIR SYSTEM			
22. INSPECT AND CHECK COMPRESSOR			
a. FLEXIBLE COUPLING OR BELTING	X		
b. CLEAN AIR INTAKE FILTERS		X	8/9 ACW
c. INLET AND OUTLET VALVES			
(1) SPRINGS	X		
(2) SEATS		X	8/9 ACW
d. FOR LEAKS IN PIPING AND INTERCOOLER	X		
e. MAKE ORIFICE TEST	X		
f. UNLOADING VALVE			
(1) CUTS IN (130) LBS	X		
(2) CUTS OUT (140) LBS	X		
23. RECORD PRESSURES:			
a. BRAKE PIPE (90) LBS	X		
b. MAIN RESERVOIR SETTING (140) LBS	X		
c. EQUALIZER RESERVOIR SETTING (70) LBS	X		
d. DISTRIBUTING VALVE SETTING (90) LBS	X		
e. CONTROL AIR (70) LBS	X		
24. AIR RESERVOIRS:			
a. HAMMER TEST (On 30 Mo) (Except Sleeved tanks)			
b. HYDRO-STATIC TEST (250) LBS	X		
c. RESTENCIL AFTER TEST	X		

ITEMS	CHECK ONE: OK	CHECK ONE: DEFECTIVE	CORRECTED (Date and Initial)
C - AIR SYSTEM (Continued)			
25. CHECK CONDITION			
a. AIR HOSES AND DUMMY COUPLING	▲		
b. CONTROL AIR HOSES	X		
26. EXAMINE:			
a. BRAKE RIGGING	X		
b. BRAKE SHOES AND KEYS		X	8/9 ACW
c. BRAKE CYLINDERS AND PISTON TRAVEL (Clean, lubricate and adjust)		X	8/9 ACW
27. DEAD WEIGHT TEST AIR GAUGES	X		
28. INSPECT, CLEAN OR RENEW:			
a. FEED VALVES	X		
b. DISTRIBUTING VALVE	X		
c. REDUCING VALVE	X		
d. INDEPENDENT BRAKE VALVE	X		
e. AUTOMATIC BRAKE VALVE	X		
f. ANGLE COCKS	X		
g. SAFETY VALVES	X		
h. DIRT COLLECTORS	X		
i. STRAINERS		X	8/9 ACW
j. CUT OUT COCKS	X		
k. CONTROL VALVES	X		
29. CHECK PIPING FOR LEAKS	X		
D - ELECTRICAL			
30. CHECK JUMPERS AND RECEPTACLES	X		
31. BATTERY CHECK:			
a. LEVEL OF SOLUTION	X		
b. CELL VOLTAGE AND SPECIFIC GRAVITY	X		
c. WASH OFF BATTERIES	X		
d. CLEAN AND LUBRICATE TERMINALS	X		

ITEMS	CHECK ONE: OK	CHECK ONE: DEFECTIVE	CORRECTED (Date and Initial)
D - ELECTRICAL (Continued)			
e. REPAINT BATTERY BOX (When required)	X		
32. ROTATING ELECTRICAL EQUIPMENT			
a. CHECK CONDITION, CLEAN AND BLOW-OUT	X		
(1) COMMUTATORS AND ARMATURES	X		
(2) BRUSHES AND BRUSH HOLDERS	X		
(3) INSULATORS, FIELD COILS AND INSULATION	X		
b. INSPECT:			
(1) STRING BANDS	X		
(2) BRUSH SPRING TENSION		X	8/9 JMH
(3) TM ARMATURE SHAFT END PLAY	X		
(4) TM SUPPORT BEARING THRUST CLEARANCE	X		
(5) AXLE BEARING PACKING	X		
(6) AXLE AND PINION GEARS	X		
(7) THAT ALL COVERS ARE TIGHT	X		
(8) MOTOR SUSPENSION SUPPORT	X		
(9) AIR GAPS	X		
(10) GENERATOR MOUNTING BOLTS	X		
(11) COUPLINGS	X		
(12) LEADS AND CASINGS	X		
33. CONTROL CIRCUITS			
a. MAKE SEQUENCE TEST	X		
b. CHECK OPERATION, CONDITION AND CLEAN			
(1) THROTTLE CONTROLLER	X		
(2) REVERSER	X		

ITEMS	CHECK ONE: OK	CHECK ONE: DEFECTIVE	CORRECTED (Date and Initial)
D - ELECTRICAL (Continued)			
(3) VOLTAGE REGULATOR	X		
(4) RESISTORS	X		
(5) LOAD REGULATOR	X		
(6) CONTACTORS	X		
(7) RELAYS	X		
(8) INTERLOCKS	X		
c. CLEAN, LUBRICATE AND GAUGE CONTROL AIR CYLINDERS	X		
d. BLOW OUT AND CLEAN HIGH VOLTAGE CABINET	X		
34. MISCELLANEOUS ELECTRICAL			
a. MEASURE SEPARATE INSULATION TESTS AND RECORD	X		
(1) MOTORS	X		
(2) GENERATORS	X		
(3) AUX GENERATOR AND EXCITER	X		
(4) POWER CIRCUIT	X		
(5) CONTROL CIRCUIT	X		
b. HIGH POTENTIAL TEST AFTER INSULATION TEST AND RECORD	X		
c. CHECK OPERATION AND CONDITION OF ELECTRICAL METERS	X		
E - STEAM GENERATOR			
35. STAND BY HEATER TYPE (Refer to appropriate maintenance manual)	X		
F - GENERAL			
36. CHECK FIRE EXTINGUISHERS		X	8/9 JMH
37. LUBRICATE IN ACCORDANCE WITH APPLICABLE DA LUBRICATION ORDER	X		
38. TEST RUN LOCOMOTIVE	X		
39. REPLACE CAB CARD	X		

G - REMARKS (Use extra sheet, if more space is needed)

H - SIGNATURES

INSPECTED BY (Organizational Mechanic) [signature]	FOREMAN (Field Maintenance) [signature]
FOREMAN (Organizational Maintenance) [signature]	TRANSPORTATION OFFICER [signature]

Figure 98—Continued.

MONTHLY INSPECTION AND REPAIR REPORT OF LOCOMOTIVES AND LOCOMOTIVE CRANES OTHER THAN STEAM

14 March, 19 65 — Locomotive or Locomotive Crane No. 2749

Operated by 714th Transportation Battalion (Railway)

In accordance with the act of Congress approved February 17, 1911, amended March 4, 1915, and June 7, 1924, and the rules and instructions issued in pursuance thereof, the parts and appurtenances of locomotive unit No. USA 2749 were inspected on 14 March, 1965 at Fort Eustis, Virginia. All defects disclosed by said inspection were properly repaired, except as noted on the reverse side of this report and the parts and appurtenances were left in the condition reported below.

1. This locomotive unit is propelled by Diesel engine
2. Hydrostatic test of 200 pounds was applied to main air reservoirs.
   Date of previous test as shown by reports on file was 15 Feb 65
3. Were main air reservoirs hammer tested? Yes
   Date of previous test as shown by reports on file was 15 Feb 65
4. Were drawbars and pins removed and inspected? Not applicable
   Date of previous removal as shown by stamping on the parts N/A
5. Were articulated connection pins removed and inspected? Yes
   Date of previous removal as shown by stamping on the pins 15 Feb 65
6. Condition of draft gear and draw gear is Good
7. Condition of brake and signal equipment is Good
8. Condition of running gear is Good
9. Condition of fuel storage and supply system is Good

I certify that I made the inspections and tests above reported in Items No. 3,4,5,6,7,8 & 9 and that statements therein are true and correct.

Roger Jones

I certify that I made the inspections and tests above reported in Items No. 1 and 2 and that statements therein are true and correct.

Frank Smith

10. Date of previous insulation tests as shown by reports on file was 15 Feb 19 65
    Were insulation tests applied at this inspection? Yes

Name of circuit	Normal voltage	Test voltage
Main power	600	800

11. Condition of current collectors is Good
12. Condition of control equipment is Good
13. Condition of control circuits and terminals is Good
14. Condition of power equipment is Good
15. Condition of power circuits and terminals is Good
16. Condition of lightning arresters is Good
17. Were meters tested? Yes Date meters were previously tested as shown by reports on file was 15 Feb, 19 65

I certify that I made the inspections and tests above reported in Items No. 10,11,12,13,15,16 and that statements therein are true and correct.

John Williams

I certify that I made the inspections and tests above reported in Items No. 14 & 17 and that statements therein are true and correct.

[illegible]

The above work has been performed under my general supervision and I believe the report is true and correct.

Earl T Cooke, Officer in Charge.

DD FORM 1 SEP 60 1336 — REPLACES DA FORM 55-230

Figure 93. DD Form 1336 (Monthly Inspection and Repair Report of Locomotives and Locomotive Cranes Other Than Steam).

- s a m p l e -

Note defects not properly repaired: N/A

Locomotive
or
Locomotive
Crane
No. 2749 was out of service the entire calendar months of: N/A

State of Virginia }
County of Warwick } ss:

On this 14 day of March, 19 65 personally appeared before me Roger Jones, John Williams, Frank Smith, Richard Roe and signed the reverse side of this report, each of whom deposes and says that he personally made the inspections and tests reported in items the numbers of which precede his signature, and that the statements therein are true and correct.

Subscribed and sworn to before me this 14 day of March, 19 65

State of Virginia }
County of Warwick } ss:

John A Doe
JOHN A. DOE, Major TC
Adjutant or [illegible]

Figure 93—Continued.

(2) DA Form 1325-1 (Depot Maintenance Inspection Worksheets for Diesel-Electric Locomotives—Section B—Platform, Cab, and Hood Details).

(3) DA Form 1325-2 (Depot Maintenance Inspection Worksheets for Diesel-Electric Locomotives—Section C—Electrical Details).

(4) DA Form 1325-3 (Depot Maintenance Inspection Worksheets for Diesel-Electric Locomotives—Section D—Truck Details).

Diesel-electric locomotive inspection worksheets, so far as practical, will be used for gasoline-mechanical locomotives.

187. Instructions Applicable to Both Monthly and Annual Reports

a. Certification of Reports.

(1) Monthly, quarterly, semiannaul, and annual reports will be signed and certified by one or more inspectors. If one inspector has personal knowledge that all the work shown on the report is performed, he may so certify; otherwise, each inspector will sign and indicate before his signature the numbers of the items to which he is certifying (fig. 91).

(2) The officer in charge must have personal knowledge that the work is done properly. If the foreman has such knowledge, reports signed by him will be accepted; otherwise, they must be signed by the officer in charge who has personal knowledge that it is performed properly. When certificates are required as to work performed at outlying points where the officer is unable to be present, the person who performs the work and is responsible for its proper performance may sign as officer in charge.

(3) Monthly, quarterly, semiannual, and annual reports will be sworn to before a notary public or adjutant by the inspector or inspectors making the inspection. The officer in charge certifies to the correctness of the reports. An affidavit used not be executed on the reports filed with the officer in charge of the shop in either the continental United States or theater of operations.

(4) Before the inspected locomotive is put into service, a copy of a monthly or annual report form will be placed in a suitable location in the cab of the locomotive. The using installation will retain a file copy of the report. These reports need not be sworn to, but must in all other ways be a duplicate of the annual report filed with the transportation group railway headquarters or the United States Army Mobility Equipment Center, St. Louis, Mo.

b. Preparation of Reports. In filling out reports, responsible personnel will —

(1) Use typewriter, ink, or rubber stamp.

(2) Make sure that reports are sworn to immediately after proper repairs are completed.

(3) Make notation, "corrected report," on top of any report which is substituted for an incorrect one previously filed; corrected report will be forwarded to the chief mechanical officer.

(4) Do not use such words as "safe" and "O.K." in answering the items listed in these reports; instead, explain the exact condition found.

(5) Answer "good," "fair," or "bad" where the questions require the condition to be shown. Apply the following definitions to these terms:

(a) *Good.* That the part or parts have no defects of consequence which could be discovered by a reasonable inspection.

(b) *Fair.* That the part or parts have defects, but are in safe and suitable condition and are not in violation of the regulatione.

(c) *Bad.* That the part or parts are not in a safe or suitable condition or are in violation of regulations.

c. *Time of Filing.*

(1) No monthly report will be required for the month in which an annual report is made.

(2) The monthly inspection will be made every calendar month and the period between inspections will not materially exceed 30 days. Where an inspection is made on the first of a month having 31 days, another inspection is not required until the first day of the immediately following month.

(3) All reports in theaters of operations will be filed with the transportation group railway headquarters within 15 days after day of inspection.

(4) In the continental United States, reports will be filed within 15 days after date of inspection. The annual and monthly reports will be forwarded to Headquarters, U. S. Army Mobility Equipment Center, St. Louis, Mo.

d. *Out-of-Service Reports.*

(1) The number of days that a locomotive is out of service will be noted on annual report form. *For example*, the notation "locomotive out of service undergoing repairs from 10 September to 25 September" would inform all concerned as to the reason for the extension of the dates between inspections. No postponement, however, is permitted on the next inspection date. An inspection will be made and a report filed for each calendar month that a locomotive is in service.

(2) Out-of-service reports may be filed for locomotives which are out of service for an entire calendar month or are out of service when due for inspection and remain out of service for the balance of the month. A copy of the out-of-service report will be placed in the cab cardholder on the locomotive.

(3) When an out-of-service report is filed, an inspection will be made and a report filed before the locomotive is again returned to service.

(4) Out-of-service reports will not be filed until the end of the month wherein the duration of nonservice occurred.

(5) Out-of-service reports used not be sworn to but will be signed by the officer in charge of the shop.

(6) The time out of service will be properly covered by out-of-service reports, and a notation as to the months out of service will be made on the back of inspection reports and cab cards.

188. Other Maintenance Records

There are other records pertinent to the operation and maintenance of diesel-electric locomotives which are required by TM 38-750, applicable to all Army equipment listed therein. DA Form 2407 (Maintenance Request) illustrated in figure 94, will be used in reporting manufacturing, design, or operation defects in equipment, and will be completed in triplicate by the person in charge of maintaining the equipment. One copy will be retained on file by the using or service organization, and two copies for the use of the supply service will be forwarded to the transportation group railway headquarters in theaters of operations, or to CG, U. S. Army Mobility Equipment Center, St. Louis, Mo., in the continental United States. Equipment log books are maintained on DA Forms 2408 and 2408-1 to 2408-18, applicable to the item of equipment involved. Entries will be made in accordance with chapter 4, TM 38-750. *The equipment logbook will be with the item of equipment to which it pertains when the equipment is operated, serviced, repaired, modified, or transferred.*

MAINTENANCE REQUEST
(TM 38-750)

*See reverse of file copy for codes and additional data. | PAGE NO. 1 | NO. OF PAGES 1 | *REPORTS CONTROL SYMBOL CSGLD-1047 (R1)*

SECTION I — ☐ WORK REQUEST ☐ MWO ☒ EIR — [12] ORGANIZATION ISSUE PRIORITY DESIGNATOR CODE

CONTROL NUMBER	1a. ORGANIZATION	b. LOCATION	c. ORG IDENT CODE
872365	774th Trans.Grp (Ry)	Fort Eustis, Va.	HH3330B

2. SERIAL NUMBER	3. NOUN NOMENCLATURE	4. LINE NUMBER	5. MODEL	6. FEDERAL STOCK NUMBER
987-654-321	Lens, Headlamp	123456	AB-1	2210-112-8499

7. STRAC	8. UTILIZATION CODE*	9. SELECTED ITEM	10. HOURS	11. MILES	12. ROUNDS	13. STARTS
☐ [1] YES ☒ [2] NO	[OM]	☒ [1] YES ☐ [2] NO	180	N/A	N/A	N/A

14. FAILURE DETECTED DURING *(Select one - use ✓ or X)*

☐ [A] SCHEDULED MAINTENANCE ☐ [C] TEST ☐ [E] STORAGE ☐ [G] FLIGHT
☐ [B] HANDLING ☒ [D] NORMAL OPERATION ☐ [F] INSPECTION ☐ [H] OTHER

15. FIRST INDICATION OF TROUBLE *(Select one - use ✓ or X)*

☒ [000] INOPERATIVE ☐ [386] OVERHEATING ☐ [799] OUT OF ADJUSTMENT
☐ [024] NOISY ☐ [387] LOW PERFORMANCE ☐ OTHER

16. DESCRIBE DEFICIENCIES OR SYMPTOMS ON THE BASIS OF COMPLETE CHECKOUT AND DIAGNOSTIC PROCEDURE IN EQUIPMENT TM *(Do not prescribe repairs)*

Headlamp lens, diesel-electric locomotive, cracks and shatters during operation of locomotive. Probable cause, vibration. Recommend installation of rubber gasket on both sides of lens instead of one side only.

- S A M P L E -

PRIOR TO USING THIS FORM READ CAREFULLY THE STEP-BY-STEP INSTRUCTIONS IN TM 38-750.

USES AND INSTRUCTIONS

1. When all appropriate entries are made in Section I, THIS FORM BECOMES A FORM PECULIAR to a specific weapon system, item of equipment or its component or separate assembly, or a group of similar items with the same FSN. This Section, when combined with either Section II or III or a combination of all three, provides the basis for controlled maintenance actions. This form will be used for:

AT THE ORGANIZATIONAL LEVEL

a. Requesting repairs and maintenance services.
b. Reporting accomplishment of Modification Work Orders.
c. Submission of Equipment Improvement Recommendations *(EIR)*.
d. Reporting receipt of defective materiel.
e. It may be used to record maintenance accomplishments.

AT SUPPORT MAINTENANCE LEVEL

a. Recording maintenance work and/or service actually performed.
b. Reporting the installation of equipment modifications.
c. Submission of Equipment Improvement Recommendations *(EIR)*.
d. Requesting repair of unserviceable components, assemblies and subassemblies as a result of direct exchange procedures.
e. Reporting receipt of defective materiel.
f. Requesting maintenance work and/or services between shops of a given field maintenance shop *(Intra-Shop Maintenance Request)*
g. Requesting maintenance work and/or services of another field maintenance unit or activity within the same echelon or at a higher echelon *(Inter-Shop Maintenance Request)*

AT DEPOT MAINTENANCE LEVEL

a. Reporting the installation of equipment modifications.
b. Submission of Equipment Improvement Recommendations *(EIR)*

2. SUBMITTING SEPARATE EQUIPMENT IMPROVEMENT RECOMMENDATIONS *(EIR's)*

a EMERGENCY EIR's will be submitted to the designated Department of the Army agency by electrical message. A follow-up DA Form 2407, checked "Emergency" in Section III will be submitted with the message number indicated as part of the narrative remarks in Block 35.
b URGENT EIR's will be air-mailed to the designated Department of the Army agency. Check "Urgent" in Section III.
c ROUTINE EIR's prepared as a separate action will require only normal mailing of the NMP Copy 2 to the designated Department of the Army agency. Check "Routine" in Section III.

23. SUBMITTED BY	24. RECEIVED BY
R.Howard	J. Gray
JULIAN DATE 3196	JULIAN DATE 3202

SECTION III - EQUIPMENT IMPROVEMENT RECOMMENDATION

29. NORMAL REPLACEMENT *(Select one - use ✓ or X)*	30. EIR *(Select one use ✓ or X)*	31. RECOMMENDATION *(Select one use ✓ or X)*	32a. ORGANIZATION/ACTIVITY	c. ORG/ACT IDENT CODE
☒ [1] YES ☐ [2] NO	☐ [E] EMERGENCY ☐ [U] URGENT ☒ [R] ROUTINE	☐ [A] IMPROVE DESIGN ☐ [C] REVISE PROCEDURE ☒ [B] MODIFY ☐ [D] OTHER *(Specify)*	Hqs. 774th Trans.Grp. (Ry) — b. LOCATION: Fort Eustis, Va.	HH3330B — d. SUBMITTED BY: R.Howard

33. FEDERAL STOCK NUMBER	34. NOUN NOMENCLATURE	35. OPINION OR REMARKS - DESCRIBE CONDITIONS UNDER WHICH FAILURE OCCURRED - ATTACH PHOTOS OR SKETCHES, IF AVAILABLE
2210-112-8499	Lens, Headlamp	Shatters during locomotive operation.

-S A M P L E-

DA FORM 1 JAN 64 2407 — 1

Figure 94. DA Form 2407 (Maintenance Request).

189. Boilers and Heater Cars

a. A heater car is sometimes utilized in cold weather when it is necessary to operate passenger or ambulance trains with a diesel locomotive not equipped with steam generator. This car is a converted box or passenger car in which a coal- or oil-fired boiler has been installed to furnish the steam necessary to heat the train, either when running or at terminal stops. The boiler may be either the upright or horizontal type.

b. Injectors for keeping sufficient water in the boiler for steam evaporation, gage cocks, water glasses, and steam gage must be applied to all boilers for safe and efficient operation.

190. Operation and Maintenance

The rules and regulations pertaining to the operation and maintenance of steam boilers authorized in TM 55-201 will be followed when heater cars are used.

CHAPTER 18
MAINTENANCE

Section I. CATEGORIES AND ECHELONS

191. General

a. Maintenance is the work that must be performed by every man in the Army to keep his equipment in first class operating condition. In its simplest form, maintenance consists of—

(1) Cleaning.
(2) Lubrication.
(3) Repair.
(4) Preservation.

b. The failure due to improper maintenance of one small part in a locomotive may cause hundreds of lives to be lost because of an accident or the lack of delivery of vital materiel. The Army maintenance system is based on experience and has proved practical in operation. This system is so constituted that the responsibility of each maintenance group is definitely established by categories and echelons. There are four established categories of maintenance (AR 750-5) organizational, direct support, general support, and depot—which are discussed below.

192. Categories of Maintenance

a. Organizational maintenance—That maintenance performed by the organization using the equipment. It consists of inspecting, cleaning, servicing, lubricating, adjusting, and replacing minor parts such as fuel injectors and subassemblies.

b. Direct support maintenance—That maintenance performed by designated maintenance activities in direct support of the using organization. It consists primarily of repair of end items and replacement of unserviceable parts, subassemblies, or assemblies. Repaired items are usually returned to the using organization.

c. General support maintenance—That maintenance authorized and performed by designated TOE and TD organizations in support of the Army Supply System.

d. Depot maintenance—That maintenance which through overhaul of economically repairable material, augments the Army procurement program in satisfying overall Army requirements and provides for repair of material beyond the capability of general support maintenance activities. Equipment rebuilt is usually returned to depot stocks for reissue. Depot maintenance repair parts and special tool lists are contained in TM 55-2210-216-35P. DA Supply Catalog 2200-IL contains identification data for locomotives and locomotive accessory items authorized for issue and for local procurement in Federal Supply Classifications 2210 and 2240.

Section II. LOCOMOTIVE MAINTENANCE

193. General

Maintenance of diesel-electric locomotives involves a greater variety of equipment necessary for repairs than is usually found in one unit. For this reason, satisfactory operation of a locomotive demands strict adherence to the maintenance schedule. This section will discuss what to do, where to do it, and when to do it as pertains to maintenance. Reference to the pertinent manual or lubrication order will provide detailed instructions for repair and lubrication procedures. Any modifications made in compliance with DA Modification Work Orders (MWO) will be recorded and reported in accordance with procedure prescribed in TM 38-750.

194. General Safety Precautions

a. Never use gasoline to clean the diesel engine. Use a good grade of flushing oil, fuel oil, or kerosene.

b. The use of waste should never be permitted in or around the engineroom or any part of the locomotive. Small particles of waste might get into the lubricating oil lines and clog them.

c. Use only clean, lintless, bound-edge cloths to wipe any equipment such as engines, filters, bearings, and other mechanical or electrical equipment.

d. Do not leave any loose cloths or rags around the engineroom. There is danger of these pieces being picked up by air currents and carried to the air filters, traction motors, or generator blowers. They also create a fire hazard.

e. When replacing engine air filter elements, always inspect the screen at the bottom of the blower adapter to make certain that it is not broken. When working around blowers, tools or materials should not be laid on the screen as there is a possibility that some object might fall through the screen into the blower rotors.

f. It is essential that the engineroom, cab, catwalks, steps, and grab irons be kept clean and free of oil, grease, rags, and dirt at all times. Sweep floors frequently. Do not rest feet upon any valve or handle as a valve may accidentally be opened or closed, which may cause serious damage to the equipment or personnel.

g. If checking lubricating oil level before the engine has cooled, do not wipe oil from bayonet gage with fingers as the oil will burn the skin.

h. If fire extinguishers are used, they should be promptly and properly refilled. Pressure-type fire extinguishers should have the proper specified pressure in them at all times, and the liquid level should be at the center of the inspection glass. Pump-type fire extinguishers should be full and available for use at all times. If carbon tetrachloride extinguishers are used, do not breathe the resultant fumes — they are toxic.

(1) Avoid overexposure to fire extinguisher fumes.

(2) The entire train crew should know the location of all fire extinguishers, first aid kits, and telephone callboxes which might be used in the event of an emergency.

i. Locomotive sump drains under engines and generators should be opened frequently to drain any accumulations of dirt, water, and oil.

j. If steam is supplied to the cooling system from an external source or steam generator during a layover period in cold weather, be sure that the G valve (if used) is open to prevent freezing of condensate in the radiators and related piping.

k. When maintenance work has been performed on the locomotive, the shop forces should inspect the locomotive to see that no tools have been carelessly left lying around electrical equipment or rotating equipment where they might cause personal injury or damage to equipment.

l. The locomotive crews and shop maintenance forces should familiarize themselves with the operation and locations of the emergency fuel cutoff pull rings. The fuel cutoff valve and pull rings should be inspected and tested periodically to make certain they work satisfactorily. In case of fire on the locomotive, any one of the three pull rings should be pulled to shut off the supply of fuel oil, thus preventing the fire from entering the fuel oil tank. The fuel oil pump should also be shut off.

m. The air box handhold covers should not be removed while the engine is running. If a cover should work loose, it may be adjusted and tightened while the engine is running. If for any reason a cover has to be removed, the engine should be shut down.

n. When an engine is being rotated with the turning bar or engine turning jack, be sure that the fuel pump switch is in OFF position, the starting fuse is removed or the starting contactors blocked open, and the cylinder test valves are backed out two or three turns. Be sure to remove blocks from starting contactors and replace starting fuse before attempting to start engine.

o. Before starting the engine, after the engine turning bar or turning jack has been used, be positive that it (whichever one was used) has been removed from the flywheel before the start button is pressed.

p. If an engine is to be rotated with the generator, the cylinder test valves must not be opened more than two or three turns, as there is a possibility that the high compression might force the valve out of the valve body, causing injury to someone. The fuel pump must be off and the lay shaft manual-control lever held in the no-fuel position. It is very important that no one stands in line with any of the open test valves as small particles of carbon are sometimes blown out of the test valves with force enough to penetrate the skin. Such particles of carbon are poisonous when they come in contact with raw flesh.

q. Before starting an engine, check lubricating oil, water, and fuel supplies. Be sure that the throttle is in idle position and that the generator switch is out. On locomotives equipped with electropneumatic or electrohydraulic governor control, the isolation switch must be in start position.

r. Before a broken valve spring is removed, rotate crankshaft until piston of that cylinder is on top dead center to prevent the valve from dropping inside the cylinder.

s. When the cooling system is drained in freezing weather, open all drain valves in cooling system, open G valve (if used) and remove pipe plugs from water pump housings so that no water is trapped in the lowest points of the system.

t. Do not work on any switches, contactors, or other high voltage equipment without first stopping the engine and opening the control switch and main battery switch. On road locomotives, the isolation switch must be in START position.

(1) Personnel should not wear rings or wrist watches when working on electrical equipment. Either of these coming in contact with electrical equipment could cause a severe burn.

(2) Metal-cased flashlights should never be used near electrical equipment. If a metal-case flashlight is placed on the equipment, a short circuit will result which might cause a severe burn. Hard rubber or any nonmetallic case flashlight should be used.

u. If for any reason the traction motors or any equipment under the locomotive have to be checked while the engines are running, the generator field switch should be pulled out and the independent airbrake and handbrakes set. The reverse lever should be removed from the controller and taken with the person making the inspection. This is to be done for his own safety in event someone might attempt to move the locomotive.

v. When the locomotive has been standing inoperative for some time and the air pressure is down, do not move the locomotive until the air pressure has been pumped up to the specified minimum pressure.

w. If the locomotive is to be left standing alone for any length of time with the engine shut down, the handbrake should be set and chains or blocks placed at the wheels. The throttle should be placed in idle, the reverse lever removed from the controller, and all switches on the control pushbutton switchbox, low voltage panels, and distribution panel should be out or open.

x. Normally, the side panels on road locomotives are made of metal sheets backed by plywood. Do not use a torch or any hot flame against these panels.

y. When working on an engine, the electrical equipment, or any of the rotating equipment, the starting fuse should be removed and the starting contactors blocked open.

(1) All tools that belong with the locomotive must be in their proper place and in good condition.

(2) None but authorized persons should be permitted in the engineroom and cab.

(3) Anyone getting off the locomotive should make certain that there are

no objects along the right-of-way or that locomotive is not on a bridge or culvert.

(4) Before starting actual operation, move the locomotive slowly over a short distance, close the throttle, and apply the air to make a test of the airbrake equipment.

(5) Try the horns, bellringers, sanders, and windshield wipers.

x. Complete railway safety rules are contained in DA Pam 55-1.

195. Lubricants

a. Engine Lubricating Oil. The lubricating oils suitable for use in diesel engines are OE 10, OE 30, OE 50, and OES (oil, engine subzero). These oils are standard and are used according to the temperatures which are to be expected. *For example,* the oil in the main engine crankcase at temperatures above 32° F. would be OE 50. If the expected temperatures were 40° to -10° F., the oil to use would be OE 10, while if the temperatures expected were 0° F. to -65° F., then OES would be used. The foregoing is only given as an example. For actual lubricating oil requirements, the pertinent lubrication order or manual should be consulted.

b. Lubricating Greases. Greases are used in applications where the use of oil is not practical. However, grease is subject to the same temperature considerations that are given to oil. *For example,* grease, lubricating, general purpose (CG) is furnished in three grades — CGI, above 32° F.; CGO, 40° to -10° F.; CGOO, 0° to -65° F.

Note. In addition to the oil and grease described above, there are many different petroleum products manufactured for use in specialized lubrication requirements. Some of these applications include preservative oils, hydraulic oils, instrument oils, waterproof greases, and other similar lubricants.

196. Locomotive Lubrication

a. Lubrication performed on a locomotive is done in accordance with the lubrication order for the particular locomotive. This lubrication order is the authority for the performance of lubrication services. Lubrication intervals shown on lubrication orders are based on normal operation, and may be either reduced or increased to compensate for a corresponding change in locomotive use from the normal. A typical lubrication order is shown in figure 95. Particular attention should be given to the part of the lubrication order containing the notes. Special instructions concerning lubricating points requiring specialized treatment are covered here.

b. Lubrication standards involved in setting up any lubrication order include —

(1) Accumulated mileage periods should be high enough to prevent failure but low enough to keep costs down.

(2) Competent trained workmen.

(3) Adequate tools and facilities.

(4) Short mileage exceptions for rebuilt assemblies which have been installed on a locomotive and need a run-in or shakedown check.

(5) Time intervals on locomotives which do not accumulate such mileage, especially for items which are more likely to need attention on some basis other than wear, such as dried out packing in brake cylinders, valves, and pumps.

c. A typical list of items which are not related to the engine lubricating system illustrates the importance of proper lubrication of other parts of the locomotive and the obvious need of various grades of grease and oil. These items are listed here without any implications of frequency or standards.

(1) The air compressor has its own crankcase, pressure gage, and oil circulation system.

(2) Traction motors require grease at the pinion, car oil and packing at the traction motor axle bearings, and a ballbearing grease at the traction motor armature bearings.

(3) Journals are packed; pedestal liners are oiled; center plates and side bearings are greased or oiled; slack adjusters, handbrake, and

other brake rigging are greased or oiled; brake cylinders are oiled.

(4) Governor uses an oil which must be kept at proper level in sight glass.

(5) All small motors (pumps, fans, blowers, heaters, steam generators, etc.) should be maintained in accordance with manufacturer's instructions.

(6) Flexible couplings, shutter linkages, governor, fuel-shaft linkages and bearings, fan and blower shaft bearings, speed recorder and cable, draft gear, reverser drum bearings, and controller notching segments all require attention.

197. Lubricating Brake Equipment

a. Brake cylinders should be dismantled for cleaning, repairs, and relubrication at regular intervals. Each piston and nonpressure head assembly should be removed from its cylinder and taken to a shop properly equipped for handling this portion. When it is returned for reinstallation on a locomotive, it should be adequately protected against dirt or other foreign matter.

b. The piston and nonpressure head assembly should be dismantled in the shop and parts cleaned. Cleaning should be done with a hydrocarbon cleaning fluid unless otherwise specified. The piston packing cup must be carefully inspected. If there are any cuts or deep scratches on the packing cup bearing surface, or the packing cup is worn so that it does nor hold a proper bearing surface on the cylinder wall, it should be replaced with one in good condition. When applying the packing cup to the piston, one side should be held slightly away from contact with the piston to allow air to escape from under the packing before it is finally snapped into place. This prevents an air pocket from forming between the packing and the pistonhead, which might cause a poor fit of the packing on the piston.

c. Before the packing cup is replaced or reapplied, the felt swab of the piston lubricator should be carefully cleaned by brushing and relubricated by soaking the unit in oil. If visual inspection indicates that the swab would not have full contact with the cylinder wall, as will be the case if the felt does not extend above the holder, the swab should be adjusted to provide proper contact.

d. The release spring must be inspected. If necessary, clean the spring to remove any rust or dirt which might later find its way to the cylinder walls. If the spring shows any rust spots, it should be given a coating of approved rust preventive after cleaning.

e. The strainer can be removed from the inside of the nonpressure head by removing the snapring holding it in place. The felt swab must be inspected and if necessary a new one applied. It can be removed by removing the nonpressured head. The hollow rod packing felt should be reconditioned by soaking it in solvent to dissolve the grease. Brush the felt to remove the surface dirt. If damaged or worn so that the spring guide cannot close firmly on the hollow piston pipe, install a new one. Soak the seal in oil and hang it up to drain off excess oil.

f. Completely coat the hollow piston rod with a standard brake cylinder lubricant and apply the release spring, felt lubricator, and nonpressure head, using the same holding fixture as for dismantling. Before applying the reconditioned piston and nonpressure head to the cylinder, clean the cylinder walls to remove all dirt and old lubricant. Lubricate the cylinder walls with a good grade of brake cylinder lubricant. If the nonpressure head gasket is in good condition, do not remove it; simply clean the gasket face. Otherwise, replace with a new gasket.

g. Valvular parts of the equipment should be cleaned, repaired, and relubricated at regular intervals. Valvular parts should not be dismantled on the locomotive. Valves or valve portions should be removed from the locomotive and taken to a shop equipped for proper cleaning, repairing, and testing. When valves or portions are returned to the locomotive for reinstallation, they should be protected adequately against dirt and other foreign matter.

LO 55-2210-203-20

LUBRICATION ORDER
LC 45A2-2-14-1

25 AUGUST 1961 (Supersedes: LO 55-1281-20, 29 April 1957)

LOCOMOTIVE, DIESEL-ELECTRIC

56 1/2, 60, 63, & 66 INCH GAGES,
60 TON, 500 HP, 0-4-4-0 WHEEL
BALDWIN-LIMA-HAMILTON RS-4-TC
(DOMESTIC & FOREIGN SERVICE)

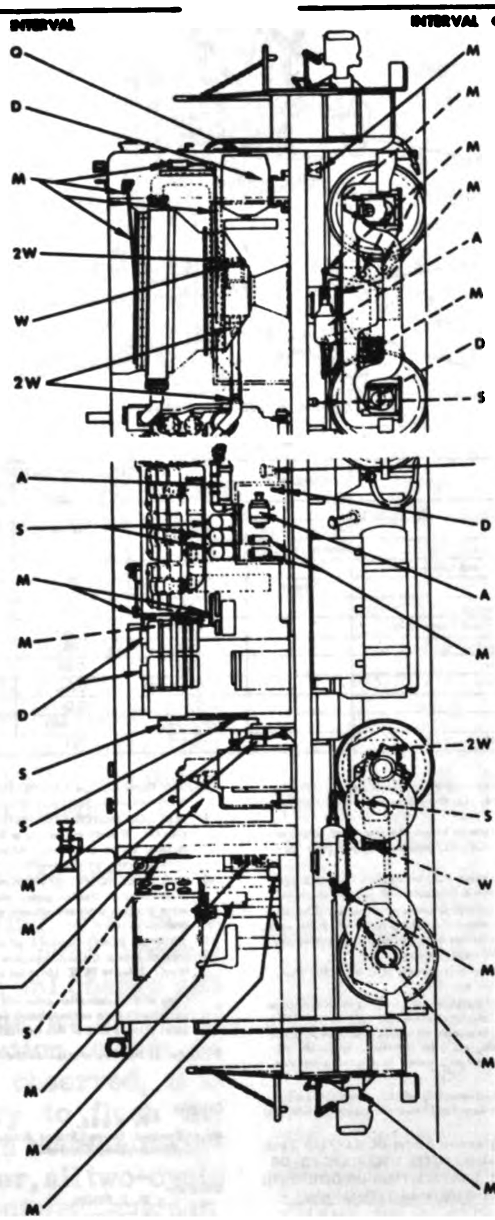
References: TM 55-2210-203-20; TBTC 15-4 & 15-16

Intervals given are maximum for normal 8-hour day operations. For abnormal conditions or activities, intervals should be adjusted to compensate.
Clean fittings before lubricating.
Clean parts with SOLVENT, dry cleaning, (SD) or with OIL, fuel, diesel (DF).

Dry before lubricating.
Lubricate points indicated by dotted arrow shafts on both sides of the equipment.
Drain crank and gear cases only when hot after operation. Replenish and check oil level when cool.

	LUBRICANT	INTERVAL
Vacuum Exhauster Motor (When applied) (2 Points) (Add 1/2 ounce each fitting) (See note 1)	BR	Q
Vacuum Exhauster (When applied) (Check daily, keep filled to level, drain & refill quarterly)	OE	D
Shutter Mechanism (Apply few drops to pins, linkage & bearings) (See note 2)	OE	M
Fan Main Bearing (1 Fitting) (1 or 2 Shots from hand gun) (See note 4)	BR	2W
Fan Angle Drive (Fill gear housing to overflow at fill cup) (See note 5)	OE	W
Fan Universal Shaft (2 Fittings) (1 or 2 Shots each fitting)	GO	2W
Lube Oil Cooler (Remove, disassemble and clean cores)		A
Lube Oil Filters (Drain, disassemble, clean & replace)	OE	S
Throttle Operator & Control Linkage (8 Fittings) (Add 1 or 2 shots each fitting)	GAA	M
Engine Crankcase Breathers (1 each side of engine) (Remove, clean, saturate element with oil replace)	OE	M
Engine Air Filters (Daily, clean & fill pan to level mark)	OE	D
Auxiliary Generator Exciter (2 Fittings) (Add 1/4 ounce each fitting) (See note 4)	BR	S
Main Generator (2 Fittings) (Add 1 ounce each fitting) (See note 4)	BR	S
Blower Belt Tightener (Add 2 or 3 shots from hand gun)	BR	M
Traction Motor Blower (2 Points) (Add 1 or 2 shots each fitting)	BR	M
Air Compressor (See detail "B")		
Windshield Wipers (Front & rear) (Lubricate air chamber parts)	LO	S
Reverser Mechanism (Add few drops at drum contacts & sleeve bearings) (See note 7)	LO	M
Controller Mechanism (Add few drops to drum contacts and sleeve bearings) (See note 7)	LO	M
Cab Heater Motor (Add few drops each oil cup)	LO	M

Fold

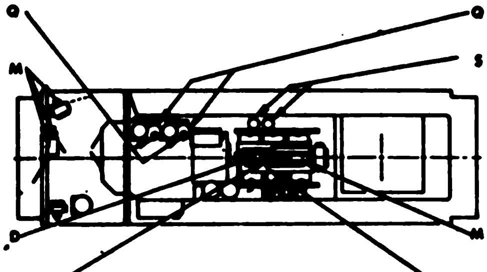


INTERVAL	LUBRICANT	
M	LO	Bell Ringer (Apply few drops to fulcrum pin)
M	OC	Truck Journal Pedestal Liners (4 Pair each truck) (Apply several drops at top each liner as needed)
M	OC	Brake Rigging (Add few drops to pins & bushings)
M	GG-1	Truck Side Bearings (2 Each truck) (Clean & apply light coat of grease)
A	GRS	Brake Cylinders (2 Each truck) (Disassemble & lubricate at overhaul)
M	OC	Slack Adjusters (2 Each truck) (Apply few drops to exposed threads)
D	OC	Journal Boxes (4 Each truck) (Check daily; maintain oil level) (See note 11)
S		Engine Crankcase Drain (Remove plug, drain & refill) (See note 4)
	OE	Engine Crankcase Fill (Add oil as needed to maintain level to full mark)
D	OE	Engine Lube Oil Dipstick Gage (With engine running, check & maintain to "full" mark)
A	BR	Fuel Pump Motor (2 bearings) (Clean & repack at overhaul)
M		Auxiliary Fuel Filters (Turn cleaning handles daily) (Drain water & sediment from sump, clean & flush monthly) (Replace elements)
2W	OC	Traction Motor Axle Bearings (2 Each motor) (Check & maintain level to 2-1/4 inches) (See note 8)
S	BR	Traction Motor Armature Bearings (2 Fittings each motor) (Add 2 ounces each fitting) (See note 4)
W	OC	Traction Motor Suspension Guide Pins (Add few drops to each pin (4 Each truck)
M	OC	Truck Centerplate (1 Each truck) (Fill oil cup to capacity)
M	LGL	Traction Motor Gears (2 Motors each truck) (Add lubricant as needed to cover bottom gear teeth) (See note 9)
M	GG-1	Coupler Carrier & Striker Plate (1 Each end) (Apply light coat grease as needed)

Fold

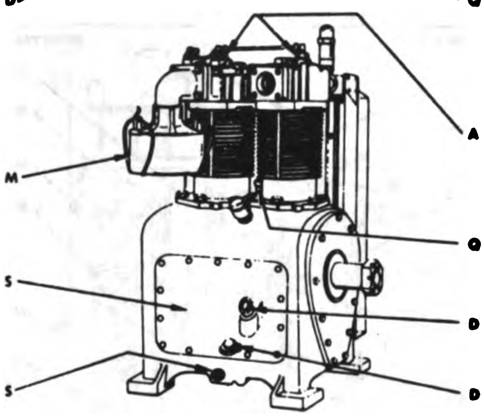
Figure 95. Typical lubrication order.

LUBRICANT • INTERVAL				INTERVAL • LUBRICANT	
Hot Water Heater Pump (Fill oil cups to capacity)	OC	Q	Q	OC	Hot Water Heater Felts, Magneto Cam (Saturate felts, wipe away excess oil)
Hand Brake and Sheaves (3 Points) (Add 2 or 3 drops each point)	OC	M	S		Lube Oil By-Pass Filters (Disassemble clean & replace element, repack)
Engine Governor (Check daily & maintain oil level. Drain & refill monthly & at oil changes)	OE	D	M		Fuel Oil Filter (Drain water & sediment, clean & replace elements)
Fuel Injection Pump Housing (Check daily & maintain oil level) (See note 10)	OE	D	Q	BR	Tachometer Drive (Remove pipe plug & insert fitting) (Add 1 shot from hand gun) (Remove fitting, replace plug)



DETAIL 'A' DIESEL ENGINE TOP VIEW

			A	LO	Compressor Unloader Valves (2 Each cylinder) (Lubricate moving parts sparingly)
Air Intake Filter (Remove, clean & pour 1 pint of oil throught element, assemble & re-install)	OE	M	Q		Crankcase Breather (Remove, clean and replace)
Crankcase Cover Plate (At oil changes, remove, clean pump screen & sludge from bottom) (Replace plate)		S	D		Oil Level Dipstick Gage (Check daily maintain level to full mark)
Crankcase Drain (Drain & refill to correct level)	OE	S	D	OE	Oil Fill Plug (Add oil as needed to maintain oil level)



DETAIL 'B' AIR COMPRESSOR

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— KEY —

LUBRICANTS	CAPACITY	EXPECTED TEMPERATURES			INTERVALS
		ABOVE + 32° F	+ 32° F To -10° F	BELOW -10° F	
OE — OIL, ENGINE, Heavy Duty					D -Daily
Engine Crankcase	Approx. 110 gals.	OE - 30	OE - 10	OE - 10	W -Weekly
Air Compressor Crankcase	Approx. 14 3/4 qts.				
OC — LUBRICATING OIL, Railway Car and Locomotive		OC	OC	OC	2W -2 Weeks
Journal Boxes	2 quarts				
LO — LUBRICATING OIL, General Purpose		LO	LO	LO	M -Monthly
LGL — LUBRICATING OIL, Railway Car and Locomotive		LGL-2	LGL-1	LGL-1	Q -Quarterly (3 Months)
BR — GREASE, Ball and Roller Bearing		BR	BR	BR	
GRB — GREASE, Railway Brake Cylinder		GRB	GRB	GRB	S -Semi-Annually (6 Months)
GAA — GREASE, Automotive and Artillery		GAA	GAA	GAA	
GG-1 — GREASE, Graphite		GG-1	GG-1	GG-1	A -Annually (12 Months)
GO — LUBRICATING OIL, Gear		GO - 140	GO - 140	GO - 140	
GL — GREASE, Aircraft and Instrument		GL	GL	GL	

NOTES:

1. VACUUM EXHAUSTER MOTOR—Quarterly add approximately 1/2 ounce (BR) grease through each fitting. Do not over lubricate. On those equipped with sealed bearings, clean & repack at overhaul.
2. OIL CAN POINTS—Monthly lubricate all exterior hinges, latches, pins, clevises, springs and exposed threaded surfaces with (OE) oil, excepting similar parts requiring other lubrication as shown on chart.
3. SHUTTER MECHANISM—Monthly apply few drops (Ot) oil to pins, linkage & bearings. Shutter air cylinder—disassemble, clean & lubricate with (GL) at overhaul.
4. OVER LUBRICATION—Over greasing is as harmful as under-greasing and must be avoided. Over-greasing is indicated by leakage of excess grease through the seals. Examine the seals before lubricating. If grease has been forced out, decrease the amount of grease or lengthen the interval between greasings.
5. FAN ANGLE DRIVE—Weekly check and maintain level with (OE) oil to fill cup. Semi-annually drain gear case when oil is hot and refill.
6. ENGINE CRANKCASE, FILTERS AND STRAINERS—At oil changes, drain and clean filters, strainers, housings, sump pans and interior of crankcase with solvent (SD) or diesel fuel (DF). Drain and dry parts. Replenish oil supply with approximately 110 gal. (OE). Check engine filters, seals, etc., for tightness. Replenish oil supply to full level. If oil is analyzed use analyst's report to determine draining interval.
7. REVERSER AND CONTROLLER MECHANISMS—Monthly add few drops (LO) oil to drum contacts and sleeve bearings. Repack upper and lower shaft housings with (BR) grease at overhaul.
8. TRACTION MOTOR AXLE BEARINGS—Using a flexible gage check and maintain every two weeks (2W) lubricant level to 2-1/4".
9. TRACTION MOTOR GEAR TEETH—Monthly inspect condition of teeth through gear case lid. If teeth appear dry or bright, replenish lubricant supply (LGL) sufficient to cover bottom gear teeth. At overhaul periods, clean and refill gear case to correct level. Do not overfill.
10. FUEL INJECTION PUMP HOUSING—Check daily and maintain oil level to prescribed mark on dipstick gage. Monthly and at oil changes, drain and refill. Remove breather wash and saturate element with (OE) oil each time housings are drained.
11. JOURNAL BOXES—Replenish oil supply until level is 1 inch deep in box at the front of journal collar. Annually clean box, renew waste and refill to proper oil level. Refer to TB TC 15-16 for installation and servicing of journal pad lubricators.

Copy of this lubrication order will remain with the equipment at all times; instructions contained herein are mandatory and supersede all conflicting lubrication instructions dated prior to date of this lubrication order.

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For explanation of abbreviations used, see AR 320-50.

By Order of the Secretaries of the Army and the Air Force:

G. H. DECKER,
General, United States Army,
Chief of Staff.

Official:
R. V. LEE,
Major General, United States Army,
The Adjutant General.

CURTIS E. LEMAY
Chief of Staff, United States Air Force.

Official:
R. J. PUGH,
Colonel, United States Air Force,
Director of Administrative Services.

Figure 95—Continued.

h. Parts of the dismantled valves and portions should be cleaned with a hydrocarbon cleaning fluid and blown dry with air or dried with a clean cloth. Felt lubricator parts should be soaked thoroughly in standard triple valve oil and hung up to drain off excess oil. All gaskets and other rubber parts should be examined carefully for wear, cracking, flatness of beads, and other damage; and those found defective should be replaced. Metal parts should be repaired or replaced as necessary. In reassembling, slide valves, slide valve seats, piston bushings, piston rings, and other friction surfaces, except rotary valves, should be lubricated sparingly with standard triple valve oil. Care should be taken to spread the lubricant over all the surfaces involved.

i. The KM vent valve is equipped with a self-lubricating piston. After cleaning the piston, the plug in its center must be removed and the felt wick saturated with standard triple valve oil.

j. Rotary valves and rotary valve seats should be lubricated with an oil or grease of high surface tension characteristics. The rotary valve of the automatic brake valve can be lubricated between the periodic cleanings without removing the portion.

k. Plugs in the oil ports in the independent brake valve self-lapping portion which lead to the felt expander should be removed and the passages filled with standard triple valve oil at regular intervals. The plugs should then be securely replaced.

198. Flushing Engine Lubricating System

a. The engine lubricating system is discussed in chapter 5. Under normal operating conditions when oil change and filter replacement periods as specified by the pertinent lubrication order or inspection worksheet are observed, it is not considered necessary to flush the lubricating oil system as a routine maintenance procedure. However, all two-cycle diesel engines, opposed-piston engines, and larger four-cycle diesel engines should be internally washed down annually at the nearest oil change period, especially when heavy black carbon oil film is noticeable on cylinder heads in the crankcase and air boxes.

(1) It is not necessary to flush the system when—

(a) Draining oil and replacing it with fresh oil of the same brand and type.

(b) Replacing a straight mineral oil with one of a different brand.

(c) Replacing a detergent type of used oil with a straight mineral oil.

(d) Replacing an oil which has become contaminated with diesel fuel.

(2) It may be necessary to flush the system when—

(a) Replacing a detergent oil with another type or brand of detergent.

(b) Replacing a straight mineral oil with a detergent type oil in a relatively clean engine.

(3) It will be necessary to drain and flush the lubricating oil system when any of the following conditions have existed:

(a) A part has failed and metal particles have been distributed throughout the oil system.

(b) Excessive water dilution has occurred.

(c) The engine is badly lacquered and dirty after detergent type of lubricating oil has been used.

b. The oil to be used for flushing may be the regular OE used in the crankcase if used at a temperature of 150° F. to 200° F., or it might be a light grade oil (OE 10) comparable to the regular oil used in the engine. When using an oil as light as OE 10, the engine must not be loaded, nor should it be idled above a speed of 425 rpm.

c. The use of flushing compounds or extra strong solvent flushing oils is not recommended as the sludge and varnish may be removed so rapidly from metal surfaces that it will clog small oil passages before it can be removed from the engine.

d. Flushing the system is necessary after excessive water contamination and should be done as soon as the condition is noted. Remove water-oil emulsions from engine filters, coolers, and piping by draining, kerosene spray, and external pumping. Where water dilution is severe, the main bearings should be inspected before running the engine. The condition of the main bearings should indicate the necessity of connecting rod bearing inspection. After inspection, the engine should not be run less than 30 minutes on flushing oil. Bearing inspection after flushing is not necessary unless some irregularity in engine operation has been noted. After flushing for water emulsions, oil coolers should be inspected and cleaned if necessary.

e. After a part failure, particles should be removed as completely as possible by kerosene spray and external pumping of flushing oil with main bearing upper shells removed. After reinstalling bearings, the engine should be run at least 30 minutes on flushing oil, after which the main bearings are again inspected for chip scoring. Rod bearings should also be inspected at this time.

f. External pumping of flushing oil is accomplished as follows:

(1) Pressure not exceeding 60 pounds should be applied simultaneously to the blower lines and to the accessory end oil manifold.

(2) Pressure is applied to the blower end of the engine to prevent forcing metal particles from the main bearing manifold into the rear gear train. Oil is applied to the accessory end because of the large passages which permit increased flow. After flushing in this manner, oil should be pumped into the blower end only to remove any dirt in the rear oil lines.

g. Lubricating oil changeovers sometimes become necessary because of supply problems and other factors. This changeover to a different oil warrants extra care even though the oil system was thoroughly flushed prior to the oil changeover. The residue which should possibly remain from the previously used oil might prove harmful to moving parts. Such residue may not affect in any way the oil responsible for the deposits, but may be very detrimental to the new oil to be used. The lubricating oil cooler is the part of the system to which special attention must be given. Two conditions may exist in the oil cooler as follows:

(1) If it is partially plugged from the first lubricating oil, it must be cleaned.

(2) If it is clean after the flushing, the second oil may pick up deposits from other parts of the engine and redeposit them very quickly in the oil cooler. For this reason, the oil cooler must be inspected a second time before changeover precautions may be considered completed.

h. Low oil pressure suction alarms are extremely significant during oil changeover periods as they indicate partial plugging of the oil strainer and starvation of the engine for lubricating oil. An engine should never be operated after such an alarm has occurred without first cleaning the suction strainers. Suction strainers are a telltale of the internal condition of a diesel engine. Metal deposits of variable sizes are trapped in the strainer, depending on the type of metal (lead or copper, etc.) and may reveal a bearing scrape or bushing wear. Therefore, strainers should be checked periodically.

199. Maintaining Fuel Oil System

a. Maintenance of the fuel system of a diesel locomotive discussed in chapter 4 requires regular and systematic inspections of the varions parts of the system such as tanks, lines, pumps, strainers, and filters. Fuel must be clean before it is put into the locomotive tank. Tanks that are kept well filled will afford less opportunity for water vapor condensation and subsequent trouble.

b. Fuel tanks must be drained of water end sludge accumulations regularly. This is best done when the locomotive has been allowed to stand still for some time and the impurities have thus had a chance to settle out into the tank sump. Drain enough fuel out of the tank to insure removal of all water and dirt in the sump.

c. Fuel lines must be inspected regularly for leaks, apparent damage, and for tightness of fittings at connecting points. Plugged lines can sometimes be cleared by the application of compressed air (with both ends of the line disconnected).

d. Fuel filters and strainers must be inspected at regular inspection intervals as provided for by the inspection worksheet. This inspection provides the means of determining if cleaning is required. Strainers may be washed in solvent or diesel fuel, while filters may require replacement of filter elemente (if of the replaceable cartridge type), or by washing in solvent (if of the permanent element type). Use care in handling the permanent type strainer to avoid damage to the element. Most filters are fitted with drain plugs in the bottom of the filter body to allow water to be drained off. When servicing fuel filters, check all relief valves for proper operation before reinstalling elements. After service, filters must be filled with fuel by opening the air bleeder petcock or plug on the top of the filter housing.

e. Fuel injector maintenance consists of testing the injector to determine if fuel is being delivered properly to the combustion chamber. Observation of engine performance generally will indicate the need of attention to the fuel injectors. As fuel injectors are not all of the same type, reference must be made to the appropriate manual or manufacturer's instructions for the procedure to be followed in testing and cleaning the injector.

200. Maintaining Cooling System

a. General. All parts of the cooling system on diesel locomotives (ch. 6) must be periodically inspected and maintained for trouble-free operation. In addition to proper lubrication of all moving parts such as fans and pumps, regular inspection of hoses, connections, belting, etc., will do much to prevent failure of any part of the system. The use of properly treated water in these systems eliminates frequent cleaning and flushing, and in addition prevents serious part failures caused by corrosive action of untreated water.

b. Water Treatment. This is the first step in the maintenance of cooling systems. When ordinary hard water is heated to normal diesel engine operating temperatures, the minerals in solution in that water are caused to precipitate out of solution onto the various surfaces of the cooling system, causing the formation of scale and sludge which cannot be easily removed from the engine. In general, these formations are of an alkaline nature and in order to remove them, an acid solution must be used to flush the system.

c. Flushing Procedures. Flushing a badly scaled cooling system usually involves six steps. Generally, an external pump is used in place of the engine's water pump and the radiator is processed separately from the block. This avoids clogging radiator passages with deposits removed from the engine. In most cases, scale removal is done with the engine cold and with thermostats and temperature gages removed to avoid damage by strong chemicals. The procedure would follow these general lines—

(1) Flush with clear water until water runs clean.
(2) Flush with strong alkaline solution to remove oil, grease, dirt, etc.
(3) Rinse with clear water.
(4) Flush with scale remover until appearance of solution indicates complete scale removal.
(5) Rinse with clear water.
(6) Neutralize with weak alkaline solution.

d. Treating Water. Treated water should be prepared properly in separate containers before introducing it into a cooling system. Mineral free water such as required by diesel engines may be obtained by distilling, or produced by modern chemical processes. Water treated in this manner is called demineralized or deionized water and will not cause scale deposits. It will have a corrosive action against metal. To prevent this, a suitable corrosion inhibitor must be added. Testing the water in a cooling system must be done regularly to maintain proper concentrations of treatment compounds.

201. Engine Maintenance

Diesel engine maintenance requires strict adherence to lubrication schedules and to cleanliness. A clean engine (inside and out), correctly operated and properly lubricated, is usually immune to unexpected part failures. Excessive dilution of the lubrication oil is one of the frequent causes of engine failures. This condition can exist to a critical extent without being readily apparent to the personnel charged with maintenance. There are several instruments available for the express purpose of measuring lube oil viscosity, one of these being a viscosimeter. This instrument has disadvantages in that it is extremely susceptible to breakage and is costly to replace. Its use is discussed in paragraph 16*c*.

202. Irregular Engine Operation

a. General. The satisfactory performance of a diesel engine depends on the presence of sufficiently high compression pressure and the injection of the proper amount of fuel at the right time. The first condition depends almost entirely on pistons, piston rings, and valves with their operating mechanism; the second condition depends on the injectors and their operating mechanism. Lack of engine power, uneven running, excessive vibration, and a tendency to stall when idling may be caused by a compression loss or by faulty injector action. The following troubles, causes, and remedies are listed to assist the mechanic in diagnosing trouble and correcting it. For other troubleshooting information, see paragraph 151.

b. Engine Fails To Start at Temperature Above Freezing (32° F.).

(1) Throttle not in starting position.
(2) Fuel shutoff cock closed.
(3) Fuel tank empty or insufficient supply of fuel.
(4) Blower rotors not revolving.
(5) Battery not sufficiently charged.
(6) Lack of compression due to sticking valves, improper valve seating, or sticking rings.
(7) Engine out of timing.

c. Engine Fails To Start at Temperature Below Freezing (32° F.). Cold weather starting aids needed.

d. Uneven Running and Excessive Vibration.

(1) Faulty injector timing or rack setting.
(2) Insufficient fuel supply.
(3) Hunting governor. Remove all the bind from injector control rack operating shaft mechanism.
(4) Cooling water temperature too low. Check thermostats.
(5) Valves in bad condition. Check compression pressures.
(6) High exhaust backpressure. Check exhaust pressure at exhaust manifold.
(7) One or more cylinders cutting out. Determine which cylinder or cylinders are cutting out, check valve springs for bad cylinder, and replace injector with a new one. Check cylinder compression.
(8) Water in fuel system.

e. Engine Stalls Frequently.

(1) Idling speed too low.
(2) Cooling water temperature too low.
(3) Too sudden application of load at low speeds.
(4) One or more cylinders cutting out.
(5) Hunting governor. Bind from injector control rack operating shaft mechanism should be removed.
(6) Choked fuel oil filters.
(7) Unsatisfactory injectors. Replace with reconditioned injectors.
(8) Improper governor adjustment and governor linkage incorrectly set.
(9) Air in fuel system. Inspect system for leaks.

f. Loss of Power.

(1) Injector racks not properly positioned.
(2) Faulty injector timing.
(3) One or more cylinders cutting out.
(4) Air filters choked.
(5) Insufficient fuel supply.
(6) Choked fuel oil filter.
(7) Air in fuel system.

(8) Unsatisfactory injectors.
(9) Improper governor adjustment.
(10) Loss of compression.

g. Engine Will Not Shut Off.

(1) Gradual development of the condition in normal operation is usually caused by misalinement of external control linkage. When a stop is attempted, the engine continues to run somewhat below idle.
(2) Diluted oil in air boxes and hot engine.

h. High Cooling Water Temperature.

(1) Water pump worn.
(2) Fan not operating properly.
(3) Thermostat stuck.
(4) Radiator air passages clogged.
(5) Circulation of cooling water restricted.
(6) Shutters closed.

i. High Lubricating Oil Temperature.

(1) High cooling water temperature.
(2) Clogged oil cooler.
(3) Oil cooler bypass not operating.

j. Smoky Exhaust. Two types of smoke may be observed coming from the exhaust stack. These are classified according to their color.

(1) *Black smoke.*
(a) Poor grade of fuel.
(b) Injector timing late.
(c) Unsatisfactory injector.
(d) Air ports in cylinder liner choked.
(e) Obstruction in blower air intake.
(f) High exhaust back pressure.
(g) Low compression.

(2) *Blue smoke.*
(a) Injectors not properly equalized.
(b) Cylinder cutting out.
(c) Lubricating oil entering combustion chambers.

k. Engine Knocks (Detonates).

(1) Due to its high compression, the characteristic sound of a diesel is sometimes mistaken for knocking. True knocking can be detected by placing a screwdriver or bar against the engine with the other end to the ear, and listening to engine sounds at various positions. Hammering in a diesel can be due either to fuel knocks or mechanical knocks. If a hard metallic knock indicates detonation in one or more cylinders, the engine should be immediately stopped to prevent serious damage due to the excessive pressures accompanying detonation. Detonation is caused by the presence of fuel oil or lubricating oil in the air charge of the cylinders during the compression stroke. The engine should be checked for—
(a) Leaky injectors.
(b) Leaking fuel connections in cylinder head.
(c) Crankcase dilution due to fuel leaks.
(d) Leaky blower housing gasket.
(e) Leaky blower oil seals.
(f) Control rack improperly adjusted.
(g) Hydraulic valve lash adjusters sticking.

(2) Mechanical knocks may be caused by loose or worn pistons, piston pins, bearings, blowby, or loose flywheel. In a two-cycle engine, knocking will not be heard from a loose connecting rod bearing because there is a downward pressure on the piston both on the upstroke (compression) and on the downstroke (combustion). To isolate connecting rod knocks, hold down on the injector plunger, cutting out injection on the cylinder suspected; then, any loose bearing will be heard.

l. Lack of Lubricating Oil Pressure.

(1) Oil supply in crankcase low.
(2) Crankcase oil diluted.
(3) Wear on crankshaft or connecting rod bearings.
(4) Lubricating oil pump relief valve sticking.
(5) Oil cooler choked.
(6) Oil pump screen choked.
(7) Oil pump drive inoperative.
(8) Oil lines choked, improperly tightened, or leaking.

203. Turbocharger

a. General. The turbocharger (fig. 32) is a closely fitted unit. Its operation is discussed in paragraph 41*b*. Great care must be used in maintaining clearances and seals. Blowers may be maintained as directed in applicable unit instructions. Turbochargers are generally maintained on a unit exchange basis, except for routine cleaning and checking the speed at which it operates. Typical routine work is as follows:

(1) Check the blower speed. (The maximum allowable speed is marked on the turbocharger nameplate.)

(2) Clean the sections of the air intake filter every week or as needed.

(3) Check air pressure at full load for the proper temperatures, pressures, and speeds.

b. Checking Rotor. The free running time of the rotor, after stopping the diesel engine, should be checked from time to time. This is an indication of the condition of the bearings. The free running time from 2,200 rpm (engine idling) to a standstill is approximately 2.8 to 3.00 minutes. If the blower speed or the charging air pressure drops under the normal values, or if the temperature of the inlet exhaust gases at normal load with pressure charging exceeds the maximum allowable temperature for continuous running, immediately reduce the engine speed and determine the cause of the trouble. This may be due to—

(1) Failure of the fuel injection system or other trouble with the diesel engine; that is, leaky exhaust valves, excessive piston blowby, etc.

(2) Losses from leaky joints in air delivery piping.

(3) Losses in the exhaust gas piping between the diesel engine and the turbine.

(4) Excessive restriction in the air filter.

(5) Troubles with the blower assembly. (Bearing troubles, rubbing of packing gland or turbine wheels, etc.) Also look for a poor connection in the generator field resistance, or slipping of exciter belts.

204. Electrical Equipment Maintenance

a. General. Maintenance requirements for cable and electrical equipment installed on diesel-electric locomotives consists of inspection, cleaning, lubrication, and adjustment. Cleaning of electrical equipment must be done with extreme care. Parts of the rotating machinery such as the armature are insulated with materials that are easily damaged by solvents, water, detergents, etc. Cleaning is accomplished by blowing dust and dirt out of the equipment with clean, dry, compressed air. This must be done often enough to avoid large accumulations of foreign matter which may become caked, causing difficult removal. Compressed air should be used at reasonably low pressures. In cases where there are heavy deposits of grease or dirt which cannot be removed with air, they may be wiped with clean, dry cloths, brushed with a stiff fiber brush, or scraped with soft wood. In severe cases, it may be necessary to dampen a cloth in solvent to remove oxidized grease or oil. Every precaution must be taken to keep the cleaner off the commutator and copper parts. Cleaners should be used only when other methods will not remove the foreign matter.

b. Motors and Generators. Motors and generators are subject to dust and dirt, oil fumes or smoke, and changes in temperature of the surrounding air. High temperature from electrical loading and severe mechanical conditions may be present. The main generator (para 70) is connected directly to the diesel engine and a main generator failure is serious in that it causes a complete breakdown of a single powerplant. In multiple powerplant locomotives such failure causes a substantial reduction in capacity and may damage the engine itself. Under those conditions, satisfactory main generator performance is assured only by close attention to service and adequate maintenance. The amount of maintenance work done at one time varies between switching and road locomotives and in both cases, depends on the severity of service. For switching locomotives, a program of thorough cleaning of armature and field, checking of field coil and brush holder connections with necessary retaping and painting, detailed inspection of brush holders and brushes with necessary repairs or replacements, general inspection and stoning of commutator, and checking and testing of bus bars or leads can be adapted to alternate with heavier repair work. All of this work can be done without removing the generator from the engine. Brushes and brush holders must be inspected periodically as required by the inspection worksheet. Brushes should move freely in the holders and the holders and insulator must be clean. Lift the springs and raise and lower the brushes in the holders in order to release any dirt that may have accumulated. Care must be taken not to snap the spring as this may chip the brush. Replace brushes that have been chipped or show excessive wear with the same grade of brush. This is especially necessary when only a partial replacement is made, as two different kinds of brushes on the same generator are likely to be detrimental to its successful operation. Do not use emery cloth or emery paper when sanding brushes (*g*(3) below). Check brush spring tension and adjust as required.

c. Commutator. The commutator should present a polished surface entirely free of pitting. If the commutator becomes pitted, it should be cleaned with a fine commutator stone. Never use carborundum or emery cloth on a commutator. When cleaning the commutator with a stone, extreme caution must be taken to keep copper dust from the windings. The air openings in the end frame on the fan end should be covered to prevent the fan from drawing dust into the windings. After stoning the commutator, blow out windings carefully with clean, dry, compressed air at reduced pressure. If the commutator has high and low spots or signs of burning, the armature should be placed in a lathe and the commutator turned just enough to give it a uniform surface. After the commutator has been turned, undercut the mica. Remove the sharp edges of the commutator bars with a hand scraper or a knife, but do not bevel the edges. Clean out the slots to remove all loose mica and copper chips. Commutator segments must be kept as tight as possible. Adjustments to correct a loose commutator require great care and should be attempted only by experienced men who are familiar with the manufacturer's specifications. Do not apply lubricant to the commutator because it is detrimental to successful operation. The brushes contain sufficient graphite to maintain proper lubrication. If the commutator is not kept clean and free of grease and oil, carbon dust will collect in the grooves between the segments and will tend to cause a short circuit.

d. Field Coils. Examine the connections and leads to the coils to determine if they are mechanically and electrically satisfactory. Field coils, leads, and cable connections must be secured and all taping made intact. Whenever examination reveals charred insulations, the cause should be determined and the trouble corrected.

e. Inspection of Overloaded Traction Motors. The leads from the armature windings are soldered into the ends (necks) of the commutator bars; these bars should be carefully inspected when examining the armature. If the armature has been overheated by the overloading and solder has been thrown out, the motor should be removed and replaced. Heavy overloading for traction motors may result in—

(1) Loosening of the armature bands.
(2) Shrinking of insulation and slot wedges, which permits vibration of armature windings and which may ultimately cause an electrical breakdown.
(3) Persistent overloads may cause the pinion end band wire to throw solder and yet leave the commutator end band wire and the commutator soldering intact. (The pinion and winding will be hottest because it is insulated and covered by a band, and is ventilated by the hottest air.)
(4) When overloads are such that all parts of the armature reach a

high temperature, all bands may unsolder as well as commutator risers. These can be easily detected through the commutator opening at maintenance inspection. The motor should be removed and replaced when there are signs of loose band wire or throwing of solder.

f. Burned Spots on Commutator. Burned spots on the commutator may result when locomotive power and brakes are applied simultaneously. Burned edges of one or a number of commutator segments about the length of the number of brushes in the brush holder may indicate a winding or cross connection open in the armature. Blackening of the commutator may be caused by oil or grease from the bearings on the commutator or brushes, or by surges of load-current from improper operation of locomotive and frozen or stuck brushes. Flat spots on the commutator may result from the following:

(1) A mechanically unbalanced armature.
(2) Commutator may be out of round.
(3) High or low commutator bars.
(4) Driving wheels of locomotive may be worn too much on one side.
(5) Flat spots on the wheels.

g. Auxiliary Generator. It is essential that the auxiliary generator (para 88) be kept clean at all times. It should be blown out with clean, dry, compressed air. Approximately every year, the insulation on the commutator cap should be cleaned and, when dry, painted with air-drying insulating varnish. The brush holder ring insulator should be wiped clean. Any accumulations of oil and dirt should be removed. The electrical equipment must not be sprayed or cleaned with a liquid of any kind. Attempting to clean the coil and windings with a liquid cleaner will destroy the protective coating, causing it to peel or crack. All that is necessary is to blow out the dust and dirt with clean air periodically. This should be done often enough to prevent any accumulations. If deposits of dirt are allowed to collect, they sometimes become caked, making them more difficult to remove. A large volume of air at reasonably low pressure should be used. If a high pressure from a nozzle is used, there is danger of loosening tape and cutting the protective coating of the various parts. Some parts, such as brush holders and contacts, should be wiped with a clean, dry cloth. In cases where there are heavy deposits of grease or dirt which cannot be removed with air and dry cloths, a stiff brush, soft wood, or fiber scrapers may be required. In severe cases, it may be necessary to dampen a cloth in cleaner to remove oxidized grease or oil. Every precaution should be taken to keep the cleaner off the commutator as unsatisfactory brush performance may result. Cleaners should be used only when other methods will not remove the foreign matter.

(1) *Creepage surface.* Refer to instructions on creepage surface care and maintenance of generator commutators.

(2) *Lubrication.* In some instances, the ball bearings are the double-shielded type and are packed at the factory with a lubricant (ANDOK C) which does not become fluid except at temperatures higher than those reached under normal operation. Since the bearings are sealed on both sides, they do not require additional lubrication. However, on overhaul, the bearings should be removed and replaced with new factory packed bearings. Other types of bearings are lubricated at lubrication fitting.

(3) *Brushes and brush holders.* Inspection and cleaning procedures for brushes and brush holders are covered in *b* above. When the new brushee are installed, they should be sanded-in one at a time, by placing a piece of No. 00 grade sandpaper under the brush with the sand side contacting the brush and moving the sandpaper in the direction of rotation. Lift the brush when moving the paper back and keep the paper close to the commutator to avoid rounding the edges of the brush. Proper brush pres-

sure should be maintained as specified under maintenance data in paragraph 245. Unequal brush pressure may cause unequal current distribution to the brushes. Maintain 1/8 inch clearance between the bottom of each brush holder and the commutator. The brush holder assembly is arranged in such a way that the brush holder may be moved toward the commutator by loosening the checknut and the setscrew on the brush arm. Brush holders should be rigidly bolted in place. The carbon brush shunts should be so arranged that they will clear the parts of the frame that are at ground potential.

Note. Do not use emery cloth or emery paper for sanding-in brushes.

h. Small Motors.

(1) Cleaning, brush maintenance, armature maintenance, and commutator maintenance are the same as for generators. Inspection procedures for motors should follow the same procedures as outlined for generators. If trouble is experienced in motor operation, make sure —

(a) The bearings are in good condition.

(b) There is no mechanical obstruction to prevent rotation. Shaft should turn freely.

(c) All bolts and nuts are tightened securely.

(d) Correct voltage is actually available at the motor terminals. Voltage drop must not be more than 10 percent of rated voltage.

(e) Fuses are good and connections are tight.

(f) The brushes make contact with the commutator and do not bind in brush holder.

(g) Armature or frame is not grounded; check with a megohmmeter.

(2) Armature should be closely inspected for condition of bands, wedges, coils, insulation, commutator, and the general assembly. Armature bands and coil wedges should be tight and secure. Soldering on band should be intact. If solder has been thrown off, the cause should be determined, corrected, and bands replaced. The coil insulation should be free of blisters, flakes, or cracked insulating varnish surface.

i. Armature Bearings.

(1) The following precautions should be observed to prevent bearing failures:

(a) When removing sheaves or fans, use a puller that does not apply a load on the bearings.

(b) Sheaves or fans must be pressed on the shaft in such a way that the forces are not transmitted through the bearings.

(c) Care must be exercised in handling the auxiliary generator to prevent bumping of shaft, which is likely to damage the bearings.

(d) Avoid excessive belt tension.

(e) Bearings which have been removed from the shaft at any time should not be used again but replaced with new factory-packed bearings.

(2) These bearings are subjected to unusually severe operating conditions and must be maintained very carefully. When lubricating and installing bearings, use particular care to prevent dirt from getting into the lubricant or on the bearings. The bearing assemblies are equipped with an elaborate arrangement of labyrinths to prevent dirt from entering the bearing while in service. The armature bearings may usually be inspected without removing the armature. To inspect the bearing at the commutator end, remove the bearing capnuts end the bearing cap. To inspect the pinion end bearing, remove the pinion, bearing seal, and bearing cap. Remove and replace bearings which show any observable wear. Bearings may become noisy and should be

removed before excessive wear occurs.

j. Controllers. Clean all contact surfaces, carefully removing all of the old lubricant and accumulated dirt. Lubricate the segments by wiping them with clean cloth greased with the proper lubricant. Only a very thin coating of lubricant should be used. Contact tips must ride squarely on drum surfaces. All screws, bolts, and nuts which secure electrical connections should be kept tight to insure good contact. If the contact surfaces of the cylinder segments, or fingertips, become roughened or pitted, they should be smoothed with a fine mill file or replaced. When filing the fingertips, preserve the contour of the tip and file in such a manner that contact will be along a lobe instead of a point. Each finger of the controller is provided with an adjusting screw to compensate for finger wear. Some tips are reversible to obtain better wear. The tip should bear firmly on the segment. Replace spring if pressure is light.

k. Engine Starting Contactors. The contactor should be inspected and cleaned in accordance with the inspection worksheet. Accumulations of dust should be removed with a brush and the bearings lubricated with a drop of oil. In no case should oil be applied to contact tips. Braided copper shunts which carry current from the moving contact to the contactor terminal should, if broken or badly worn, be replaced with a new assembly. During inspections the contactor should be operated by hand (open the main battery switch or remove the fuse) to detect any excessive resistance to movement. The contact tips, gap, and wipe should be checked at this time. Silver contacts may become blackened through normal operation, but this should not interfere with their efficiency. Silver oxide is a good conductor of electricity and no attempt should be made to remove such discoloration. Do not use abrasives when cleaning contacts unless precautions are taken to keep metal particles away from contact surfaces and moving parts. Such repair should be done with contacts removed from the contactor.

l. Relays. Perform periodic inspections as required by inspection worksheets and check the following items:

(1) Contacts for burns and discoloration of contact arms; clean contacts as required and inspect for wear. Replace contacts when worn 1/8 inch on each contact.

(2) Current coil connections for tightness.

(3) Electrical connections for tightness and electrical contact.

(4) Coils and resistors for burns and discoloration. Adjustments should not be attempted unless detailed instructions for the type of relay in use are available. Some relays have a seal wire to guard against tampering. Check that the seal is undisturbed.

m. Voltage Regulators.

(1) Voltage regulators found on locomotives are two types: those of the motor-operated type (torque motor) and the relay type. The voltage regulating relay controls the auxiliary generator output which furnishes auxiliary power for battery charging, control, etc. Auxiliary generator voltage must be maintained constantly regardless of engine speed. inspection and routine maintenance for the latter type will be similar to *l* above. Inspection and cleaning of the torque motor type are as follows:

(a) If discoloration or sparking develops on the regulator commutator, the regulator should be cleaned as soon as possible. Thorough cleaning requires the removal of the sector from the regulator. Refer to the specific instructions for proper procedures.

(b) Inspect sector and carbon rim assemblies; replace if burned, broken, or worn.

(c) Check piston in dashpot for freedom of movement. If piston sticks at any point, the dashpot must be removed and overhauled.

(d) Sector bearings should be lubricated according to the pertinent lubrication order or manual. Use oil sparingly to avoid accumulations of dust.

(2) The voltage regulator should be set to the manufacturer's specifications. Check these required settings to see if the regulator is operating properly. Before making adjustments, study the appropriate instructions thoroughly to gain an understanding of the working parts. Poor regulation may be the result of the following:

(a) Dirt in the dashpot.

(b) Worn or dirty actuating shaft bearinge.

(c) Dirty commutators and sectors.

(d) Dirt in the main shaft bearings.

n. *Load Regulator.* Essentially, the load regulator is a vane-type automatic rheostat in series with the main generator battery field. The commutator-type regulator is simple in construction and has few wearing parts; consequently, minimum maintenance is required. Piping connections should be kept tight to prevent oil leaks and entry of air into the system. At intervals, the commutator cover should be removed and the commutator assembly cleaned. Insulation surfaces should be wiped with a clean cloth and dirt removed from the commutator and slipring, using canvas or crocus cloth. Do not use sandpaper or cleaning solvent. Clean diagonal slots in slipring. Brushes should move freely in the brush holder. Release the springs and raise and lower the brushes in the carbonways to remove any dirt that has accumulated. Wipe off any dirt on the exposed sides of the brushes. If face of brush is grooved or embedded with copper or if new brushes are applied, they should be sanded to fit the commutator or slipring. The resistor assembly should be blown out with clean, dry, compressed air at low pressure. Oil lines to the operating cylinder or motor shaft should be inspected. Replace the seal if there is any leakage. Load regulator timing is accomplished by controlling the flow of oil through the pilot valve to or from the load regulator. The rate of motion of the load regulator is controlled to secure satisfactory locomotive starting, to improve transition loading and unloading characteristics, and to permit stable operation under all load conditions.

o. *Magnet Valves.* Inspection of valve operation and valve wear and a limited amount of cleaning of the valve parts may be done with the valve unit assembled on its apparatus. If a valve sticks or leaks, it may be due to a deposit of gummy oil and dirt on the seating surfaces or on a valve stem. Satisfactory operation possibly may be restored by washing the parts with a cleaner. The valve seats and clearance holes for the valve stems may be flushed out by pouring cleaner fluid through the magnet core. The cleaner recommended is trichloroethylene III or petroleum spirits. Take necessary precautions against the hazards involved in using either cleaner. It may be necessary to grind-in the valve and its seat to make them tight. Make sure all grinding compound is removed with dry, compressed air and a thorough washing with the cleaner. At intervals, depending on the number of operations and the amount of foreign matter in the air system, the valve unit should be removed from its manifold and disassembled sufficiently to permit cleaning, checking, and replacing worn valve parts. To disassemble the magnet valve, first remove the cover. The pole plate may be lifted off and the valve stem pulled. Taking off the large nut at the bottom allows the removal of the needle valve and spring. Dirt may be removed by flushing with a cleaner such as mineral spirits.

(1) If magnet valve leaks because the seats are scored, it is necessary to grind the valves. Fine grinding compound is used. When replacements are made, a complete new assembly should be installed in order to be sure the valve stem has the correct length with relation to the pole plate position. If it becomes necessary to grind the seats, remove parts as stated

above. To grind the upper seat, coat the end of valve stem with grinding compound. Replace the valve stem in the magnet valve housing, insert screwdriver in the slot of the adjusting screw on the valve stem, and rotate back and forth. To grind the lower seat, insert the needle valve after coating it with valve grinding compound. Leave the valve stem in the magnet valve housing to act as a guide for the needle valve, then insert a screwdriver in the slot and rotate back and forth. After both the upper and the lower seats have been ground, the magnet valve housing, valve stem, and the needle valve should be thoroughly cleaned. Make certain that there are no particles of foreign matter in the housing, then reassemble the magnet valve and connect it to 90 psi air pressure.

(2) To test the lower valve seat, cover the air ports in the side of the magnet valve housing with soapy water. If bubbles form, the lower seat must be reground. To test the upper valve seat, press down the button on the cover of the magnet valve housing. This has the same effect as though the magnet coil were energized. While holding the button down, again cover the air ports with soapy water. If bubbles appear, the upper seat must be reground. If bubbles do not appear while making the above test, both seats fit properly. If, after considerable grinding, either seat still leaks, the valve seat is so damaged that a new needle valve, stem, and seat assembly are necessary. Check both the needle valve and the valve stem for damage. If a valve blows through the exhaust port when the coil is energized, it is an indication that the valve stem is not seating properly. This may be due to any one of the following causes listed in the order of the probability of occurrence.

(a) Dirt on valve seat.

(b) A weak battery of low voltage applied to the coil will sometimes give a sufficient pull to unseat the lower valve but not enough to close the exhaust.

(c) Dirt under the pole plate.

(d) Valve stem worn down so that pole plate strikes the core before the valve seats. This rarely occurs until after the equipment has been in service for several years. If the stem is found to be too short, it can be slightly stretched by peening the shank. However, it is recommended that a new assembly be installed.

p. Reversers. Reversers should be removed for dismantling, cleaning, lubrication, and repairs (para 73). Piston packing should be renewed, pinions and racks examined for wear, and magnet valves cleaned and tested. Contact segments should be renewed or built up and remachined. Stationary contacts, shunts, and springs should be inspected for overheating or wear and replaced as necessary. Contact tension should be checked and adjusted and interlocks inspected.

q. Main Power Switches. Main power switches should be inspected for free movement of all moving parts and checked for excessive play or clearance. Replace any movable parts worn sufficiently to cause excessive play. Inspect for burning or pitting of contact tips. Dress with medium or fine mill file if necessary. Inspect for correct alinement, wiping action wear, and pressure of all contacts. When the main contact is properly closed, the contact tips are heeled. Inspect for tightness of all electrical connections and contactor mounting. Do not lubricate the main contact tips. Grease or oil of any type around the contactor will collect dirt which causes the deterioration of insulation. Inspect the interlock fingers and bars for wear, sharp edges, burrs, alinement, and burned and pitted areas. Maintain magnet valves as in o above.

r. Instruments. Voltmeters, ammeters, or load indicators should be removed for testing and calibration. This applies also to engine or locomotive speed indicators of either the mechanical or electrical types.

s. *Summary.* There are many items of electrical equipment installed on diesel locomotives. Most of these items can be inspected and serviced in the same manner as similar items discussed in the foregoing paragraphs. Reference should always be made to the appropriate publication for any special procedures for particular pieces of electrical equipment.

t. *Safety Precautions.*

(1) Do not work on electrical equipment without first isolating the equipment from the power source by stopping the engine and opening control and battery switches or by removing fuses where applicable.

(2) Do not perform work while wearing rings or wrist watches; remove them.

(3) When traction motors or under-locomotive equipment must be inspected while the engine is running, the generator field switch must be opened and the independent airbrakes and handbrakes set. The reverse lever must be removed from the controller and carried with the person making such an inspection.

(4) Do not use metallic-cased flashlights around electrical equipment.

(5) Adjustments that must be made on equipment while actually operating should be done with the person making the adjustment standing on dry insulating material, newspaper, etc., with one hand in his pocket. Another person should be standing by to render assistance, if necessary.

(6) Never use volatile cleaning solvents in inclosed spaces and never use them anywhere without adequate fire extinguisher apparatus at hand.

205. Battery

a. Proper maintenance of batteries is essential in order to obtain long, dependable battery performance. The maintenance procedures are not difficult. The battery compartment must be well ventilated. A free flow of air over and around the battery dissipates heat and prolongs battery life. Openings should be screened to keep out dirt. Suitable drain openings should be provided in the bottom of the battery compartment to allow washing solution and rinse water to drain away from the locomotive and not mar the paint or superstructure.

b. The battery should be well blocked to prevent excessive movement. Do not wedge. Cables should not be subject to crushing or rubbing which may destroy insulation and result in grounds. Keep all connections clean and tight.

c. Maintain the battery in a healthy state of charge by keeping voltage regulator properly adjusted. An ideal setting will maintain the specific gravity of the electrolyte without using an excessive amount of water or heating up the battery. Too high a setting increases water consumption and heat. Too low a setting will result in progressively lower specific gravity readings and negligible water consumption.

d. Add approved or distilled water at regular intervals. In cold weather, add water just before the locomotive goes into service in order to mix it with the electrolyte. If left standing without mixing, the water will freeze and damage the battery.

e. Keep the battery and its surroundings clean and dry. Vent plugs must be kept in place. If covers and trays are neutralized with soda, do not allow any of the solution to get into the cells or the cells will be neutralized. Keep continuous records of the condition of the battery. The specific gravity lowers on discharge and rises again on charge. Hydrometer readings vary from 1,280 when charged to 1,160 when discharged. Electrolyte from the battery is drawn into the barrel of a syringe which contains the hydrometer. The hydrometer will not sink as far in a solution with a high specific gravity as it will in a solution with a low specific gravity. The stem of the hydrometer is graduated accordingly.

f. The capacity of a storage battery is

measured in units of ampere hours, which is the product of the electrical current in amperes multiplied by the time in hours. *For example,* an MVMT-13 battery has a capacity at the 6 hour rate of 204 ampere hours, or 6 hours x 34 amperes = 204 ampere hours. Although current may be obtained after the end of this time, the voltage of the battery has dropped to a point where it is inadequate. Little, if any, permanent harm will result if the battery is discharged to the limit of its capacity, provided it is recharged promptly. The ampere hours which may be obtained from a battery are greater for a long low rate or intermittent rate discharge, in amperes, than for a short high rate. This is because the voltage drops faster at the higher discharge rates. High discharge rates should not be confused with overdischarge.

g. Practice the following safety rules and cautions:

(1) Do not work on the battery without opening the main battery switch.
(2) Keep all flames away from the battery.
(3) Do not lay tools on top of the battery.
(4) Do not permit oil to drip on the battery.

206. Air System

a. The air system discussed in chapter 12 must be kept clean and well lubricated. Faulty operation is most frequently caused by wear and corrosion of moving parts and dirty, sluggish, dry and deteriorated filters, pistons, and diaphragms. Many filters, cocks, and fittings are provided for running maintenance of this equipment, but the high standards of cleanliness involved require that many operations of a maintenance nature, such as lubrication, be done in a shop after removing the assembly from the locomotive. Information in paragraphs 197 and 209 should be used for both maintenance and repair work, according to the circumstances.

b. Lubricate, clean, and test the compressor and its components as follows:

(1) Maintain the oil in the compressor crankcase at the proper level. Change the oil periodically as specified in maintenance schedules. When the oil is changed, clean out the crankcase with a regular flushing oil. Do not use gasoline, kerosene, or other flammable agents in cleaning the crankcase. If the oil pressure is abnormally high or low, check the operation of the oil relief valve and oil pump and the condition of the oil filters.

(2) Clean and oil the elements in the air filter periodically. Direct dry, compressed air along, not against, the outer surface of the filter, or clean with an alkali-free hydrocarbon solvent; dry, dip in an oil bath, and drain.

(3) Drain condensate from the intercooler, keep the intercooler core sections clean to permit free passage of cooling air, and check the intercooler safety valve by hand to be sure it is not stuck. If intercooler pressure is unusually high, check the operation of the high-pressure suction and discharge valves. If the pressure is unusually low, check the operation of the low-pressure suction and discharge valves. About the only attention the intercooler should need is draining to insure removal of moisture. Drain the intercooler every time the main reservoirs are drained. A drain cock is located in the bottom header of each bank of intercooler tubes. When handling the intercooler, care should be exercised to avoid damage to the finned tubing and also to see that undue strains are not placed on the header assembly. The top header is one piece while the bottom header is in two pieces to accommodate expansion due to temperature change. The lower headers are tied together with a bottom tie strap and capscrews; upon their removal, the intercooler may be lifted vertically. When handling, replace the strap

to prevent distortion of the assembly.

(4) An orifice test shows whether a compressor can maintain a specified reservoir pressure while reservoir air is escaping through a specified orifice. This pressure varies with the dimensions of the orifice and the speed of the compressor. A condemning limit is usually set at approximately 80 percent of the capacity of a new compressor. If the air escapes from the orifice faster than the compressor can pump, the compressor should be reconditioned.

(5) The governor needs very little attention after being properly adjusted, except periodic cleaning and oiling. A few drops of good oil should be placed on the working surface of cutting-in and cutting-out valves. The exhaust opening must be free of dirt and gum and the strainer must be clean.

207. Trucks and Brake Rigging

a. Trucks are not subject to routine maintenance other than inspection, periodic cleaning, and lubrication as required by inspection worksheet schedules and lubrication orders. Badly worn wear plates on journal boxes and pedestals can be renewed without removing the wheel and axle assembly, but a better job can be done if the assembly is removed, thus allowing wear plates to be clamped tightly into place.

(1) Inspect for apparent damage to main castings such as cracks in the transom, bolster, etc.

(2) Inspect all bolts, nuts, and other fittings for tightness.

(3) Inspect center plates and side bearings for excessive wear. If the clearance between the frame and the side bearings is low, the center plate is worn and may need replacing or shimming.

(4) Inspect springs for indications of weakness, cracks, or broken leaves.

(5) Check swing hangers for excessive wear at upper and lower ends.

(6) Inspect pedestal liners.

b. Brake rigging must be inspected thoroughly at each daily inspection. Brake lever pins, bushings, and clevises must be maintained in good condition. Wear or damage must be corrected immediately or, if inspecting personnel are unable to correct the trouble at once, a report to the next higher authority must be made. When levers, pins, and bushings have worn until brake travel can no longer be taken up by turnbuckle adjustment, the brake pull rod may be shortened by moving the pin to the second hole in the rod. When it becomes necessary to move the pin to the third hold to maintain piston travel, all parts should be replaced. Brake adjustments should be done at a time when main reservoir air pressure is pumped up. When making adjustments, release the handbrake and set locomotive brakes by applying the independent brake valve control. Brake cylinder piston travel should be set in accordance with standard operating practice. Adjustments usually are necessary when travel exceeds 2 inches for each piston.

c. When making adjustments on brake rigging or when inspecting underparts of a locomotive, it is always good practice to block the wheels of the locomotive to prevent any possible movement.

208. Bearings

a. Hot Bearings. A hot traction motor axle bearing or journal bearing gives off smoke and/or odor. In switching service, notify the nearest maintenance facility. In road service, remove the waste, discard charred portions, and repack the bearings, being sure the waste is against the axle. Add plenty of oil, pouring some directly on the waste. After running several miles, inspect the bearing again. Repeat as required to reach a terminal.

b. Maintaining Bearings. Typical axle bearing maintenance involves inspection at regular intervals to check the oil depth (1-3/4-in. minimum, 3-1/2-in. maximum, measured on slant). Clean off all dirt around the waste pocket and oil well covers. Lift covers and examine waste. Change any glazed waste. Make sure that waste is packed tightly against window and the bearing lining flanges are being properly lubricated. Use a suction pump to take a sample of oil from the bottom of the oil chamber to check for water. If water is found, it should be withdrawn and the bearing repacked with fresh waste. Bearings normally require repacking after 25,000 to 30,000 miles of service or every 6 months, whichever occurs first.

c. *Packing Axle Bearings.* To pack axle bearings, empty and clean out waste chamber. Be careful that no dirt drops into it. The axle caps are fitted with a spring waste pusher. A thin wood or fiber wedge should be inserted between the pusher and the axle to keep the spring compressed while the bearing is packed. If the wedge is inserted in the center of the waste openings, the waste can be packed on both sides of it. The wedges should be removed after packing. Long fiber wool waste should be used as packing. All the waste to be used should be thoroughly saturated with warm oil for 24 hours and allowed to drain for 12 hours (temperature approximately 85° F.).

(1) Make several wicks or skeins by twisting the long strands together once or twice.

(2) Place the wicks in the window side of the waste chamber so that they extend from the bottom to about 6 inches above tho top and force them firmly against the shaft by packing more waste behind them.

(3) Fold the top of the wicks back over the packing and fill the remaining space with a wad of waste well saturated with oil to exclude dirt.

(4) Replace cover on waste chamber.

d. *Oiling Axle Bearings.* Fill the bearing with lubricating oil conforming to specifications applicable. Unless the climate is very uniform throughout the year, two grades of oil are required, one for summer and a lighter grade for winter. Open the oil well cover and gage the depth of the oil by inserting a clean rod or stick into the auxiliary oil well. If the bearing is not sufficiently full, pour oil into the auxiliary oil well until the proper depth of oil is reached (3-1/2-in. maximum measured on slant). Close oil well cover.

e. *Journal Bearings.* To remove journal bearing and thrust bearing—

(1) Remove waste or lubricator pads from the journal box.

(2) Jack journal box high enough so the weight of the locomotive is not resting on the journal bearing.

(3) Remove spring caps and gaskets.

(4) Remove the nine lateral springs and two snubber lateral springs. Remove one spring with a pin punch or driftpin. The other may be removed by hand. Note that the outer snubber spring camber is bowed away from axle. Inner snubber spring has chamfered edge.

(5) Hold thrust bearing while removing springs so it does not fall and mar the thrust face.

(6) Remove wedge from top of journal bearing.

(7) Insert bolt in hole in front side of bearing and pull out. Be very careful not to scratch bearing surface on collar of axle when removing.

(8) Repack housing with clean oil soaked spring packing waste or new lubricator pad, as applicable.

(9) After parts have been inspected, reassemble by reversing the above procedure.

f. *Journal Box Parts.* All parts of the journal box are interchangeable when new. This has led to the practice of interchanging journal boxes from one axle to another, particularly at wheel changes. Experience has shown, however, that after bearing parts have operated together for a considerable period of time, they will wear-in in a complementary and individual manner. For this reason, it is recommended that each journal box and bearing be treated as a unit and be used only on the journal to which it belongs. When parts which belong together are kept together, the maximum possible life will be realized from each part.

209. Miscellaneous

a. *V-Belts.* Correct tension should be maintained on V-belts. If the V-belt is too loose, it will slip and cause both the sheave and the belt to wear and the engine to overheat. If the V-belt is too tight, bearings are subjected to a very great overload and will wear rapidly. Belt tension may be checked roughly by depressing the V-belt in the center, halfway between the two sheaves. The amount of this deflection will vary somewhat due to the variation in drive center distances, but usually the deflection will run 1/2 inch to 1 inch. The pressure exerted at the center of the belt to check this deflection should be the normal pressure possible to exert with one finger without straining. Whenever any matched set of belts is applied, whether new or used, the center distance of the drive must be reduced so that the belts can be placed over the sheaves freely. If this were not done, it would be necessary to force the belts into the sheave grooves, causing ply breakage and cover damage and resulting in shortened service life for the belts. Check pulley alinement after belt tension is adjusted, since movement of the equipment, and consequently the pulley sheave movement, will cause undue wear and strain on new belts. After a set of V-belts has been applied and drawn up fairly tight, the drive should be run for at least 15 minutes. This will allow the belts to stretch and become well seated in the grooves and equalized on both sides of the drive before checking for tension and any possible mismatching of belts. After the belts have made this preliminary run, check the belt deflection. It should be about 1 inch at midspan. Run the drive at top speed, checking the driven pulley speed with a hand tachometer. If tho driven pulley speed falls within 5 percent of calcualted speed, the belts should be tight enough. If not, tighten the belts a small amount and check the speed again. If the driven pulley speed cannot be brought up to rating, check the wear condition of the sheaves. Sheaves that are badly worn may not deliver the proper speed.

(1) To find the speed of the driven pulley, multiply the diameter of the driving pulley by its speed in revolutions per minute and divide the product by the diameter of the driven pulley.

Example:

Speed of driving pulley = 800 rpm
Diameter of driving pulley = 18 inches
Diameter of driven pulley = 6 inches
Required speed of driven pulley
18 inchee x 800 rpm ÷ 6 inches = 2,400 rpm (calculated speed of driven pulley)

(2) The same formula is used for flat belts as for V-belts. Use outside diameter of pulleys.

b. Cleaning Procedures. The first step involves the selection of the type of cleaner best adapted to the equipment, assembly, or part to be cleaned and the kind of deposits to be removed. There is no one cleaner that will perform all cleaning operations. Because of the strong chemical action necessary to remove carbon, lacquer, etc., these cleaners often attack nonferrous metals. Others have disagreeable or harmful fumes and some irritate the skin. Some cleaners are flammable and must be used with extreme caution. In making up cleaner baths, or making subsequent additions with any solid type cleaner, care should be exercised to insure complete solution of the cleaner. This can be accomplished by adding the cleaner in small portions at different points in the tank, or by the use of fine mesh baskets hung from the sides of the tank. The action of a cleaner may be considerably accelerated by agitation and controlled heating of the solution. Agitation may be mechanical or by bubbling air or steam through the solution. Steam is very satisfactory and accomplishes a dual operation by both heating and agitating the solution. Since dilution will be experienced in using steam, the concentration of the solution will require more frequent checking. Mechanical agitation is the most effective and requires less time. Mechanically agitated tanks which are constructed in a variety of sizes to economically handle any cleening encountered are available. Since some cleaners decompose at higher temperatures and some are not effective unless held at a determined temperature, the manufacturer's recommended solution temperature must be maintained to obtain effective parts cleaning. In most cleaning operations, the quality of work obtained is determined, to a large degree, by the rinsing operations following the cleaning. Rinsing can be accomplished by spraying the part with hot water, steam jet, or by dipping in a rinse water tank. To temporarily prevent rusting, 1 to 3 ounces of water-soluble oil per gallon of water can be added to the rinse tank. The use of soft grit blasting has proven very successful and economical in some types of cleaning. The abrasive agent used with this equipment is either crushed corncobs or hardwood sawdust. Sand or metallic abrasive blasting is not recommended.

c. Flow of Sand. The flow of sand can be adjusted by a nut which moves an air nozzle either farther into, or out of, the sand trap. The sand control valve should be checked and cleaned annually or as conditions require. Inspect cup washer O-ring and composition rubber valve. Replace if necessary. Inspect sanding jets. Make certain they are not plugged. Examine vent port at bottom of actuating cylinder. Make certain it is not plugged. Check spring. Replace if weak. Clean all parts thoroughly and place a small amount of airbrake oil on the cup washer, O-ring, and composition rubber valve before assembly.

Section III. PAINTING, LETTERING, AND NUMBERING

210. When to Paint

a. General. The painting and stenciling of all railway equipment, including locomotives, is governed by AR 746-5. Locomotives, normally, will be repainted completely during the performance of depot maintenance. At other times, when the painted surface has deteriorated to such an extent that rusting or peeling is evident, equipment should be spot painted to prevent further deterioration and to provide a presentable appearance. It is the responsibility of the paint foreman to determine whether to paint over old paint or to remove old coatings. Military Specification, MIL-P-3321C governs painting locomotives.

b. Inspection. During monthly inspection of locomotives, condition of paint will be noted carefully and recorded. Records will include specific reference to any surfaces on which paint may have blistered, peeled, or otherwise deteriorated. By maintaining inspection records, it is possible to use a system of periodic spot painting which insures the retention of suitable protective coating on wood and metal surfaces and often avoids completely repainting a piece of equipment.

211. Safety

a. Safety Precautions.

(1) Respirators will be worn during all spray painting operations.

(2) Preparations containing benzol will not be applied by spraying (inhaling benzol fumes is extremely injurious to health).

(3) Cover lugs of pressure feed paint tank will not be loosened unless it is certain that pressure in the container has been released.

(4) Pressure feed paint tank safety valves will be tested regularly.

(5) Rubber gloves should be worn when handling sealer or acid solvents.

b. Causes and Prevention of Fire.

(1) Rags and waste are soaked with paint and oil are fire hazards and will be placed in standard, self-closing metal cans having legs at least 4 inches high to provide space for air circulation. Cans will be emptied at the end of each working day and contents removed to a safe place and destroyed. Trash and rubbish will be placed in covered metal containers which will be emptied daily and contents destroyed or stored in an isolated vault.

(2) Main stock of solvents, paints, and other flammable materials will be stored outside the paint shop in a separate inclosure. Cans containing paints, thinners, and other paint materials will be covered tightly before being stored or put away for

the night. The precautions outlined in Army regulations for the storage of gasoline will also be followed for paint, thinners, etc.

(3) Empty drums or other containers in which solvents, thinners, and similar materials have been shipped are potential hazards, since they often contain enough vaporized material of a flammable nature to cause an explosion. Heat or flame, such as used in welding or soldering operations, must never be applied to such drums or cans unless they are first steamed out thoroughly, filled with water, and inspected to insure that all traces of the odor of paint material are removed.

212. Preparation

a. *Surface Preparation.* Surfaces requiring repainting must be prepared in accordance with instructions contained in MIL-P-3321C. Competent supervision and inspection of this phase is mandatory since paint will not adhere uniformly to surfaces which are dirty or otherwise poorly prepared for applying paint. Immediately prior to painting, all surfaces will be clean, dry, and conducive to the best adhesion of the materials to be applied. Grease, oil, and other foreign matter will be removed. Extreme caution will be exercised when sandblasting locomotives to insure that sand does not enter bearings or contact surfaces to which it may be detrimental. Parts to be sandblasted will ordinarily be removed from locomotive. Old paint will not be stripped except where essential.

b. *Masking.* Glass surfaces, rubber components, valves, pressure gages, throttle and reverse levers, upholstered surfaces, dynamos, airpumps, packing, piston rods, valve rods, etc., will be masked or otherwise protected during spray painting.

213. Painting Procedures

a. Military Specification, MIL-P-3321C, a complete list of materiel approved for use on Army railroad equipment, also contains complete instructions for selecting approved materials, preparing (mixing), and applying paint to properly prepared surfaces of diesel-electric locomotives. This specification is to be used as a guide by personnel engaged in painting the above equipment. Paint will be applied with care and under competent supervision. For the protection of the surface, the first or priming coat is of the greatest importance, since corrosion or rot may spread rapidly under the paint film if the primer is improperly applied. All surfaces will be cleaned of loose paint, dirt, scale, grease, and rust before painting.

b. Steel surfaces, other than welded or hot-riveted surfaces, which are inaccessible after assembly will be given one coat of red lead before assembly. Wood surfaces which are inaccessible after assembly will be given one coat of synthetic primer prior to assembly.

c. Wood or steel sills, braces, posts, stringers, etc., which are exposed during repairs to equipment, will be brush painted or sprayed with one coat of synthetic primer.

d. Paint applied to trucks and component parts will be thinned out sufficiently so that detection of cracks or other flaws is not prevented. Parts contained in journal box will not be painted

e. Surfaces painted with red lead or zinc dust primer will not be primed with synthetic primer.

f. If engine or generator housings have been removed from the locomotive, they may be spray painted; if they are installed in the locomotive, they will be brush painted.

(1) Engine assemblies should be painted only after repair or rebuilding operations are completed and cylinder heads and crankcase or oil pan are assembled to the cylinder block.

(2) Mask all intake openings, filler pipes, and generator grilling if paint is to be sprayed. Exercise extreme care to prevent paint entering the openings or grilling if brush painting is done.

(3) Hose of adequate inside diameter must be used with paint spray equipment. In a great many instances, malfunction of the spray gun is due to an insufficient supply of air at the gun. This condition is usually caused by the use of improper size hose. A drop in pressure occurs whenever compressed air is transmitted.

214. Lettering Requirements

a. General. The primary purpose of lettering and numbering is to identify and classify equipment. Marking will be in clear-cut, properly located figures and will reflect the same high quality of workmanship comparable to that in the equipment itself. Distinction can be lent to an engineering design with letters and numbers of neatness and quality that contribute to the general appearance of the equipment. Even the roughest freight equipment will be given the highest possible degree of perfection in the balance, proportion, and design of its markings. Because in many instances letters and numbers are copied from the equipment by yard or train personnel at night and while the equipment is in motion, it is extremely important that letters and numbers be legible and correctly placed.

b. Lettering and numbering of Department of the Army railroad equipment will comply with requirements of AR 746-5 and MIL-P-3321C and in accordance with allocation of numbers for continental United States or theaters of operations. Letters and numbers will be in accordance with illustrations in this manual of the various types of equipment.

c. Letters and numbers illustrated in figure 96 are authorized for all railroad equipment and will insure uniformity in identification and classification labels. Style and proportion have been analyzed mathematically and geometrically in the drawings. Lettering and numbering on a locomotive are illustrated in figure 98. The Air Force insigna (fig. 97) will be of the dimensions given in paragraph 215.

d. Illustrations in this manual are presented as typical of the various types of equipment used by the Department of the Army. Marking arrangements, therefore, must be flexible to fit all types. On some equipment, it will be impossible to adhere strictly to size, arrangement, and location of markings; good judgement will be exercised in locating the elements to suit the construction of the equipment.

e. Information on the drawings will be shown in its entirety on the equipment in all cases. Information not shown on the drawings will not be added unless specifically authorized by the U. S. Army Materiel Command.

f. Marking on motive power equipment will have the position of its elements defined as related to the front and back ends, while markings on rolling stock will be arranged so as to present the same view when the car is seen from either side.

215. Lettering Procedures

a. All letters, numbers, and insignia on locomotives will be applied with white gloss enamel. One coat of yellow enamel will be used for safety markings which will be an alternate 4-inch black and yellow diagonal stripe as indicated in drawings. This stripe around the periphery on the bedplate will be no less than 2 inches in width. Safety markings will not be used in theaters of operations.

b. When necessary, due to the presence of louvers, vents, doors, etc., the size, arrangement, and location of markings may be revised to suit the construction of the equipment. However, deviations from figures 99 and 100 will be kept to a minimum.

c. Diesel-electric locomotives will be marked in accordance with figures 99 and 100.

(1) The locomotive number, in 7-inch figures, will be spaced properly and located centrally on right and left sides of cab.

(2) Locomotive number, in 7-inch figures, will be shown on front and back ends of diesel-electric locomotives.

(3) On equipment owned and operated by the Department of the Army,

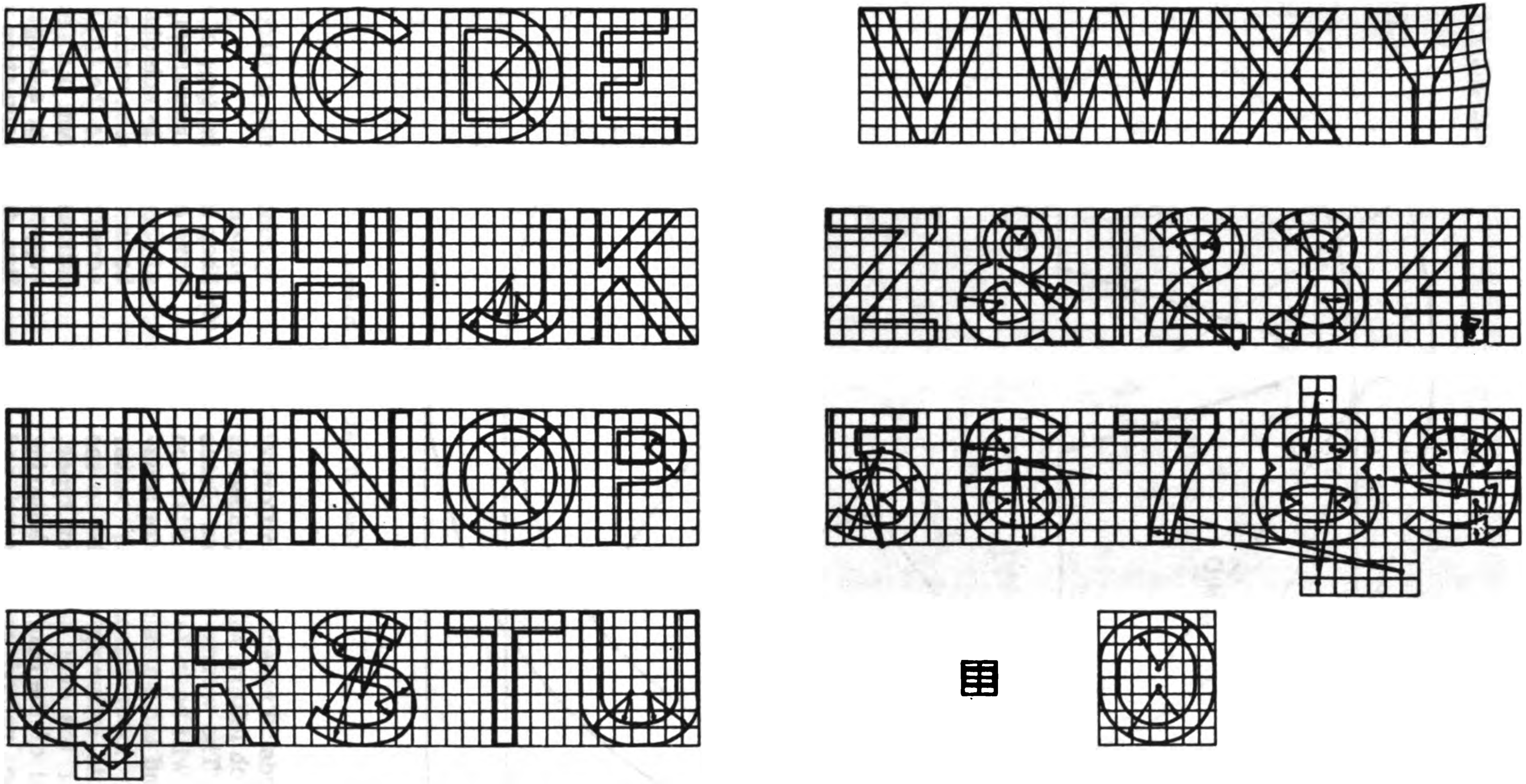


Figure 96. Standard letters and numbers.

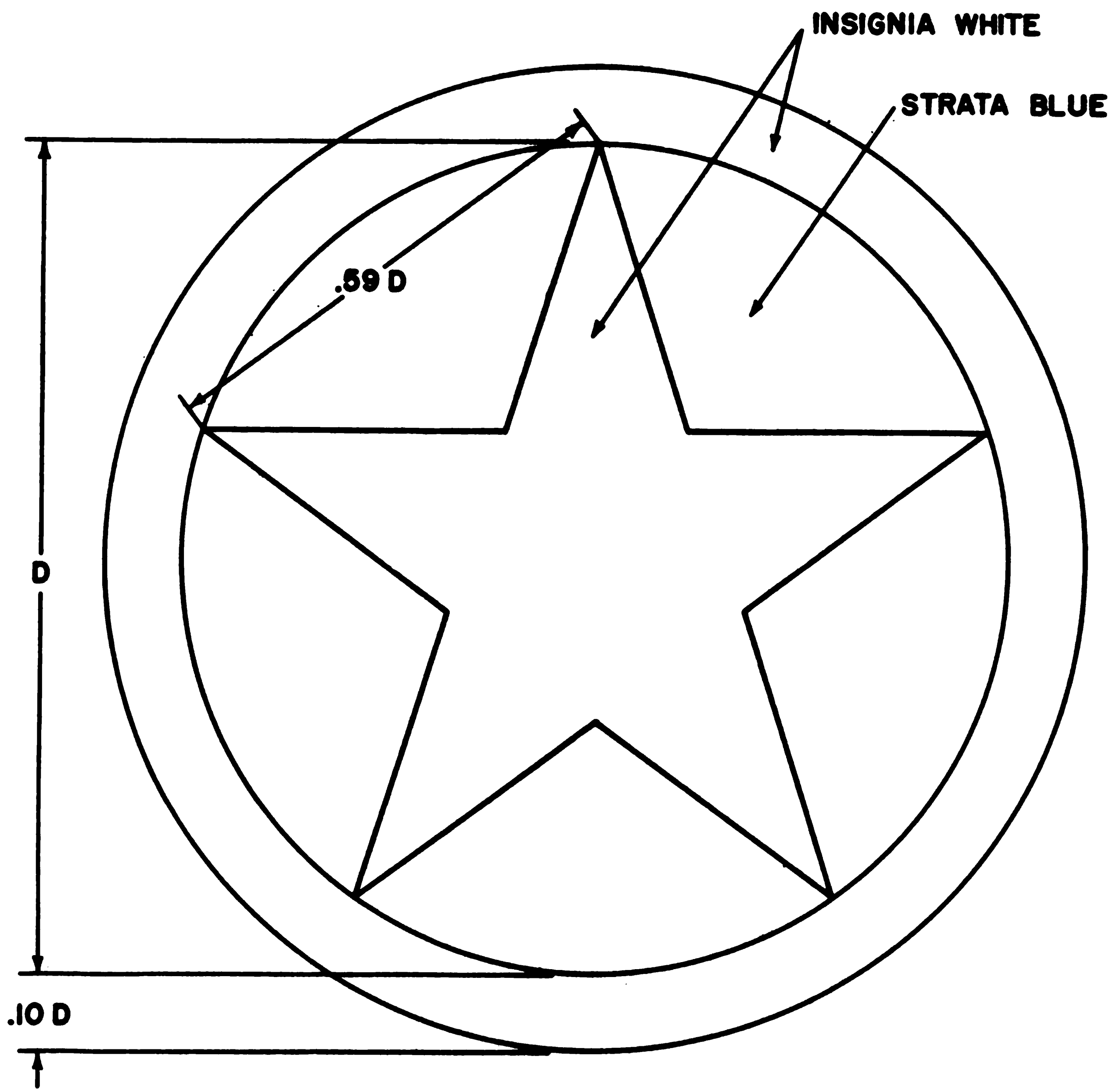


Figure 97. Air Force insigne.

the words "Transportation Corps" in 3-inch letters will be placed as shown. The words "United States Army" will be in 7-inch letters on right and left sides of motor housing; on locomotives with center cab, this lettering will be to the rear of the cab; on other types, forward of the cab. This lettering may be raised or lowered and spaced to suit grill openings inside plates.

(4) Shop initials, type of repair (category of maintenance), and date out of shop, in 1-inch characters, will be indicated on main air reservoirs according to the following conditions: When reservoirs are supported in a longitudinal position, the information will be shown

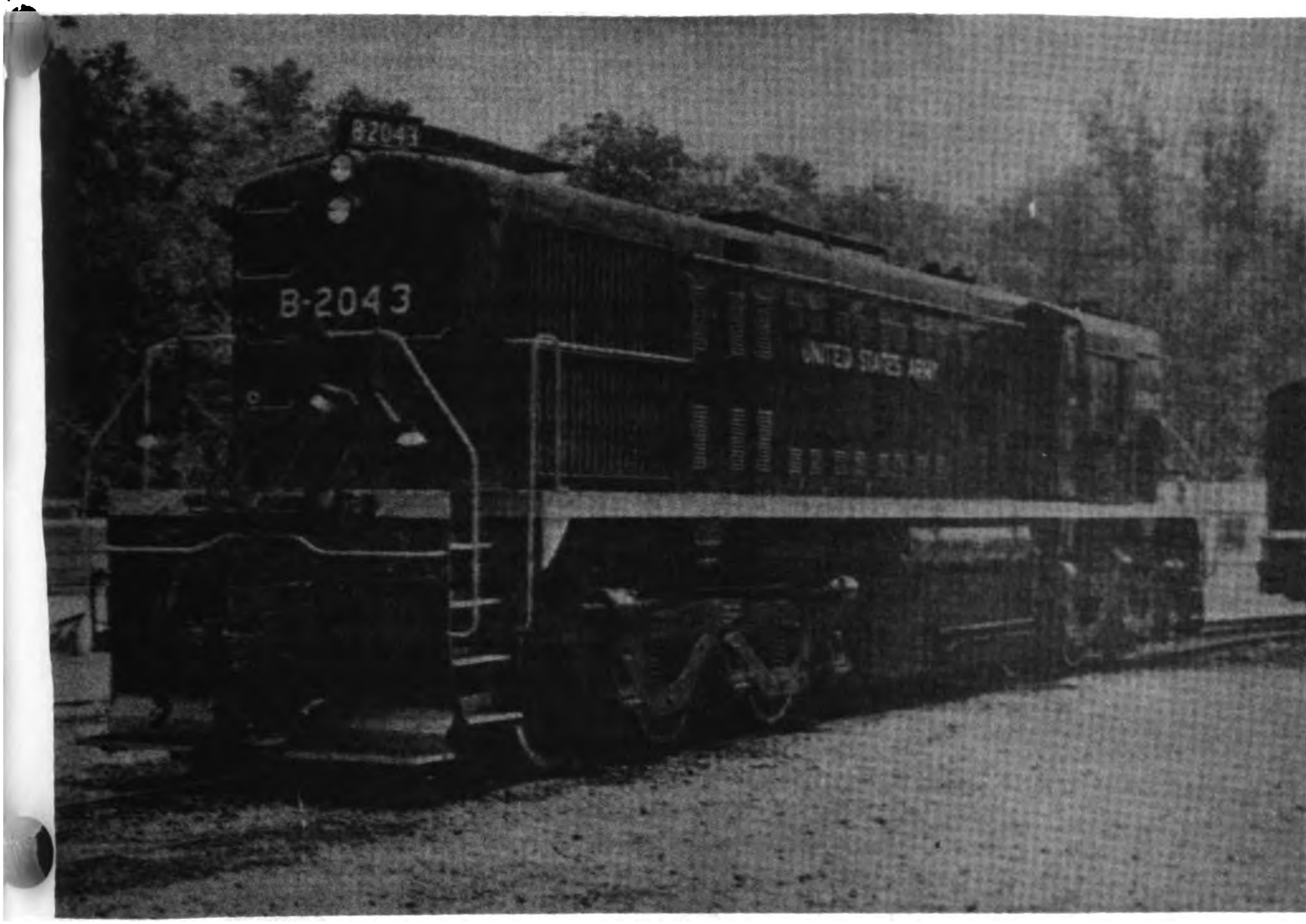


Figure 98. MRS-1, diesel-electric locomotive.

on left main air reservoir only, near the forward end; when reservoirs are supported in a lateral position, the information will be shown on rear reservoir, near its left end, where the data can be readily seen from left side of locomotive.

Example:

M.S. B-1-6-65

In theaters of operations, shop initials will not be shown.

(5) Test pressure in pounds per square inch on top line, shop initials and date of hydrostatic test on second line, in 1-inch characters with 1-inch space between lines, will be applied to each main air reservoir according to the following conditions: When reservoirs are supported in longitudinal position, the information will be applied near rear ends; when reservoirs are supported in a lateral position, the information will be applied to reservoirs near left ends where it can be readily seen from left side of locomotive.

Example:

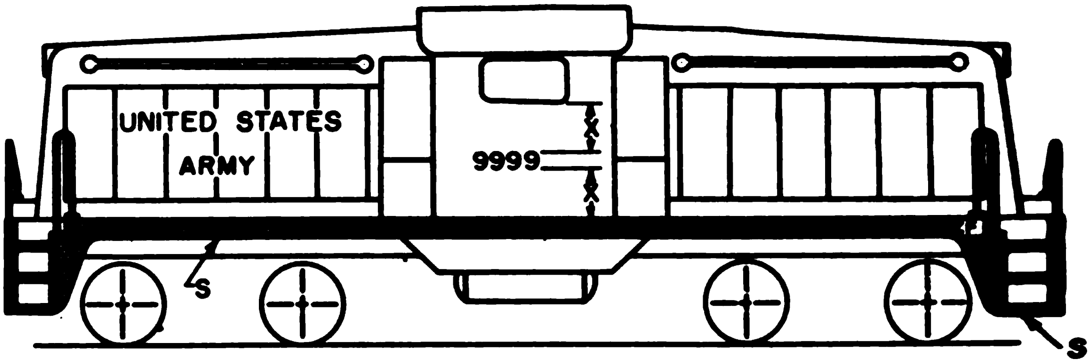
Tested 190 pounds
M.S. 1-6-65

In theaters of operations, shop initials will not be shown.

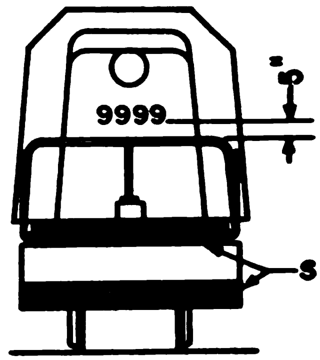
(6) Shop initials, HT (hammer test), and date of hammer test, in 1-inch characters, will be applied to each main air reservoir below the two elements required in (5) above.

Example:

M.S. HT-7-6-64



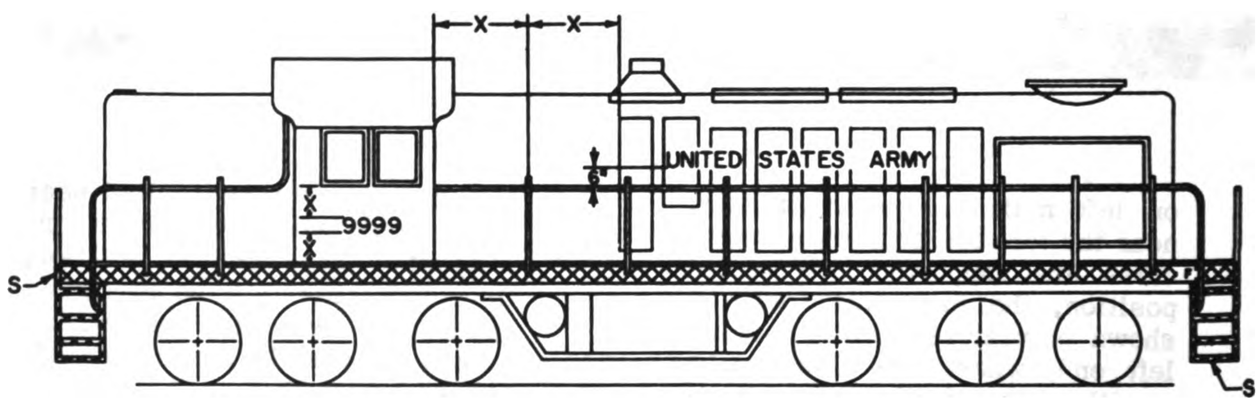
MARKING	HEIGHT-INCHES
UNITED STATES ARMY	7
LOCOMOTIVE SERIAL NUMBER ON.	
CAB	7
FRONT	7
BACK	7
LETTER "F"	4



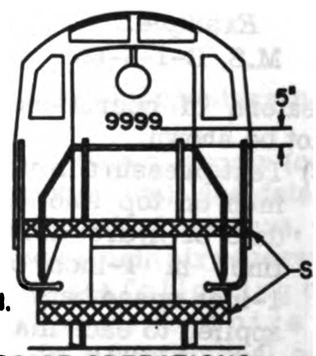
NOTE-"X" INDICATES DIMENSIONS OF MARKINGS ARE CENTERED AS SHOWN.
"S" INDICATES SAFETY MARKINGS.

SAFETY MARKINGS WILL NOT BE APPLIED IN THEATERS OF OPERATIONS

Figure 99. Markings for diesel-electric locomotive with cab in center, CONUS and theaters of operations.



MARKING	HEIGHT-INCHES
UNITED STATES ARMY	7
LOCOMOTIVE SERIAL NUMBER ON	
CAB	7
FRONT	7
BACK	7
LETTER "F"	4



NOTE-"X" INDICATES DIMENSIONS OF MARKINGS ARE CENTERED AS SHOWN.
"S" INDICATES SAFETY MARKINGS.

SAFETY MARKINGS WILL NOT BE APPLIED IN THEATERS OF OPERATIONS

Figure 100. Markings for diesel-electric locomotive with cab to rear of center, CONUS and theaters of operations.

In theaters of operations, shop initials will not be shown.

(7) The letter "F" in 4-inch characters will be shown on each side sill near the end of diesel-electric locomotive which, for identification purposes, is designated as the front end.

PART SEVEN

DIESEL-ELECTRIC LOCOMOTIVE REPAIRS

CHAPTER 19

REPAIR FACILITIES

216. Classes of Work

a. General. Two classes of work are performed at diesel-electric locomotive shops. One is routine servicing and regular inspection; the other is maintenance and repair. The principal types of work and facilities are discussed below.

b. Routine Servicing and Regular Inspection. Routine servicing includes fueling; watering; sanding; addition of lubricating oil; and daily inspection and general check of condition of diesel engine or engines, electrical equipment, mechanical parts, airbrakes, and safety appliances, all of which are necessary to release the locomotive for its next run in road service or tour of duty in switching service.

c. Maintenance and Repair. Maintenance and repair includes inspection, lubrication, and all repairs or replacement of parts required as the result of continued operation or failures in service. Diesel motive power, except under special operating conditions, is maintained on a progressive or preventive basis rather than on a periodic basis of heavy overhaul characteristic of steam locomotive repairs.

217. Supplies

a. General. To expedite movement of repair parts and prevent serious motive power delays, the following information should be included when requisitioning or ordering parts for locomotive equipment:

(1) Military identification, type number of locomotive.

(2) The locomotive builder's name, model, and serial number. This usually is found on the brass nameplate located toward the front on each side of locomotive.

(3) The manufacturer's type or model and serial number of the mechanical unit for which the part or assembly is being ordered, such as engine, generator, compressor, fan motor, traction motor, etc.

(4) Specify part numbers and part names exactly as listed in parts book and/or DA supply bulletins. Part numbers vary for different equipment. Do not order by reference numbers on plates and be sure that the correct parts book is referred to. Failure to do this frequently causes errors in supplying desired part, with consequent delay in shipment.

(5) Specify exactly the quantity required. Do not order parts in sets. Assemblies of parts will be listed in parts book or the supply manual with correct part number for assembly and name. The publication used will state specifically of what parts the assembly is comprised.

(6) When in doubt as to the part number and name, supply a sketch of the item required. Such a sketch should include general dimensions and a full description of the part. If a used or damaged part is supplied as a sample, it should be tagged "Sample of Part Ordered" stating on tag the name and address of sender and, when possible, the order or requisition number.

(7) State on order whether it is —

(a) Confirmation of telegraphed or telephoned order.

(b) Emergency order to be rushed.

(c) Unit exchange service.

(d) Stores' stock.

(e) Major repairs.

b. Checking Shipment. As notice of shortages, errors, etc., must be given within 10 days after receipt of shipment, the shipments received direct from the manufacturer or supply activity should be checked immediately.

c. Unit Exchange Service.

(1) Owing to the impracticability of making repairs to certain units because of their mechanical nature, some manufacturers maintain a unit exchange service whereby a used and faulty unit may be exchanged for a new or rebuilt unit. The following list contains some of the unit exchange items:

Main generator	Bosch pump
Main generator armature	Bosch spray nozzle
Exciter and auxiliary generator	Scavenging blower
Traction motor	Cylinder liner
Starting motor	Fan motor
Starting motor armature	Fan motor armature
Engine governor	Air compressor motor armature
Injectors	Air compressor governor
Fuel pump and motor assembly	Throttle control switch
Fuel pump motor	Compressor unloader pilot
Automatic chain takeup assembly	Supercharger
Load control unit	

(2) The instructions regarding the correct method of ordering parts apply in using this service and the words "Unit Exchange Service" should appear conspicuously on the requisition. Requisitions are submitted in accordance with AR 725-50 to the applicable supply source in conformance with current instructions of the managing activity responsible for each item. These activities, with identity codes, supply status codes, etc., and are listed in DA Supply Catalog SC 2200-ML, Management Data List. Locomotive accessories and components are classified FSC Class 2240, irrespective of the managing activity. See paragraph 192c.

CHAPTER 20
DIESEL ENGINE REPAIRS

218. General

a. The repairs ordinarily made on the diesel engine of a locomotive are those repairs required to keep the equipment in operating condition without the necessity of a major overhaul. Whenever the nature of the required repair necessitates considerable disassembly of the engine, all parts made accessible by such disassembly should be inspected and repaired or replaced.

b. The burden of preventive maintenance is placed with the using organization.

c. Direct support maintenance is performed by maintenance activities in direct support of the using organization. It consists primarily of repair and replacement of unserviceable parts, subassemblies, or assemblies.

d. The best detailed procedure to follow for any particular make of diesel-electric locomotive is governed by the applicable manual or the manufacturer's instruction book.

e. A stock of complete repair units of diesel engine equipment is maintained at depot maintenance repair shops to replace similar units removed from an engine for repairs and reconditioning. This interchange of units in reassembly of an engine prevents delay caused by waiting for repairs to be completed on individual parts and allows the different classes of repairs to be segregated and handled by specialized groups in the shop. Quantity production methods can, therefore, be employed in depot engine repairs.

219. General Repair Procedures

A given type of repair may be handled all at once, at extended intervals, or progressively during such intervals, depending on the amount of time available for the repair and the tactical situation. *For example,* if the part in need of repair can be replaced as a unit without deactivating the equipment, this course should be followed. If more extensive repairs should be required, the procedures outlined in depot maintenance instructions should be followed.

220. Run-In and Test of Repaired Engines

a. Each repaired diesel engine should be run in adequately before it is released for service. Time, fuel, and labor spent "breaking in" the engine will result in greater longevity and efficiency of the unit. A check is made of compression pressures in each cylinder; exhaust gas temperature for each cylinder at various engine speeds, lubricating oil pressures and temperatures, cooling water temperatures, supercharger or blower pressures, and horsepower output under varying conditions of current and voltage, as indicated by the main generator characteristic curve; individual throttle position speeds and loading; color and quality of exhaust gases; general sound and action of the engine under load and acceleration; and other indications of proper and improper operation.

b. A "liquid rheostat" or "water box" is a convenient testing device. It consists of two sets of plates in a tank, one set being stationary and the other arranged to be lifted out of the tank gradually. The tank is then filled with water. By connecting the diesel-electric generator to the rheostat, current may be passed from one set of plates to the other. The amount of current depends on what portion of the movable plates is immersed, thus varying the load imposed upon the engine. Other facilities for this work include a cylinder pressure indicator, either of the maximum instantaneous pressure or the curve drawing type, pyrometer and thermocouples, voltmeter and ammeter with shunt and the usual complement of pressure gages, and thermometers and temperature indicators which are a part of the regular engine equipment.

221. Load Testing of Diesel Motive Power

a. In addition to the run-in test of repaired engines, periodic inspections are necessary to keep the engine in condition to produce its rated power. By measuring the electrical output delivered to a "water box," the engine loading and capabilities may be determined accurately. The electrical characteristics of generators and motors do not change with age or use.

b. The following precautions and procedures are to be complied with when "load testing" locomotive powerplants. Since generator characteristics or "load setting" values are not the same for all locomotives, a separate generator loading curve sheet is used for each group of locomotives which have generators of similar characteristics. To determine what the loading values should be for any locomotive, refer to the loading curve sheet corresponding to the type or model of powerplant being tested. There are so many different wiring combinations of the many locomotives now in service that it would not be practical to refer to each locomotive. Use the proper locomotive wiring diagram to determine the necessary physical connection of meters and load cable connection. Safety of personnel and equipment cannot be overemphasized. After ammeters and voltmeters are properly connected, as directed in individual locomotive testing instructions, readings are taken at each throttle position for engine speed, field amperage, main generator amperage, main generator volts, auxiliary generator volts, pertinent readings of temperature and pressure gages in the oil and water systems, and related data.

222. Piston and Connecting Rod

a. *Interval of Inspection.*

(1) Pistons and connecting rod assemblies should be removed from diesel engines for inspection and repairs as follows:

(a) Cast aluminum pistons normally at 75,000 miles.

(b) Forged aluminum pistons normally at 85,000 miles.

(2) Pistons and connecting rod assemblies of diesel engines used in switching locomotives should be removed for inspection and repairs in accordance with special instructions covering each particular type of diesel engine, or whenever any defective condition is reported.

b. *Maintenance of Pistons.*

(1) Whenever a piston and connecting rod assembly is removed from a cylinder for repair, the first and second compression rings should be replaced with new rings.

(2) Pistons should be cleaned and inspected thoroughly for defects such as cracks in body of piston, broken ring lands, worn ring grooves, carbon in ring grooves, burned pistonhead, scored piston skirt, or any other defective condition.

(3) Piston pin and piston pin bearing should be removed and examined for wear, cracks, and chipped condition of hardened surface; any defect found should be corrected.

(4) Wear plate which fits over end of pin into piston must be oil pressure tight.

(5) Before pulling piston, remove any ridge on the liner with special reamer. When reamer is used, caution must be taken to prevent any chips from falling into the crankcase of the engine. Chips can be caught by inserting a cup in the cylinder, such as one made from a brake cylinder piston leather. The crankcase should be inspected after the piston is removed and any chips cleaned out.

(6) All cylinders and pistons must be measured to insure that proper size pistons and rings are being installed. For this reason, it is best to measure gaps of rings while holding them horizontally in

place in the liner instead of using ring gages at the bench.

c. Connecting Rods.

(1) Oil passages through connecting rod should be checked to make certain that they are open.

(2) Connecting rods should be cleaned and inspected for cracks. Any rods that are cracked, bent, twisted, or that have eye of rod worn so that bearings are a loose fit, should be replaced.

(3) Connecting rod studs, bolts, and nuts should be examined for defects. Replace studs, bolts, and nuts which have defective threads and replace nuts with bured slots. If piston seizure is experienced prior to removal of connecting rod stud or bolt nuts, remove cotter pins and check tightness of nuts to ascertain whether or not bolts have been stretched. If nuts are loose, new studs or bolts should be applied. Piston seizures may cause the stressing of bolts or studs beyond the elastic limits, in which case the bolts and studs are not safe for further operation.

d. Connecting Rod Bearings.

(1) The upper and lower halves of the connecting rod bearing should be given special attention; if there is any indication of pitting, shelling, flaking, scoring, excessive wear, or any other defect, the bearing should be replaced.

(2) In removing bearing shells, hammering or forcing should be avoided. The bearing face must not become scratched or the shell distorted; never strike or pry on the back of the shell as the contour may be distorted. The identification mark on the shell should be noted so that the shell can be replaced correctly, particular attention being given to lining up the oilholes.

(3) Periodic inspection of connecting rod bearings can be made without removing the piston and connecting rod assembly; this is done by blocking the piston in the top position, removing the lower half of the piston rod bearing, and backing the shaft away from the shell.

(4) When connecting rod assemblies are removed, the face and fillets of the crankshaft journal should be inspected for scored condition. If the crankshaft journal is found scored in the bearing area, smooth off all irregularities by stoning with a fine grit stone. Do not stone lengthwise or use a file. Check to see that the crankshaft is not out of round, then clean all parts carefully.

(5) Connecting rod bearings, whenever removed, should be examined for any defective condition, such as a distorted shell; cracked, scored, or shelled bearing metal; or uneven wear. Uneven wear is usually an indication of a misalined bearing and the cause should be determined and corrected. The bearing surface should be free of any dirt or grit. The two bearing halves must fit squarely and tightly together in order to prevent working in the rod and oil leakage through the joints. Bent or damaged bearing shells should be scrapped.

(6) If new bearings are to be installed, make certain that the oilholes and grooves are properly located with respect to the oil feed hole in the connecting rod and the oil feed hole in the crankshaft. When connecting rod bearings are in place, they should have proper clearance on the crankshaft journal. Their clearance should be 0.001 per inch of crankshaft diameter unless otherwise specified, and their thrust must be parallel with respect to the crank cheek or adjoining bearing and be free to move laterally with the crankshaft in any angular position. Connecting rod bolts should be tightened to the required torque specified by the

manufacturer or to proper bolt elongation or stretch.

(7) A bearing fitted in the above manner should give no appreciable break-in trouble, but in all cases after assembly, it is advisable to make a running test before releasing for service. Idle the engine for 5 minutes and then stop and examine the bearings for any increase in temperature; feel the bearing shell directly. There should be no appreciable heat in the bearing shell after 5 minutes of running, but if there is, the bearing should be removed and the high spots relieved, then repeat the test. When inspection shows the bearings to be free of excessive heating, the engine can be placed in service under full load.

223. Crankshaft and Bearings

a. General. Performance of the crankshaft depends upon proper maintenance of main and connecting rod bearings. Under normal conditions, bearings receive ample lubrication by means of the forced lubrication system built into the engine; proper alinement normally is assured by the rigid engine frame and method of mounting bearings. However, misalinement may occur if one or more bearings are permitted to wear unduly.

b. Alinement. It is important that the main crankshaft bearings be maintained in perfect alinement. If one or more of the bearings become low, the span between the bearings actually supporting the shaft will be increased and this will introduce heavy stresses in the crankpins; if this condition is permitted to continue, it will result in a main crankshaft bearing failure. There are several ways of checking the bearings. One method follows:

(1) Locate crankpin at upper dead center and force the shaft down to a firm seat in the bearings. Remove the valve levers and connect an airhose to a T at the indicator cock connection. Provide a pressure gage on the cylinder head side of the T. Lock flywheel from turning and maintain air pressure in the cylinder at 125 pounds or more by regulating the valves located on the inlet side of the T. Measure distance between gage points on crank cheeks with micrometer or strain gage.

(2) Locate crankpin at lower dead center and again force the shaft into the bearings as above. Measure distance between the same gage points.

(3) Measure distance between gage points for the two opposite horizontal positions; do not use air pressure in the cylinder.

(4) When the bearings are in line, all measurements will be the same. If the measurement test 1 is larger than test 2, bearing on one side of the crank is low.

(5) Apply same inspection method to adjacent cylinders. Comparison of measurements will indicate which bearings are out of line; alinement should be corrected.

(6) When assembling main bearings and whenever parts removal conditions permit, examine all grooves and oilholes in connections through frame and crankshaft in order to make sure these passages are clean and free of obstructions.

c. Removal and Inspection.

(1) In most diesel engines, the top bearing shell is removable with the top cap and the lower shell is rolled out of or into position by the crankshaft. Unless bearings are at opposite ends of the engine, they should be removed one at a time in order that the crankshaft may be held in position. The shell should be rolled out of and into position with the same directional rotation of the crankshaft; mark the bearing when removed in order that there will be no mistake as to its original position.

(2) The face and fillets of a crankshaft bearing journal should always be inspected for scored condition when the bearing is removed. If any of the shaft journals in the bearing areas are scored, all irregularities should be smoothed out by stoning with a fine grit stone around the periphery of the journal; do not stone lengthwise or use a file. All parts should be cleaned carefully.

(3) Main crankshaft bearing failures often are caused by crankshaft misalinement or flexing; this, in turn, can be traced to a low or misalined bearing resulting from a loose or distorted bearing support or a cracked engine frame. Bearing supports should be tight and in perfect alinement before a shell is installed. If inspection shows that the bearing support strap has closed or is out of line, than it should be removed for correction or replacement. The engine frame should be inspected carefully for cracks and the support strap studs for fractures or looseness in the frame. If the support stud is fractured, it and the remaining ones at that bearing should be removed and replaced with new studs. The studs removed should be given a magnetic test to determine their exact condition. Before installing a stud, make certain that the threads at both ends are in good condition.

(4) Whenever a bearing is removed, it should be inspected carefully for any defective condition such as a distorted shell; cracked, scored, or shelled bearing surface; and for uneven wear. Uneven wear, normally, is an indication of misalinement and the cause must be determined and corrected. The position of the excessive wear will indicate whether it is out of line vertically due to a low bearing or horizontally due to a loose or closed bearing support strap. Bent or damaged bearing shells should be scrapped. Bearings showing excessive wear, whether the result of natural wear or from an abnormal condition, should be checked and renewed if the wear limit has been reached. When checking the wear on a bearing, the shell thickness should be measured with a micrometer at both sides and the bottom and at any other points showing wear. Limits are established also for thrust bearings and they should be checked accordingly. If any number less than a complete set of bearings is renewed, the shells applied must be scraped to within 0.001 inch of the same thickness as the adjoining bearings or of the old shell, provided the old shell was removed because of failure. Before attempting to roll a shell into place, remove any sharp edges on the shell back with a fine mill file.

d. Application.

(1) After the new shell is sized properly, it should roll into place freely. If difficulty is experienced, the shell should not be applied until the cause is determined and corrected.

(2) When installing a complete set of main bearings, a shell should be rolled out from one end of the engine and a new one installed, after which the shell at the opposite end of the engine should be removed and replaced with a new shell. In this manner, the crankshaft is kept in place while intermediate bearings are being changed; less force is thus necessary in rolling in the shells. When an intermediate bearing is rolled into place, there should be proper clearance on either side of the journal with no clearance between the support and the shell back.

(3) The upper shell should extend out of the cap 0.002 to 0.003 inch, thus allowing draw when the cap

and bearings are applied. With the cap tightened into place, it should be possible to get a 0.001- to 0.002-inch feeler gage between the cap and the lower support; this will prevent the bottom shell from working in the support. The jacks or cap bolts should be made tight, but excessive pressure avoided as this may distort the cap and shell. Connecting rod bolts should be tightened to the required torque specified by the manufacturer or to proper bolt elongation or stretch.

(4) With all the shells in place and the caps tight, the shaft should be rotated by hand to make sure that it is free. The engine then is reassembled, after which it is idled under its own load for a few minutes in order to locate any indication of localized friction. The engine then is stopped and one shell removed at a time and scraped if necessary. This operation is continued until all shells show a good bearing. Be certain that each shell is carrying its share of the load.

(5) After the bearing or bearings are fitted properly, subject them to the same test used for connecting rod bearings (para 222*d*(7)). In addition, after the bearing is refitted and given a proper idling test, further tests of 5-, 10-, and 15-minutes duration should be made. An application of electrical load against the engine also should be made.

(6) If a diesel engine is used on a switching locomotive, an additional test should be made consisting of light switcking duty for the first 8 hours followed by an inspection of the bearings at the end of the period.

224. Timing Unit Injectors

a. After the installation of injectors, they must always be checked and readjusted before the engine is run, since the compression ignition in each cylinder is governed by the injection of the fuel into the combustion chamber. To insure the proper timing of the injection, the plunger follower of each injector has to be adjusted to a certain position in relation to the injector body. An injector may be timed as follows:

(1) Set the throttle in the OFF position.

(2) Jack the engine over by hand or by air in the direction of rotation until the exhaust valves of the cylinder to be timed are fully open.

(3) Place the injector timing gage in the timing gage hose on the top face of the injector body.

(4) Rotate the timing gage to determine the lowest surface of the head that will just pass over the upper surface of the plunger follower guide.

(5) Adjust the injector rocker arm by means of the screw adjustment on the upper end of the push rod until the lowest surface of the timing gage head is just passing over the top face of the plunger follower guide. Tighten the locknut on the rocker arm shaft nuts. Recheck with the timing gage.

b. The amount of fuel injected into each combustion chamber is governed by the control rack position of the fuel injector. The maximum amount of fuel is injected when the rack is all the way in. No fuel is injected when the rack is all the way out. Bearing in mind that the injector racks must be completely in for maximum fuel injection, obviously, each rack should be initially adjusted as near as possible to this position. Each individual rack may be adjusted in or out relative to the other racks by the two adjusting screws on the rack operating levers.

225. Fuel Pump Timing Adjustment

a. When each cylinder has an individual pump, the pump is timed. All fuel pump timing adjustments are made at the factory for the initial assembly. Under normal operating conditions, it seldom should be necessary to make any changes in fuel pump adjustments. Changes in individual fuel pump timing adjustments should not be made until proper inspection has been made and it is determined definitely that the injector and such parts as fuel pump discharge valve, discharge valve spring, and plunger are in good working order, and fuel flow conditions are normal. Unsatisfactory operating conditions in the individual cylinders are usually traceable to the defects in the above parts. When these are corrected, operating conditions return to normal.

b. The engine should be operated at no load until it is warmed up to normal running conditions. Compression pressures, maximum cylinder pressures, and exhaust temperatures for all cylinders should be substantially the same under conditions of constant load speed, fixed timing, and constant water jacket temperatures. These conditions are the same for all cylinders, but exhaust gas temperatures at about full load vary more than 50° F. The injector nozzles should be inspected carefully and reconditioned as required. After it is established that these injector nozzles are in proper operating condition, the condition and performance of fuel pump discharge valve and spring assembly should be checked. This valve must function easily and seat tightly.

c. If the above procedure has not indicated the cause of the trouble, the fuel pump timing adjustment should be checked. If this adjustment is correct, the distance between the horizontal mark on sleeve and horizontal mark on window port in the pump body will the the same for all pumps when each plunger is at the bottom of its stroke. As the engine is barred slowly over in the direction of rotation, the mark on the moving sleeve in all of the pumps should be visible through the window port in the pump body for all positions of the total plunger travel. If the fuel pump timing adjustment is not correct, the correction should be made by adjusting the thickness of the shims. Variation in shim thickness raises or lowers the position of pump suction support for the individual pump. This alters the starting time relationship of that pump as compared to the other pumps.

d. If the above procedure has not corrected the trouble, the plunger and barrel or the complete pump assembly should be replaced. To do this, the engine should be barred over slowly until mark on sleeve for the pump on which work is to be done alines exactly with mark on window port in the pump body. Make replacements without changing position of pump camshaft. After the new parts are installed, the mark on sleeve should aline exactly with the mark on window port in the pump body. If they do not so aline, adjust thickness of shims or reset cam following adjustment so that alinement is obtained. The engine then is turned two full revolutions as a final check for this setting, after which the engine again is barred over slowly so that the mark on moving sleeve for all positions of plunger travel is visible through the window port in the pump body.

e. If individual pump timings are correct, equalization of load distribution between cylinders may be made by altering settings of pump rack adjustment screws.

226. Maintenance of Bosch Injection Nozzles

a. Checking Nozzles.

(1) Serious engine failures can be caused by fuel leaking into the crankcase. Caution must be used in tightening the following nozzle parts and inspecting and checking them for fuel leakage.

(a) If the nozzle holding nut is not tight, it will leak large amounts of fuel into the combustion chamber. This raw fuel will flow down past the piston into the crankcase lubricating oil.

(b) The spring guide holding nut and locknut must be tight. If they are not, the fuel will seep out onto the cylinder head and drain back to the crankcase.

(c) The fuel leak-off stud must be tight and also the nuts holding the

injection and overflow pipes to the holder. These two nuts should not jam against the nipples before they tighten their respective pipes; if they do so, the nuts must be ground off.

(2) When installing fuel pipes, the pipes should not be sprung to catch the nuts. If the fuel pipes do not line up with their connections, they must be bent slightly. However, the pipes should not be bent enough to weaken them. The fuel pipes must be securely clamped to prevent any vibration or chafing.

(3) Nozzles on switching locomotives should be tested and checked once each year.

(4) Smoky exhaust and engine pounding will occur if a nozzle valve sticks in the nozzle. The defective nozzle can be located by cutting out cylinders in rotation; it should be changed as soon as it is isolated.

(5) The opening pressure of injection nozzles may be checked by a nozzle testing device (fig. 101) which utilizes a spare pump to develop the injection pressure as follows:

(a) Attach spare pump securely to the injection tube on the test rack. Set the fuel pump rack at 20-mm travel.

(b) Test the nozzle by pumping the lever steadily until fuel discharges, and note the pressure indicated on the gage. The maximum pressure noted on the gage at each stroke is the opening pressure of the nozzle. Do not operate the lever quickly as this will cause extremely high pressure to be built up, giving an unreliable gage reading.

b. Checking Pressure.

(1) Check the pressure against the manufacturer's pressure specification and readjust the nozzle if necessary. The adjustment is made by turning the pressure adjusting screw on top of the nozzle holder; this screw should be turned slightly in the necessary direction and the new setting tested. Proceed in this manner until the correct setting is reached.

(2) After the nozzle assembly is set at the proper opening pressure, set the fuel pump rack at the limit of its travel, or approximately 50-mm, and operate the test rig to see if the nozzle operates properly. Also check to see if there is any afterdribble. If any faults are detected, inspect the nozzle and remedy the defect.

227. Fuel Pump Calibration

a. The fuel injector nozzle spray pattern should be checked after cleaning any type of fuel injector to determine that spray outlets have been properly cleaned and that spray angles are correct and uniform. A calibrating stand enables maintenance personnel to test the efficiency and adjust the calibration of used and overhauled fuel injection pumps with greater accuracy. A reversible constant speed electric motor is used to operate the equipment. The cam in this test stand (fig. 102) has two distinct profiles. When operated in the forward direction, its actuating profile is the same as the cam in the production engine. This direction provides fuel injection characteristics of full fuel conditions at maximum rpm. When the cam motion is reversed, the actuating profile which normally was used for deceleration on production engines has been altered so that the cam will give the fuel pump the same injection characteristics as at idle speed. To conduct the flow of fuel under pressure from the injection pump, a standard injection tube is used together with a special calibrating nozzle and holder. After the oil is discharged from the nozzle into the discharge chamber, it flows into a tube from which it can be directed either into a graduated beaker or returned to the storage tank by means of a three-way valve (TM 55-1277).

b. To measure the flow of fuel, it is necessary to know the number of pump strokes as well as the quantity of fuel for the position desired. A direct revolution

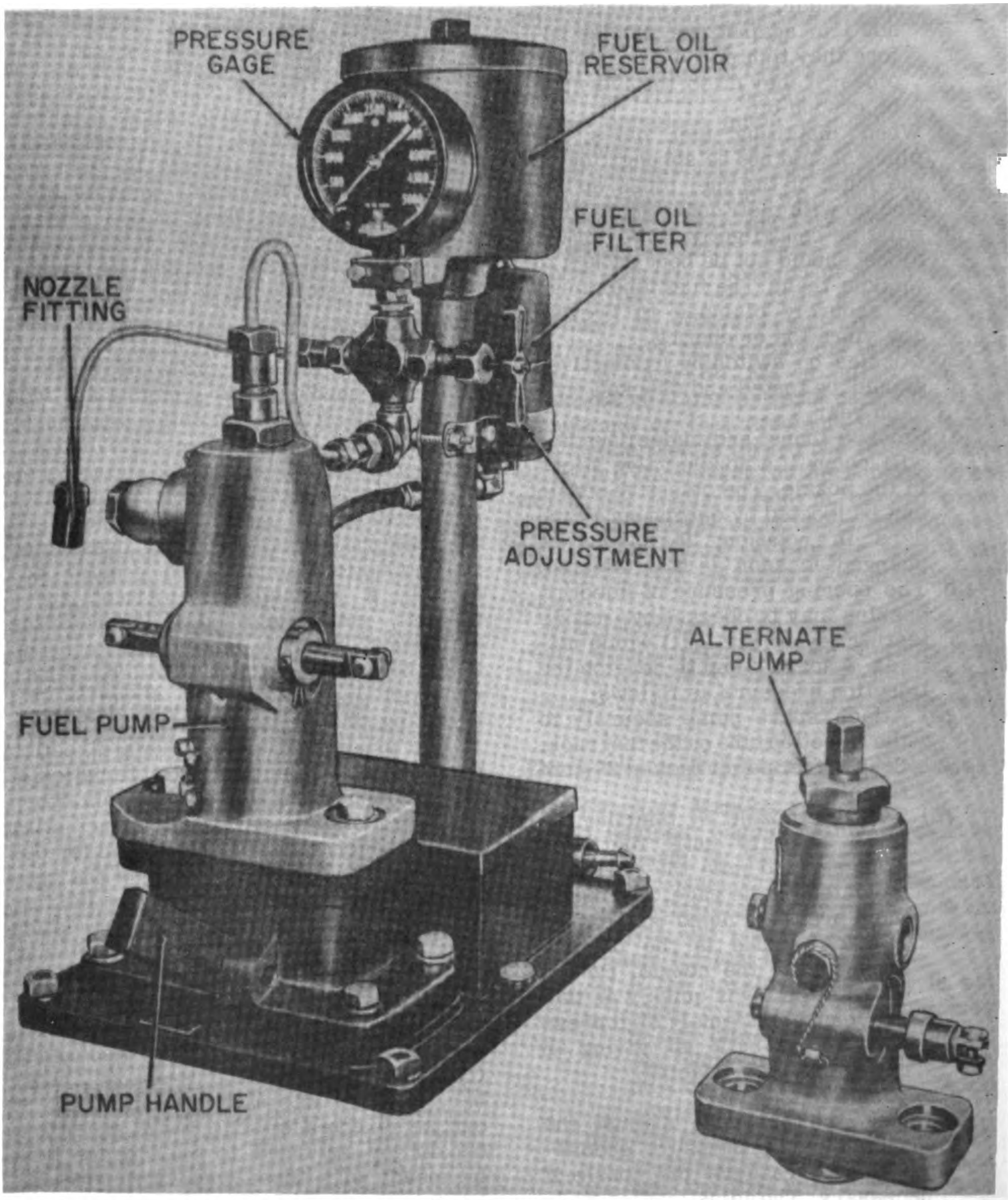
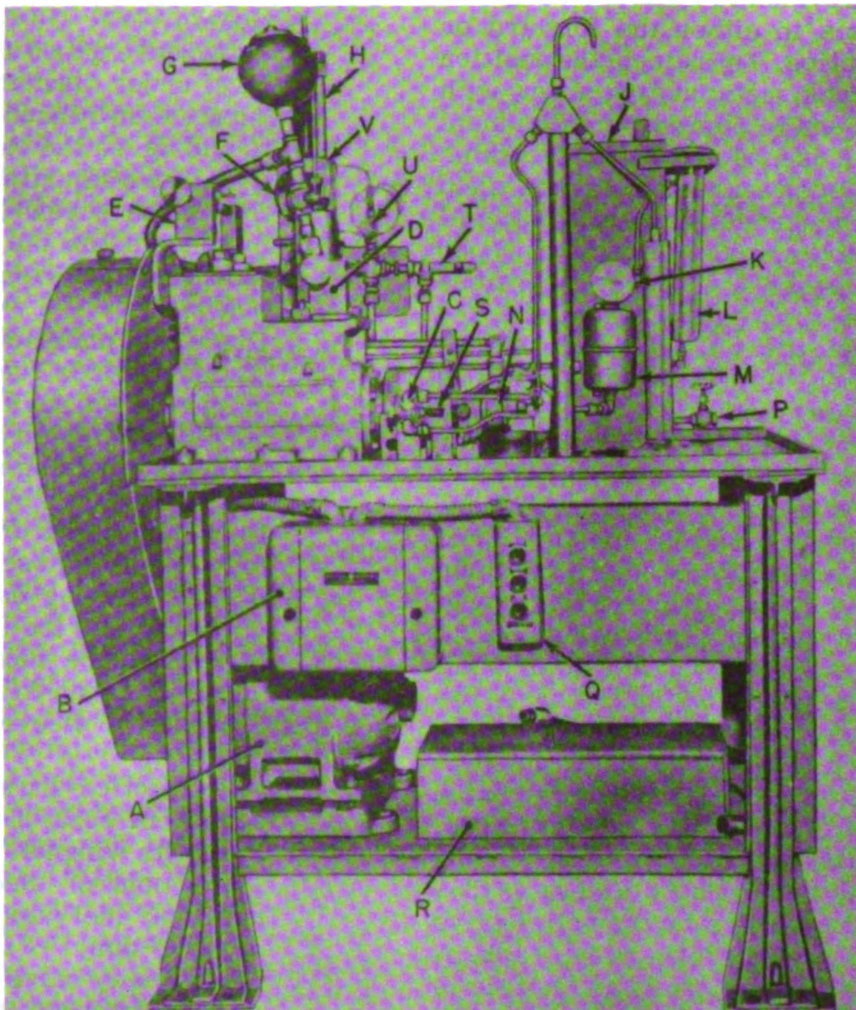


Figure 101. Injection nozzle testing device.



A MOTOR
B CONTROL PANEL
C THREE WAY VALVE
D CONTROL SLEEVE ASSEMBLY FOR "CC" PUMPS
E CONTROL SLEEVE ASSEMBLY FOR "D" PUMPS
F PRESSURE GAGE
G ACCUMULATOR
H CALIBRATING NOZZLE
J STORAGE TANK
K FUEL GAGE
L GRADUATED BEAKERS
M FILTER
N FUEL OIL PUMP
P TANK DRAIN VALVE
Q CONTROL SWITCH
R TOOL BOX
S COUNTER
T PRESSURE REGULATING VALVE
U PRESSURE GAGE VALVE
V NOZZLE RESERVOIR

Figure 102. Fuel pump calibration stand.

counter is provided to measure the number of strokes in either the forward or reverse direction. To indicate the position of the fuel rack, an adjusting screw with a ball socket end to correct for alinement is provided. It is mounted in a sleeve which is notched in such a manner that the fixed positions of the rack, namely: idle, full fuel, and off, are maintained in their proper relationship. After any of these positions are adjusted by the adjusting screw, the screw is locked to the sleeve and the sleeve and screw then move as a unit known as the control sleeve unit. The other parts of the equipment function to provide for proper support, filtering, and return of fuel oil to enable continuous operation. The entire assembly is self-contained and supported on a specially constructed table approximately 3 feet high and 3 feet long. The top of the stand has a welded pan to catch excess leakage while a lower shelf serves as a support for the motor. A reversible pump draws the fuel from the storage tank through a filter mounted on the stand. Filtered fuel is delivered to the injection pump through a flexible hose, relatively constant fuel pressure being maintained by a pressure relief valve (35-40 psi). Fuel bypassed by the relief valve is returned to the fuel storage tank. A special calibrated pump and nozzle is available for checking the operation of a new calibrating stand. This pump and nozzle should be cared for as a master gage and used only when doubtful of correct calibration figures. Apply caps or dustproof bags to the open connections on both the pump and nozzle; cleanliness cannot be overemphasized.

c. A suggested calibration procedure is as follows:

(1) Remove fill plug on cam housing and check quantity of lubricating oil. The supply should be such that oil will run from this hole. The same grade of lubricating oil is used as in the diesel engine.

(2) Check quantity of calibrating oil in storage tank maintaining level above low level mark indicated on tank level gage. Use only clean fuel oil in accordance with specifications.

(3) Make sure graduated beaker is level under discharge pipe.

(4) Rotate cam by hand until cam roller is riding on the base circle of the cam. Turn adjusting screw until the top of the screw is the specified distance below the top of the pump mounting surface and secure locknut.

(5) Place fuel pump to be tested on cam housing; place fuel rack between compression spring and adjusting screw and tighten down.

(6) With pump timing window exposed, rotate camshaft by hand to be sure the timing mark does not go out of sight of the exposed area.

(7) After removing caps or dustproof bags, connect the flexible hose and high-pressure tubing to the pump and from pump to nozzle.

(8) Set control sleeve unit at full fuel position.

(9) Set injection pump by adjusting screw in control sleeve unit and lock with wingnut.

(10) Move control sleeve unit to idle position; fuel pump pointer should read 11-mm.

(11) Move 3-way valve so fuel will flow into fuel storage tank (vertical position).

(12) Open valve to fuel injection pump.

(13) Place control sleeve unit in OFF position and start electric motor (forward button).

(14) Check for leaks.

(15) Move control sleeve unit to FULL FUEL position.

(16) Operate test stand for several minutes to insure a steady flow of oil from the nozzle chamber into the fuel tank. It is important that the temperature of the calibrating oil reach 100° to 110° F. (as indicated by the thermometer in the fuel storage tank) before any tests are performed.

(17) Place the graduated beaker in position, note count on the counter, and pull 3-way valve handle with a

snap (toward operator—horizontal position) so that the flow starts into the beaker.

(18) After 300 strokes have elapsed as determined by the counter, push the 3-way valve handle to the extreme back position so as to interrupt the flow to the beaker. This may take several attempts before the operator can perform this operation with accuracy.

(19) Accurately read and record fuel in beaker.

(20) Stop motor and place control sleeve unit in IDLE position.

(21) When motor has stopped turning, start motor in reverse direction (reverse button) and repeat items 17, 18, and 19. It is important to run IDLE FUEL test immediately after FULL FUEL test as any great variation of calibrating oil temperature will affect test results.

(22) If a pump fails to come within the specified calibration limits, the motor should be stopped, the control sleeve unit moved to FULL FUEL position, and the motor started again in forward motion.

(23) The adjusting screw is turned either in or out to obtain more or less fuel and make a test run with the wingnut tight until the required amount of oil measured in the graduated beaker is within the limits.

(24) When the limits are reached, the fuel pump pointer must be shimmed to read 24-mm.

(25) Rerun the IDLE position and check idling limits. Sometimes it may be necessary to shim the pointer at the FULL FUEL position either on the high or low side in order to bring the IDLE position within the idling limits.

(26) Move the control sleeve unit to OFF position and pull the 3-way valve to the horizontal position. No fuel should flow at this position with the stand operating. This is an assurance test to make sure the pump will not deliver oil when in the OFF position.

(27) If the calibration limits are not obtained, it is then necessary to dismantle the pump and renew the delivery valve assembly, the plunger and barrel, or possibly the pump rack and its bushings. Any of these items or any combination may provide the needed correction. This correction may be determined by observation or by experiment with the items noted above in the order named. After this work has been done, the pump must be recalibrated.

(28) After the pump has been calibrated and the shims have been changed at the pointer, place pump on calibrating rack gage to correct for the change of the rack length. Apply gage pin in pump rack clevis.

(29) If the reading at the pointer is not proper, adjust the rack length by first unlocking and removing the rack sleeve at the clevis end. Loosen the locknut and turn adjusting nut until a reading is indicated by the pointer. Reapply sleeve and relock. Do not change shims at pointer to obtain this setting.

(30) On the machined surface of pump rack boss, opposite the clevis end, stamp the total thickness of the shims used in back of the pointer, deleting all remaining figures. For example, a stamping of 0.092 will indicate that the thickness of shims beneath the pointer is 0.092 inch.

(31) When the calibrating stand is not in use, fasten cover to oil storage tank securely in place, protect exposed ends of flexible hose and high-pressure tubing by caps or dustproof bags, empty graduated beakers and hang on rack in an inverted position to drain, and close globe valve and 3-way valve. Cover the entire stand with a canvas or hood to protect it from dust and dirt.

228. Lubricating Oil Pump Drive Assembly

a. *General.* The lubricating oil pump drive transmits rotary motion from the crankshaft to the lubricating oil pump. This rotary motion is transmitted to the pump in the following manner: The head of the drive pin which serves as a crank is positioned between two hardened steel buttons which are fitted to a pair of lugs on the face of the crankshaft bearing ring. As the crankshaft revolves, the head of the drive pin is carried with it causing the horizontal shaft of the drive assembly to rotate. The drive gear which is meshed with the gear on the vertical shaft causes this shaft to turn. A spline coupling connects the vertical shaft to the pump drive shaft.

b. Mounting the Assembly. When the drive and pump assemblies are completed and ready for mounting on the end cover of the main base, gaskets are fitted to the mounting flange of the drive assembly and to the distance piece located between the pump suction flange and the end cover. This distance piece is ground to suit each installation and must not be interchanged with those of other units. When mounting the completed assembly on the end cover, the mechanism should be tested for freedom as the bolts are tightened. This can be done by inserting the hand through the inspection ports provided in the drive casing.

c. Lubricating Oil Supply. Lubricating oil is supplied to the drive assembly by a tube leading from the main lubricating oil header of the engine. This tube is connected to a passage in the casing which communicates with a circumferential groove machined in the outer diameter of the upper section of the vertical shaft bushing. From this groove drilled passages in the bushings, shafts and casings conduct the oil to the bearing surfaces.

d. Inspection and Reassembly. All parts of the oil pump drive assembly may be inspected and the various clearances checked through the openings provided in the casing. If the drive must be disassembled for any reason, the following will serve as a guide in reassembly of the parts:

(1) Fit the vertical gear to the gear shaft bushing with a diametrical clearance of 0.003 inch and an end play of 0.008 inch. (The latter clearance is obtained by scraping the end faces of the bushing.)

(2) The case-hardened collar is then to be fitted to the shaft, dowelled and secured in place by the lockwasher and locknut.

(3) Install the gear shaft and bearing assembly in the casing and secure in place by means of the lock screw.

(4) Install the horizontal drive shaft end bushing.

(5) Scrape the horizontal drive shaft bearing until a 0.003-inch feeler can be inserted between the bearing and shaft.

(6) Fit the drive gear key in the keyway provided in the horizontal shaft.

(7) Place the drive gear in the bearing and press the horizontal shaft in the gear until the latter is hard up against the boss.

(8) Check the thrust of the horizontal shaft which should be a minimum of 0.0015 inch.

(9) Fit the bearing flange tooth housing and secure it with the bolts provided.

(10) Check the backlash of the gears which should be about 0.006 inch.

(11) Remove the bearing and drive shaft as a unit from the housing and by means of the lockwasher and locknut provided for this purpose; secure the gear in place on the drive shaft.

(12) Install the drive pin in its tapered and dowelled fit in the head of the drive shaft and secure it by means of the drive pin nut.

(13) Reinstall the completed drive shaft and bearing assembly in the casing and secure by means of the bolts provided. Lock the nuts by wiring them together with soft iron wire.

(14) Check the assembly shafts for freedom.

(15) Slip the spline coupling on the vertical shaft and pin it in place with a cotter key.

(16) With the pump cover flange gasket in place, bolt the pump to the drive

casing and check the shafts for freedom.

(17) With the large drive casing flange gasket in place, position the spacer between the pump and cover and mount the assembly.

(18) Check the shafts for freedom as the mounting flange bolts are taken up.

(19) Install the lubricating oil lines and the inspection port covers, completing the assembly.

CHAPTER 21
OTHER MECHANICAL REPAIRS

229. General Repair Procedure

a. Other mechanical repairs include all nonelectrical work not previously described in this manual in the chapters on running maintenance and diesel engine repairs. Such items of auxiliary equipment as the traction motor blower, belts, feed water pump, fuel pumps, and the various control switches, relays, and protective devices should be removed for cleaning, calibration, or adjustment or replaced with completely reconditioned units. Fuel, water, and steam lines should be cleaned and all valves inspected and repaired.

b. Repairs to the air compressor consist principally of thorough cleaning, reringing of high- and low-pressure pistons, renewal of valves including unloader valves, and other needed corrections or renewal of defective parts. The bearings of the air compressor crankshaft should be inspected and replaced if necessary; unless bearing trouble was experienced, the crankshaft will require little or no attention for extended periods.

c. Trucks should be removed and dismantled completely. Truck frames, brake rigging, equalizers, and other mechanical parts should be inspected and cleaned; equalizers should be tested with the magnetic tester. Pins and bushings should be renewed if necessary and wear plates built up or replaced. Journal boxes should be dismantled and cleaned. Roller bearings should be checked and cleaned or renewed.

d. Wheels and axles should be inspected and turned or renewed if necessary. If the wheels are to be renewed, the axles should be tested by the magnetic method after the wheels are removed. Motor mounting and axle bearings and caps should be given necessary repairs and axle gear should be inspected. Brake cylinders should be cleaned and lubricated in accordance with standard practice and slack adjusters should be checked. The complete airbrake equipment of the locomotive should be inspected and repaired. Wheel mounting pressures referred to in table 4 must be used when pressing wheels on axles.

e. Sanders will be checked before each trip to see that they operate properly. The sand control valve should be checked and cleaned annually or as conditions require. Inspect cup washer, O-ring, and composition rubber valve. Replace if necessary. Inspect sanding jets. Make certain sanding jets are not plugged. Examine vent port at bottom of actuating cylinder. Make certain it is not plugged. Check spring and replace if weak. Clean all parts thoroughly and place a small amount of airbrake oil on the cup washer, O-ring, and composition rubber valve before assembly.

f. If the locomotive is equipped with a train-heating boiler (steam generator), it should be replaced with a reconditioned unit or be repaired for the next period of operation. Maintenance will consist of removal of coils for cleaning, testing, and replacement if necessary; removal and reconditioning of the burner element; removal of firebox section; and cleaning the steam separator and water treatment tank.

g. The cab, including safety appliances, warning devices, windows, window wipers, seats, armrests, and doors should be inspected and repaired.

Table 4. Wheel Mounting Pressures in Tons

Minimum and maximum pressure limits are absolute – no tolerance permitted

Class of axle	Journal size	Nominal wheel seat diameter	Cast iron wheels		Steel wheels	
			Minimum	Maximum	Minimum	Maximum
A	3 3/4 x 7	5 1/8 in.	30	55	50	70
B	4 1/4 x 8	5 3/4 in.	35	60	55	80

Table 4. Wheel Mounting Pressures in Tons—Continued.

Class of axle	Journal size	Nominal wheel seat diameter	Cast iron wheels		Steel wheels	
			Minimum	Maximum	Minimum	Maximum
C	5 x 9	6 1/2 in.	40	65	70	100
D	5 1/2 x 10	7 in. .	45	70	75	110
E	6 x 11	7 5/8 in.	50	75	80	120
F	6 1/2 x 12	8 1/8 in.	....	....	85	130
		8 3/4 in.	....	....	90	140

230. Packing Journal Boxes

a. *General.* Locomotive journal boxes may be packed with conventional waste as described and illustrated herein, or by use of AAR conditionally approved mechanical journal lubricating devices. The procedures applicable to all Department of Defense railroad equipment and the names and Federal stock numbers of journal lubricators applicable to the several journal sizes are contained in DA Technical Bulletin 55-2200-205-25/1. New waste should be treated prior to use to remove excess lint and any foreign matter prior to saturation. Waste journal packing may be made from all new, all renovated, or a mixture of new and renovated waste and oil. New waste should be mixed with old waste, on a 50-50 basis, prior to saturating. Practices prescribed herein are based on current AAR lubrication manual procedures, cited in the above technical bulletin.

b. *Preparation of Packing.* The waste must be loosened thoroughly, placed in a saturating vat, and kept completely submerged in the oil at a temperature of not less than 70° F., for a period of at least 48 hours to insure proper saturation. Then, it must be drained to remove excess oil and leave the packing in a resilient or elastic condition. Oil should not drip from drained packing when lifted from drain rack, but oil should flow from it when squeezed in the hand. Any process of saturation that will accomplish the equivalent result may be used. Packing being currently used from vats or other containers must be turned over at least once every 5 hours (more frequently if necessary), or the oil which is accumulated in the bottom of the container must be drawn off and poured over the top of the packing. Stored packing, awaiting use, must be kept in containers with tight-fitting lids to prevent contamination.

c. *Inspection of Journal Boxes.* Before packing a journal box, the interior must be cleaned of all dirt, sand, scale, and grit, and the front of the box as well as the inside of the lid must be wiped off. Remove water if present. The same treatment must be given new or replaced boxes, including the dust guard wells; and close fitting dust guards, dust guard plugs, and box lids complying with specifications must be installed. Boxes must be inspected for cracks which might cause oil leakage. Journal boxes are described in paragraph 126.

d. *Application of Packing.* Apply sufficient packing in one piece (B), or in rolls (A and C), as shown in figure 103, to firmly fill the space under the journal so as to prevent settling away; taking care to have packing bear evenly along the full length of the lower side of journal. Free oil must be added to boxes that do not contain sufficient oil after repacking. Mechanical journal lubricators will be applied in accordance with manufacturer's instructions furnished with each lubricator shipping container.

e. *Handling of Removed Packing.* All reclaimable packing removed from journal boxes must be placed in containers, avoiding any possible contamination, and shipped to the reclaiming plant. Such packing must not be reused until it is renovated.

f. *Cleaning and Installing Bearings.* Care must be taken to thoroughly clean all parts of the bearing and the journal before installation (para 126*b*). A drycleaning

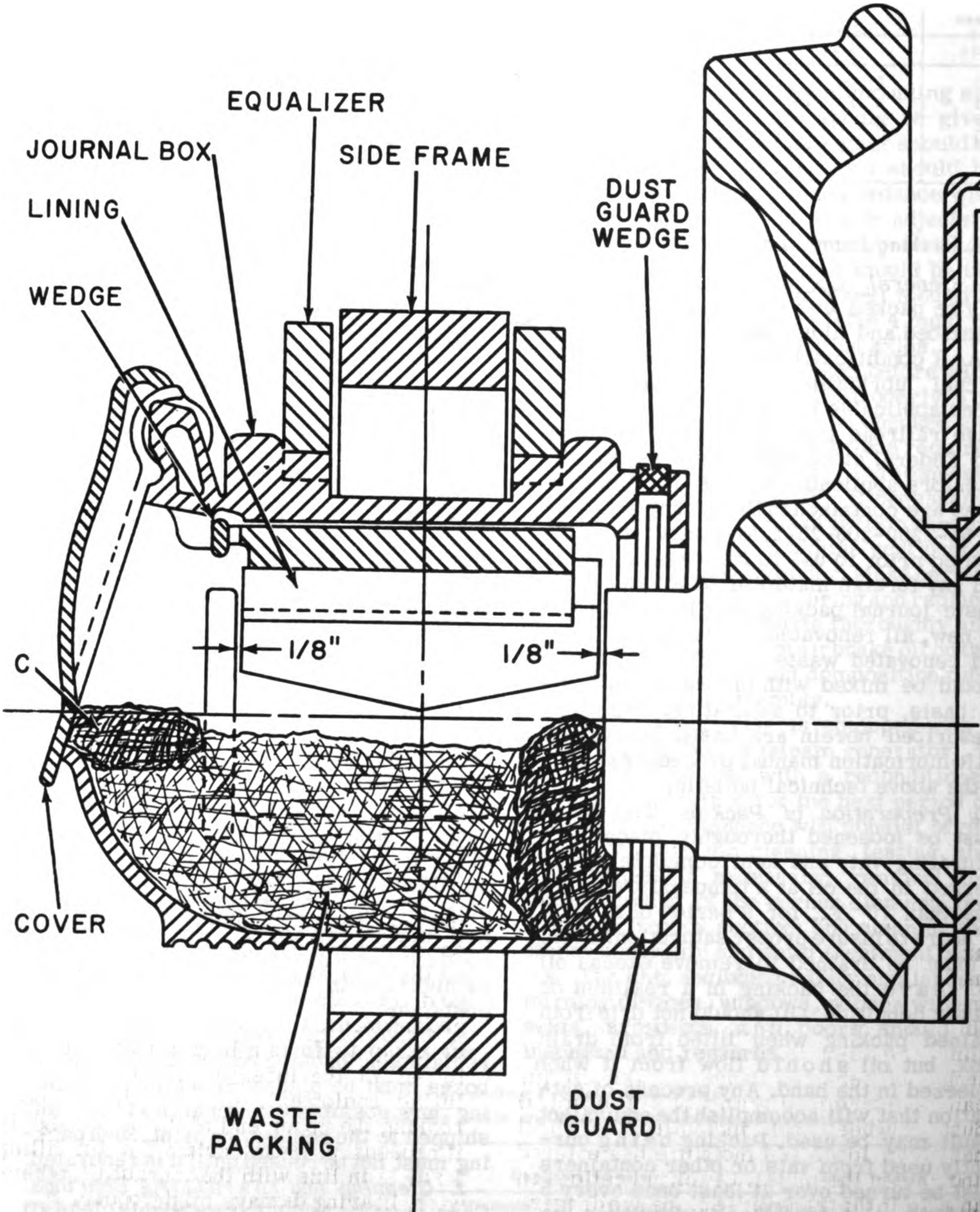


Figure 103. Packing journal boxes.

solvent should be used followed by a wipe-down with a clean, dry cloth. When necessary to remove metal from the bearing to obtain the proper fit to the journal, be sure to use the proper tools. Do not use sandpaper, emery paper, or emery cloth as the abrasive particles will embed themselves into the soft bearing metal and will cause excessive wear. The bearing should be scraped. It is always good practice to coat the bearing surfaces with the prescribed lubricating oil when the installation is made.

g. Wedge. The wedge must conform to the specified dimensions. The wedge must be properly seated on the crown of the bearing, so as not to pinch the side of bearing or rest on the lugs.

231. Wheel and Axle Repairs

a. Wheels and axles are inspected after each trip as part of the daily routine inspection. Wheels are also checked for wear, sharp flanges, shelling, cracks, and flat spots. Wheel sets may be removed while the truck is under the locomotive or the truck itself may be removed and taken to a truck overhaul shop. Jacking pads are provided on the body of the locomotive to support the locomotive frame when raising it from a truck. To remove a wheel and axle assembly without removing the truck, it is necessary to use a drop table. The ends of the axles are bearing surfaces and should be protected when journal boxes are removed.

b. The service life of axles and gears will vary with the type of locomotive service. Because of the dangers resulting from axle cracks, axles should be given a magnaglo or magnaflux test whenever a wheel is removed. Magnaglo is more effective for this inspection and should be used each time a wheel is changed regardless of length of service. Danger of axle fatigue can be determined by a deposit of red metal dust on wheel seat, indicating the wheel has worn loose and moisture has entered and rusted the metal. Crack indications on an axle in the transverse plane are dangerous and the axle should be scrapped. After the second pair of wheels is worn to its condemning limit but the axle and axle gear are free of cracks or defects and the gear is not to the condemning limits, new wheels may be applied; however, this practice is not recommended except when necessary. If axles are not magnafluxed at each wheel removal, the axle should be scrapped after two pairs of wheels have been worn to condemning limits. The axle gear, if not magnafluxed, should not be used beyond the life of two axles.

c. When a pair of new wheels is to be mounted on an axle, the wheels must be carefully mated with a maximum variation of 1/16 inch in circumference, or 0.020 inch in diameter. If new wheels are not available within these limits or variations, or if old wheels are to be used, they should be matched as closely as possible and turned or ground after mounting. The allowable pressure range for wheel applications, using new or old wheels or axles, is 70 tons low limit and 140 tons high limit (see table 4, para 229). A permanent record should be kept as to the pressure required to mount the wheels. Wheels on idler axles will require the same pressures as are used on power axles.

232. Air Compressor Repairs

Disassembly and overhaul the air compressor periodically. Drain the oil from compressor crankcase. Disconnect and remove the compressor coupling from the shaft to prevent damaging the compressor bearings. Clean the exterior of the compressor thoroughly before disassembly. Mark the parts as necessary in order that they can be reassembled in the same relative positions. When removing the crankshaft, a coupling device must be attached to the crankshaft end for lifting. Such a device should be made by welding a standard crankshaft nut to a U-shaped steel rod or strap to form a loop of sufficient size to permit the insertion of the hook of the lifting equipment. Lift the shaft slowly, rocking the upper end of the shaft slightly if necessary. Make certain that the lifting force is in line with the crankshaft; otherwise, bearing damage might occur.

a. Cylinder liners and pistons are removed and inspected. Hone all cylinders retained in service. After honing, check the clearance between each piston and cylinder with piston rings removed. Also, make certain that cylinder flange face is perpendicular to the cylinder bore.

b. The crankshaft must be examined to see if it is bent or cracked or if the bearing seats are worn excessively. If such conditions exist, replace the shaft.

c. Valves should be checked for lift and wear limit.

d. Intercooler tubes should be cleaned inside and outside. Check whether any tubes must be replaced.

e. Main bearings should be examined for general condition and proper end clearance.

f. The oil pump on pressure lubrication system should be checked and oil pump strainer screen replaced.

g. The compressor governor should be disassembled, cleaned, and oiled approximately once a year. Clean or replace strainer element.

233. Alining Flexible Coupling

a. General. If two or more rotating shafts are coupled, proper alinement should be provided in order to eliminate vibration and bending of the shafts. The method of securing satisfactory alinement will vary with the number of bearings on each shaft and the type of coupling used. If shafts with single bearings are alined properly, there will be no radial displacement between the coupled ends of angular displacement of shafts. If each shaft to be coupled has more than one bearing, a type of coupling must be used which will permit a small amount of angular or radial displacement, since it is not always possible to achieve absolute alinement between two shafts carried in separate housings.

b. Radial Misalinement. Radial misalinement occurs when the centers of the two shafts do not coincide. The displacement causes excessive vibration and wear within the coupling due to radial movement of the two halves of the coupling with respect to each other. This displacement also causes pulsating loads on the bearings, thus shortening their life; the magnitude of this pulsating load will depend on the resistance of the coupling to radial movement.

c. Angular Misalinement. Angular misalinement is present when the two shafts come together at a slight angle. In addition to setting up vibration, angular misalinement causes bending stresses to be set up in the shafts and additional bearing loads. The more flexible the coupling, the less will be the load on the bearing and the stress set up in the misalined shaft.

234. Locomotive Test Run

When the foregoing maintenance attention and repairs are completed (also the electrical work described in ch. 22), the locomotive should be given a test run to make a final check of its operating adjustments and conditions before it enters regular service. Although many operating conditions can be determined on the stationary loading tests at the shop, such items as running gear performance, braking, journal bearing heating, and other characteristics can be checked more effectively on an actual run. A test run should verify that traction motor connections result in proper direction of rotation, that sanding occurs during an emergency brake application (if so provided in the original design), and that circuits through multiple units function properly.

CHAPTER 22
ELECTRICAL EQUIPMENT REPAIRS

235. Main Generator Repairs

a. General. Heavy repairs to the generator require its removal from the engine and its complete dismantling. This heavy repair program includes the following:

(1) Rebanding the armature, if necessary, and turning the commutator.

(2) Inspecting roller bearings, cleaning, and repacking.

(3) Inspecting the bearing housing in the end frame.

(4) Thoroughly cleaning both armature and field windings. All traces of solvent, if used, should be carefully removed with compressed air.

b. Insulation should be dipped and baked, if necessary, but it may need only a light spray coating of insulating varnish or, in the case of the armature, a "rolling" in such varnish. Needless dipping and baking adds useless material to the windings which will decrease heat transfer and reduce the area of ventilating air passages. To determine whether dipping and baking are needed, a detailed inspection in conjunction with megger readings is all that is required. Complete rewinding of generators and renewal of commutators in the absence of fires, major insulation failures, bed flashovers, or mechanical damage, is seldom necessary.

c. High-potential teating of insulation and dielectric strength to ground is essential to proper maintenance of main generators on diesel-electric locomotives. Under the effects of heat, dirt, or moisture, or a combination of these, insulation deteriorates in service and presents a twofold problem. One part of this problem is testing before repairs are made to determine if any special work is necessary or if there are any weaknesses present. The other part is testing after repairs to make sure the generator is in suitable condition for the normal period of service.

236. Auxiliary Generator Repairs

a. General. Auxiliary generator overhaul consists of careful inspection of the stator field assembly, armature assembly, brush holder assembly, and bearing assembly, especially with respect to defects or necessary repairs; also application of required tests, checks, cleaning, and varnish treatment. The auxiliary generator should be overhauled as follows:

(1) Remove the armature.

(2) Remove and discard (scrap) ball bearings.

(3) Clean and repaint field coils and leads.

(4) Clean, dip, and bake armatures.

(5) Turn and undercut the commutator if necessary.

(6) Replace string band if necessary.

(7) Assemble, using new double-shielded bearings. Make certain that bearing retainer nut is locked with washer provided for that purpose.

b. The following precautions should be observed to prevent bearing failures:

(1) When removing coupling flange or blower fan wheel assembly, use a puller that does not apply a load on the bearings.

(2) Coupling flange or blower fan must be pressed on the shaft in such a way that the forces are not transmitted through the bearings.

(3) Care must be exercised in handling the auxiliary generator to prevent bumping of shaft—this can damage the bearings.

(4) Bearings which have been removed from the shaft at any time should not be used again, but should be replaced with new factory packed bearings.

237. Traction Motor Repairs

a. It is necessary to recognize a distinction between traction motors used in switching locomotives and those used in road locomotives. This tends to involve different periods, or time intervals, rather than different maintenance procedures. *For example,* the work done by a motor on a road locomotive over a given period is greater than the work done by a motor on a switching locomotive. More frequent and active attention is required to motors on road locomotives than on switching locomotives. The kind of repair attention, however, is generally similar.

b. Three important factors governing traction motor repairs are cleanliness, roller bearings, and commutators. The maintenance program must take these into account to prevent trouble which might develop from any or all of them.

238. Growler Test

The most common method of testing for short circuits in field coils is the growler test, and many repair shops are equipped with a transformer or growler for this purpose. The growler test is a very simple and effective method, since no accurate electrical measurements are required. Apply pressure to the field coil when it is being tested, in order to approximate actual conditions when it is clamped in the frame. If pressure is not applied, the coil may show no defect on test but may give trouble from short-circuited turns when clamped between the pole tips and the inside surface of the frame. With the test in operation, after adjusting the knife switches for the desired number of turns on the transformer, place the removable portion of the core in place but without the field coil. Note the deflection of the ammeter, which indicates the value of primary current. Open the line switch and place the coil in position around the transformer core; close the switch to reapply voltage to the transformer. If the ammeter shows the same deflection as before, the coil is free of short-circuited turns; if there is a short circuit, a much heavier current would flow in the primary coil of the transformer and would be indicated by a greater deflection of the ammeter.

239. Dipping and Baking

Coils which have been in operation 4 or 5 years should be dipped and baked as a preventive maintenance measure. Some coils such as field coils are dipped before mounting on their core. In the case of armatures, the entire assembly is suspended with the axis in a vertical position and the commutator on the upper end and lowered into the compound up to, but not including, the commutator. The varnish or impregnating compounds is hot, and the coils or armature are cleaned and preheated in an oven before dipping. Dip for 5 or 10 minutes, drain for 5 minutes, and then place in oven for about 6 hours at about 300° F. When an armature is rewound, it is baked before banding and again after banding.

240. Cables and Wiring

It is extremely important that cables and wiring be thoroughly inspected whenever a suitable opportunity presents itself. This includes insulated bus bars as well as wires and it applies, of course, only to exposed sections. In the latter case, reliance as to condition must be placed in the results of megger and high potential tests. Cleaning should be done by wiping with rags or using a suitable solvent; if a solvent is used, as mentioned in connection with repairs to main generators and traction motors, all traces must be removed. When the cleaning is completed, it is good practice to paint accessible sections, particularly those exposed to dirt, with a good grade of insulating paint which should add to the moisture-resisting and flame-retarding properties of the insulation. If any section of wiring is found to have deteriorated excessively because of heat, consider relocating the wire to reduce such exposure.

241. Sequence Testing

a. General. Electrical testing instructions are issued by the manufacturer for each group of locomotives. These tests must be followed accurately, and no attempt should be made to adapt approximate substitutions. The following discussion of typical testing procedures merely tells, as a matter of general information what is usually done and why it is done. Operating sequence of shutdown control circuits is tested at battery voltage by manually moving interlocks and controls, after disconnecting generator so that it will not crank the engine or produce power voltage. The following is a partial list to be used when testing.

(1) Starting circuit interlocks must prevent the armature contactors from closing until the field contactors have closed.

(2) Fuel pump must operate and proper pressure show on fuel gage. Shutdown valve in fuel line must function with any safety devices, such as low oil pressure switch, or high water temperature switch, according to the wiring in each individual case.

(3) Interlocks between the throttle and reverser, as well as any directional auxiliary equipment such as sanders, must insure proper operation.

(4) Interlocks in fan motor circuits and shutter control circuits must function properly.

(5) Traction motor field shunting and transition must occur at the proper time and sequence.

(6) Wheel slip relays, ground relays, etc., must give proper protection and turn on the alarm and indicator lights.

(7) Any replaced traction motor must be checked for proper direction of rotation and direction of field connections.

b. Drying With Internal Heat. If equipment has been flooded, coils may be dried by circulating current through the windings to develop internal heat. The voltage is low and will not harm the insulation but the heat is not quickly dissipated and must be regulated by experienced personnel. Steam or gas pressure within the winding may also damage the insulation. The exact procedure depends on the type of equipment to be dried and the facilities available.

242. Insulation Testing

a. General Description.

(1) Insulation should be tested periodically at voltages in excess of the normal operating voltage in order to detect any weakness which may cause a breakdown in service. Any defects must be remedied before failure occurs en route. Two types of insulation tests are—

(a) Resistance tests which indicate the presence of moisture, grease, carbon, or other dirt which would cause grounds, false indications, or miscellaneous failures which are not due to a breakdown of the insulation.

(b) Dielectric tests in which a voltage above normal is applied to the circuit to determine whether it can withstand voltage stresses which may occur during normal or abnormal operating conditions. Such tests are confined to the main power circuits. The recommended test voltage is 1,200 volts to ground.

(2) An annual dielectric test of 1-minute duration at voltages at least 50 percent to 75 percent above normal working voltage is set forth in Department of the Army directives. The damage which may result from insulation failure during a properly applied dielectric test is likely to be small compared to the loss caused by a breakdown while apparatus is carrying a heavy load. Reference should be made to the testing instructions for each individual locomotive for information on terminals, connections, or specific conditions for testing.

b. Resistance Tests. Resistance tests are adequate for the low voltage control circuits which operate at about 75 volts. Department of the Army directives do not require dielectric tests for circuits which operate below 150 volts. However, it is always desirable to keep the control circuits free from grounds. Although high insulation resistance does not necessarily indicate high dielectric strength, low insulation resistance does indicate low dielectric strength. Control circuits of new locomotives should have a resistance of 1 megohm, and should not fall to less than one-half of this value on locomotives in service. An important feature of these tests is the comparison of readings taken under similar conditions at various times. If wide variations appear in successive readings made under approximately the same conditions of temperature and dryness, the cause should be determined. Insulation resistance on rotating apparatus is useful in indicating the condition of the insulation, particularly before applying a high potential test. The recommended minimum megger reading for the power circuit of either a main generator armature plus commutation field, or a traction motor, to remain in service on the locomotive is 1 megohm at 77° F. If the windings or parts of the windings are oil or water soaked, the damaged parts should be removed regardless of the megger reading. Insulation resistance of the windings varies greatly with humidity and temperature. As an approximation, the insulation resistance for dc motors halves for every 22° F., rise in temperature. Because winding temperatures, except those at known room temperatures, cannot be measured accurately in shops, it is recommended that the apparatus be permitted to level off to the known room temperature before insulation resistance is measured.

c. Dielectric Tests. Dielectric tests of not less than 1-minute duration should be made on the main power circuits annually, or whenever the insulation of apparatus has been repaired. It is important that:

(1) The equipment be clean and dry and be checked with a megger before making test. High voltage should not be applied unless the insulation resistance measures at least 1 megohm when the motors and generators are clean, dry, and cool (about 77° F.). It is considered good practice to insist on 1 megohm or above before applying insulation tests to any electrical machinery. In the case of diesel-electric equipment, the megger reading should be taken over a 30-second period or longer. If the reading is constant or rises steadily with continual application of the megger voltage, it is considered that the insulation is sound and can be safely tested. If the reading is unsteady and rises and falls excessively with steady application of megger voltage, it is likely that leakage paths may be present due to presence of dirt or moisture. In the latter case, it may not be safe to "hi-pot" the machine without further cleaning and drying.

(2) The test leads be securely connected to the circuit before power is applied to the test box (to avoid surges from poor connections).

(3) The voltage from the test box be varied smoothly, both when increasing and decreasing the setting, in order to avoid surges.

d. Test Boxes. Sudden application or removal of test potentials may result in surges as much as 100 percent over the intended test voltage. Excessively burned contacts or contact tips on the test box may result in undesirable fluctuations in test voltage. Test boxes that have fixed, definite secondary steps of voltage are certain to produce surging if the primary voltage cannot be smoothly controlled from zero to maximum. The most effective and inexpensive modification for test boxes of 1/2 to 5 kv.-a. capacity can be accomplished by adding a Variac to the primary winding. Variacs have the ability to vary the voltage smoothly without steps and, as a result, there is practically no surging of voltage. The V 10 H Variac may be used with 1/2, 1, and 1-1/2 kv.-a. test boxes; the V 20 HM Variac with 2 and 3 kv.-a. boxes, and two V 20 HM Variacs in series for 4 and 5 kv.-a. boxes. These Variacs may be used on 115 or 230 volts ac supply. To use a Variac, connect the test leads to the machine or circuit being tested before applying power to the test box, then raise the voltage to the test value with the Variac, hold for the prescribed time, and then lower the voltage to zero with the Variac before removing power and disconnecting the test leads. Maximum test voltages on the main power circuits should be 1,200 volts to ground. If working voltage values higher than 600 volts are established as normal for any locomotive, corresponding higher test voltage should be applied.

243. Lining Up Generator With Engine

a. *General.* The proper operation of a generator set requires that the armature shaft and frame be in line with the engine crankshaft and that the airgap be equally spaced. The eccentricity at the coupling should be held to a minimum as this directly affects balance and brush and bearing wear. The airgap of the generator must be uniform within plus or minus 10 percent from average under each main pole as well as under each commutating pole, and also from front to rear, so that the generator will have the proper electrical characteristics. Since the generator has only one bearing, the recommended method for alining the airgap and coupling is at the engine end of the generator.

b. *Alining Airgap.* Where the generator installation permits, the airgap should be measured under each pole at the coupling end. This should be done with a long feeler gage inserted through from the commutator end. Since the generator has a nonuniform airgap under the main poles, measurements must be made under the tip of the pole piece. As an alternative, the radical clearance between the edge of the fan and the generator frame may be used if one point on the fan is used for reference and the fan is rotated so that measurements can be made between this point and the frame at the top, bottom, and each side. If the difference in these measurements 180° apart is less than 0.020 inch, the airgap may be considered satisfactory. Under no circumstances should an attempt be made to use the end of the generator frame to aline the airgap.

c. *Alining Coupling.* The coupling is alined by means of a dial type indicator fastened to a support extending out radially from the armature flange through a hole provided in one fan blade. The indicator is attached to this support so that the indicator plunger rides against the face of the generator fan. The dial of the indicator should be set at zero at the top position and readings taken 90° apart. An allowance of plus or minus 0.010 inch at the bottom and plus or minus 0.005 on each side will result in satisfactory alinement if the coupling is concentric with the crankshaft and armature shaft.

d. *Final Operations.* Since any movement of the generator frame affects both the coupling alinement and airgap, readings must be repeated for both after setting. Experience will indicate the proper shim thickness to bring the readings within the limits specified. Only full length shims should be used under each generator mounting pad. Not more than three shims should be used under each mounting pad with one shim not to exceed 0.060 inch in thickness; the thickest shim should be tapered if necessary so that the airgap and coupling will conform to the specified limits. After the generator is coupled to the engine, the generator frame should be placed so that the single bearing at the commutator end is located axially to avoid thrust load in either direction. The generator has a float of approximately 3/16 inch between the outer race of the bearing and the housing, and must be coupled to the engine with no clearance between the bearing outer race and the engine side of the housing. When the crankshaft is forced toward the generator, the generator frame must be as far away from the engine as possible without putting an end thrust on the coupling; this arrangement provides the maximum amount of clearance required by expansion of the generator shaft and engine crankshaft as they heat up. The armature shaft should be forced toward the coupling end of the generator before coupling to the engine.

244. Bearings

a. The term "antifriction bearings" is applied to all ball or roller bearings to distinguish the rolling type of bearing from the common sleeve type bearing. There are many styles and types of these roller and ball bearings — single row ball, double row ball, self-alining ball, single row roller, double row roller, self-alining roller, tapered roller, and further modifications of inner and outer races of each type. The types found suitable for diesel-electric apparatus are limited to a few standard designs. If properly applied and lubricated, ball or roller bearings need much less attention than sleeve bearings. They are in general use for main generators, armature bearings of traction motors, belt driven auxiliary generators and exciters, blower motors, and nearly all electrical rotating apparatus of a diesel locomotive. Each time a motor is overhauled, clean, inspect, and repack the roller bearings.

(1) Clean bearing parts with kerosene or other petroleum cleaner. Do not allow them to lie around with old grease in them. Do not use compressed air on a bearing; it may contain moisture which would cause corrosion of races or rollers. Do not take cages apart.

(2) Inspect bearing parts for wear or defects. Examine inner race under a good light. Look at the roller path and examine it for flaking or cracks. Examine for pitting, signs of excessive wear, and any excessive amount of dirt. Examine side surfaces and bore of inner race for evidence of rubbing or turning on the shaft. On commutator end bearing (traction motor), look for smearing on flange and thrust collar. Examine outer race and rollers (or balls). Examine cages for wear.

(3) To prevent corrosion, immediately after cleaning and inspection, dip bearing in light mineral oil (SAE-10), heated to 203° F.

(4) Drain bearing and wrap it in waxed paper to keep it clean.

(5) Clean bearing housings, flingers, and adjacent parts with kerosene, safety solvent, or other petroleum cleaner. After cleaning, wipe housing dry. Dip flingers and adjacent parts in SAE-10 mineral oil, heated to 203° F., and drain. Store parts in a dry, clean place.

b. On any shaft having two bearings, one is suitable for taking end thrust and normally is clamped rigidly to take this thrust; the other bearing must be free to allow end movement which results from expansion or contraction of the shaft when temperatures change.

(1) For ball bearings in which balls normally roll in grooves in the inner and outer races, it is necessary to allow a free fit between the outer race of the bearing and the supporting housing. This fit should be loose enough to allow the outer race to move horizontally with the shaft; sufficient clearance should be provided in the housing to permit this longitudinal movement.

(2) For the roller bearings, it is frequently the practice to provide one of the races with a grooved path for the rollers while the other race is cylindrical, thus allowing longitudinal movement of one race with respect to the other.

c. Since one end of the armature shaft of a single-bearing generator is unsupported prior to application, the armature usually rests on the pole pieces with the result that the armature shaft is not perfectly alined with the bearing housing. For this reason sufficient clearance must be allowed between the balls or rollers and their races to permit this slight angularity of the shaft, or else, a self-alining type of bearing must be used.

d. Since locomotives are subject to a wide range of operating conditions, such generator parts as shafts, bearings, and balls or rollers may be subjected to high temperatures which cause expansion of the metal. For this reason, the clearances normally allowed for industrial antifriction bearings are not sufficient for diesel-electric generators or traction motors and special "free fit" bearings should always be used. These clearances are measured under the rollers or balls after the bearing is assembled on the shaft and in the housing at normal room temperatures.

e. It is customary to insure a tight fit of the inner race of a ball or roller bearing on its shaft by heating the race in oil at a temperature of 212° to 257° F., and allowing the bearing to remain in the hot oil for about 1 hour before applying it to the shaft. The fit of the outer race in the housing, however, differs for the different types of bearings.

f. For ball bearings where longitudinal movement of a shaft means that the outer race must also move, the outer race should be of such fit that it can be pushed into the housing by hand; this also applies to spherical "self-alining" roller bearings. For the larger bearings, it is customary to limit the housing bore to 0.002 inch greater than the outside diameter of the outer race. For the smaller bearings, adherence to this tolerance may be less rigid. For roller bearings which have one cylindrical race, the outer race is usually larger than the housing bore by 0.001 inch to give a tight fit. In replacing bearings after equipment has been in service, however, it is always well to check both the bearing and the housings to insure a good fit.

245. Commutators

a. Regular Maintenance.

(1) Proper maintenance and care of commutators eliminates excessive stoning. Each time a road locomotive comes into a maintenance point where diesel locomotives are maintained, the commutator should be touched up with a canvas-covered block to prevent excessive formation of oil scum and the development of a condition requiring a heavy stoning. On switching locomotives, this work should be done at the time of monthly inspection.

(2) If excessive formations of scum cannot be removed with canvas, the use of a fine finishing stone lightly applied may be required; this will permit the operator to touch up commutator lightly and thus maintain true surface on the commutator.

b. Stoning.

(1) A commutator having a smooth glaze of chestnut color is in satisfactory condition. Slight burning often occurs at the edges of every few bars, due to the method of winding to get high electrical efficiency. No maintenance attention is required for this type of defect. However, if such spots are deep enough to cause a brush to leave the commutator, or if commutator is dirty or smudgy, it may be necessary to smooth the surface and bring the commutator back to concentricity by means of a grinding stone. Eccentricity may be ascertained by clamping a dial gage on the frame of the generator or motor and rotating the armature by hand, one commutator bar distance at a time. The dial gage measures, in thousandths of an inch, variations in commutator radius. An eccentricity of 0.001 inch, within a distance less than the brush spacing around the commutator, may indicate the necessity of stoning. For bad burns and extreme eccentricity, it may be necessary to turn the commutator on a lathe.

(2) For motors or generators having roller or ball bearings, a satisfactory stoning job is done as follows:

(a) Use a grinding rig which can be clamped firmly to the frame of the machine, with two directions of feed for the stone.

(b) Operate the motor or generator at slow, or idling, speed. Operate a traction motor by jacking the wheels off the rails and connecting the motor to a welding generator as a source of power. Remove all pulsating torques,

such as compressor drives, when turning a generator commutator.

(c) Take extremely light cuts at first until the commutator approaches a true condition. Avoid heavy cuts as these cause some deflection of the rig and may not produce concentricity. Take the final cut with a fine grained stone.

(d) Check trued commutator with the dial indicator.

(e) Clean out the undercut slots between bars to a minimum of 3/64 inch, leaving no mica at the sides; use rotating saw or clean by hand with pieces of hacksaw blade. Chamfer edges of bars slightly at the slots with fine sandpaper (not emery cloth).

(f) Use sandpaper laid on the commutator under each brush to sand the face of each brush to the commutator contour.

c. Brush Pressure. In the operation of commutators, the brush grade and pressure should be as recommended by the manufacturer. To measure brush pressure, a stirrup attached to a spring balance should be slipped under the brush hammer at the middle of the brush and the pressure determined by pulling the hammer away from the brush in the direction of hammer movement. This pressure should be determined on the basis of a half-worn brush, not a new one.

d. Turning. If the commutator is badly worn or burned, remove the armature from the machine and turn the commutator in a lathe. Remove only enough copper to give a uniform surface, after which the side mica between segments should be recut and the commutator surface polished and cleaned. Whenever possible, turn the commutator by supporting the armature in its own bearings. If the armature is held on lathe centers, be sure that these centers are true with respect to the bearing seats. Before turning a commutator, make a suitable covering to keep the chips and dust from working into the armature. Make sure that the turning post is so set that the ways are absolutely parallel to the commutator and that they are fastened and braced securely. Use a side-cutting tool with point ground to about 1/16-inch radius. The cutting side of the point should be given more rake than is customary for working iron and steel. The tool should be sharp enough to make a clean, smooth cut, without dragging copper over the mica. While turning the commutator, it should be run at a peripheral speed of approximately 300 feet per minute, which is about as fast as the tool will cut without burning. With a file, round off the ends of the commutator bars to at least 1/16-inch radius, while the commutator is still in the lathe. After the commutator has been turned, undercut the mica in the same manner as when stoning.

246. Traction Motor Pinion Gears

a. General Rules. Care must be taken to avoid bumping pinion gear or pinion end of armature shaft in shipping, handling prior to application, applying, and removing traction motors from trucks. If the pinion gear end of armature shaft is bumped against a heavy object, the commutator end bearing should be examined for damage to the thrust portion or ends of the bearing race. Extreme care should be used in handling traction motors to avoid damage which will result in failure of motor due to armature shaft locking.

(1) Pinions on traction motors in road service should be pulled at intervals of about 250,000 miles and armature shaft magnafluxed for defects.

(2) Whenever pinions are pulled for any reason, armature shafts should be magnafluxed and placed in perfect condition before pinions are again applied.

b. Removal Procedure. In removing traction motor pinion gears, use a suitable gear puller. Never heat gear before pulling and never use wedges between gear and bearing cap. To prevent damage to antifriction bearing, remove the armature from the motor frame and place in suitable V-shaped supports; then pull off pinion gear. Never strike pinion gear or gear puller with sledge or any heavy object while armature is in place in motor frame.

c. *Mounting Procedure.* In replacing traction motor pinion gears, clean the armature shaft and the bore of the pinion gear thoroughly. Remove any scoring on either surface and spot cold pinion gear on the shaft by hand until at least 85 percent fit is obtained. After checking fit between the armature shaft and pinion gear, mount the pinion cold on the shaft by hand. Record the position of gear on shaft with respect to end of shaft. Make measurements using (preferably) a micrometer depth gage set in a suitable frame (fig. 104). Mark the points of measurement and the end of the shaft so that the pinion can be mounted in exactly the same manner after heating. Heat the pinion gear in an oven or in oil until it has reached a uniform temperature and is the required number of degrees above the shaft temperature. Check shaft and pinion gear temperature with a hand pyrometer. Never permit the temperature of the pinion gear to exceed 375° F. Be sure maximum advance is obtained, using a dummy pinion nut which has loose threads to permit quick tightening. Use a suitable spanner wrench for prompt tightening of nut before the pinion gear cools. After pinion gear has cooled, remove dummy pinion nut and check pinion gear carefully by measurement for proper advance. If the mounting is satisfactory, apply and tighten the regular lockwasher and nut.

247. Traction Motor Axle Bearings

a. Tolerances on traction motor axle bearings vary slightly depending on the manufacturer of the locomotive and if it is to be used in road or switcher service. The appropriate manufacturer's maintenance bulletins or appropriate technical manuals should be followed when bearings are to be repaired or renewed. Whenever a traction motor is removed from a locomotive, the bearing alinement should be checked before the motor is reinstalled in the locomotive. If bearing shows sign of cutting, scrape it down to a new surface; if too badly worn, replace with a new one. Before installing bearing, examine journal for roughness or cutting.

b. Hot bearings will occur occasionally and are usually the result of one of the following causes:

(1) Insufficient amount of oil.
(2) Dirt working into the bearing.
(3) Improperly packed waste.
(4) Excessive end play in truck axles.
(5) New bearings with insufficient clearance.
(6) Traction motor nose clamped in truck frame.

c. If bearings are hot, use the following checklist:

(1) First check oil level in the oil cavity.
(2) Examine waste packing to make sure it has not fallen away from journal.
(3) If bearing has been recently installed, check clearance as it might have been set up too tightly.

248. Traction Motor Axle and Pinion Gears

a. The service life of railway gearing depends very largely upon the type of service in which it is used and the quality of maintenance and lubrication which it receives. Gears in highspeed road service should be maintained to more rigid standards than is necessary for gears in switcher duty. Gears become unsuitable for further service for a variety of reasons the most common of which is wear.

b. When a wheel set is removed from a truck for any reason, the gears should be thoroughly inspected. The condemning limits for axle and pinion gears are given in the inspecting procedure as follows:

(1) Visually inspect or magnaflux for broken, chipped, spalled, or pitted teeth. Pinion and axle gears should be condemned when more than 20 percent of total working surface of teeth are spalled or pitted. Axle gears should be scrapped

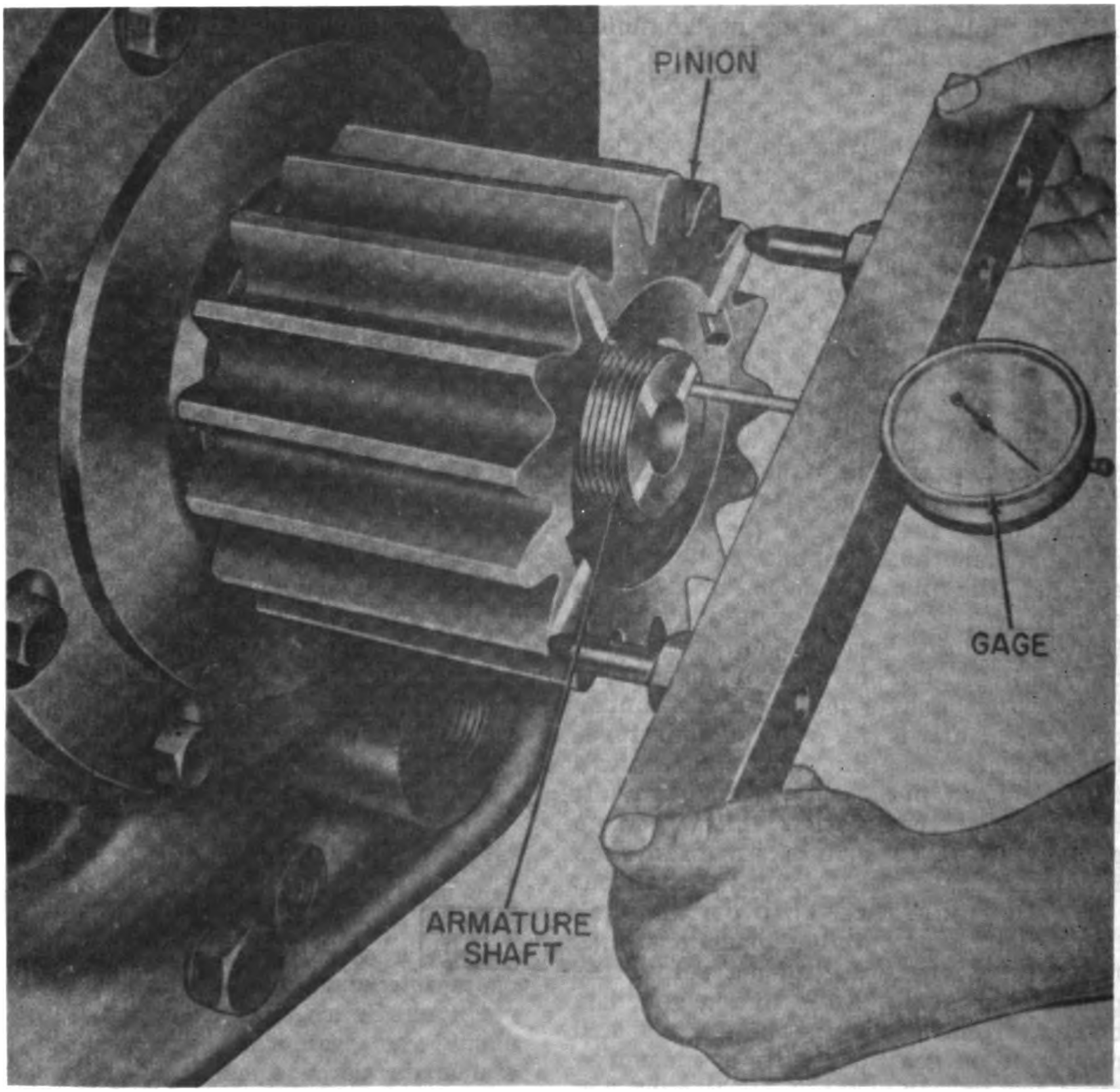


Figure 104. Method of using pinion gear advance gage.

when either one of the working surfaces is worn to a point where a step 1/32-inch deep exists in the root of the gear tooth where contact with the pinion ends.

(2) Check for wear limits determined by dimensions across tip of tooth The minimum allowable dimensions at this point is 3/32 inch for axle gears and 1/32 inch for pinions.

(3) Light scuffing is characterized by vertical, root-to-tip lines and is an indication of faulty lubrication which, if not corrected, may result in ultimate destruction of the teeth. The heat generated as a result of this condition may cause damage to the armature bearings.

c. When gears with a hump at the pitch line or steps at root of tooth are disturbed by application of new axle linings or mated with other gearing, they will operate with interference stresses and torsional vibration until battered in a new mating fit. Operation under this abnormal condition may lead to fatigue failure of gear teeth and shorten the life of armature windings.

CHAPTER 23
DEMOLITITION OF LOCOMOTIVES TO PREVENT ENEMY USE

249. General

a. Destruction of a locomotive, when subject to capture or abandonment in the combat zone, will be accomplished only when in the judgment of the unit commander concerned, such action is necessary in accordance with orders of or policy established by the Army commander.

b. In general, destruction of vital parts followed by burning with usually be sufficient to render the locomotive useless. However, selection of the particular method of destruction depends on the facilities at hand under the existing conditions. Time is usually a critical factor to be considered.

c. If destruction is directed, due consideration must be given to:

(1) Selection of a point of destruction that will cause greatest obstruction to enemy movement and also prevent hazard to friendly troops from fragments or ricocheting projectiles which may occur incidental to the destruction by gunfire.

(2) Observance of appropriate safety precautions.

d. Where time does not permit firing or complete hand destruction, the same key part or assembly on each locomotive abandoned will be destroyed to prevent possible cannibalization by the enemy.

250. Destruction by Mechanical Means

Using an ax, pick, mattock, sledge, or any other heavy implement, smash all vital elements such as controls, water and fuel pumps, air compressor, generators, switches, and traction motors. If time permits and a sufficiently heavy implement is available, smash the engine block and cylinder heads.

251. Destruction by Burning

a. Remove the drain plug from the fuel tank, or puncture the tank as near the bottom as possible, collecting diesel fuel for use as outlined in paragraph c below.

b. Pack explosive ammunition, if available, on or about the locomotive so it will be fully exposed to the fire and in such locations that the greatest damage will result from its detonation.

c. Pour fuel oil, or preferably gasoline, over the entire locomotive. Ignite by any appropriate means; if available, use an incendiary grenade fired from a safe distance, a burst from a flamethrower, or a combustible train of suitable length.

252. Destruction by Gunfire

Fire on the locomotive with the heaviest weapons available, aiming at the engine traction motors, generators, and controls. Although one well-placed direct hit may make the equipment inoperative, several hits may be required for complete destruction of all components.

253. Destruction by Demolition Explosives

Place as many charges as the situation will permit and detonate them simultaneously. Use a TNT block or its equivalent per charge. Complete details on the use of demolition materials and methods of priming and detonating are found in FM 5-25.

APPENDIX
REFERENCES

1. Army Regulations

AR 55-650	Railroads
AR 108-6	Motion Picture Production
AR 320-5	Dictionary of United States Army Terms
AR 320-50	Authorized Abbreviations and Brevity Codes
AR 345-200	Program Policies and Procedures
AR 345-215	TOE Units of Active Army and the Army Reserve
AR 746-5	Color and Marking of Army Materiel
AR 750-5	Organization, Policies, and Responsibilities for Maintenance Operation
AR 385-10	Army Safety Program

2. Department of the Army Pamphlets

DA Pam 55-1	Transportation Railway Service Safety Rules
DA Pam 310-5	Index of Graphic Training Aids and Devices

3. Field Manuals

FM 5-25	Explosives and Demolitions
FM 21-5	Military Training Management
FM 21-30	Military Symbols
FM 55-21	Transportation Railway Supervisory Units
FM 55-22	Transportation Railway Battalion

4. Technical Manuals

TM 38-750	Army Equipment Record Procedures
TM 55-200	Railway Operating Rules
TM 55-201	Operation, Inspection, and Maintenance of Steam Locomotives and Locomotive Cranes
TM 55-1260	General Instructions for Baldwin Diesel-Electric Switching Locomotive, F-2-43
TM 55-1263	Locomotive, Diesel-Electric, 56-1/2-inch Gage, 65-ton, 0-4-4-0, 400-hp, General Electric, Cummins, Engine Model HBIS-600
TM 55-1264-1	Locomotive, Diesel-Electric, 80-ton, 500-hp, General Electric, Model B-B 160/160-4, GHM833
TM 55-1264-2	Engine, Diesel, Cummins Models K, KO, and L Series
TM 55-1265	Operation and Service Manual, Diesel-Electric 56-1/2 inch Gage, 0-4-4-0 American Locomotive Co, 100-ton, 660-hp and 115-ton, 1,000-hp
TM 55-1268	Locomotive, Diesel-Electric, 56-1/2-inch Gage, General Electric, 23- and 25-ton, 0-4-0, 150-hp, Class B-46/46-1 GE733 and Class B-50/50-1 GE733
TM 55-1271-1	Locomotive, Diesel-Electric, 56-1/2-inch, 60-inch, 63-inch, 66-inch Gages, 120-ton, 0-6-6-0, 1,600-hp, Electro-Motive Models MRS-1, SW8, GP7L
TM 55-1271-2	Engine Maintenance Manual No. 252B for Model 567B Engines, Electro-Motive Division, General Motors Corporation

TM 55-1275-3	Brake Equipment, Air Locomotive, NYABCO No. 6BL
TM 55-1276-1	Locomotive, Diesel-Electric, 56-1/2-inch Gage, 120/123-ton, 0-4-4-0, 1,200-hp, Fairbanks-Morse Model H12-44
TM 55-1277	Locomotive, Diesel-Electric, 56-1/2-inch, 60-inch, 63-inch, and 66-inch Gages, 120-ton, 0-6-6-0, 1,600-hp, General Electric Model 19B238G1 and G2
TM 55-1278	Locomotive, Diesel-Electric, 56-1/2-inch Gage, 80-ton, 0-4-4-0, 470-hp, General Electric Cummins Engine Model NHBIS-600
TM 55-2021	Brake Equipment, No. 14-EL for Diesel-Electric Switching Locomotive (Westinghouse Airbrake)
TM 55-2026	Brake Equipment, Air, Railway Locomotive, NYABCO No. 6-SL
TM 55-2029	Brake Equipment 6-SL for Diesel-Electric Yard Switching Locomotives (Westinghouse Airbrake Pamphlet 5046-15)
TM 55-2034	Air Compressor, 4-YC and Z for Diesel-Electric Locomotives, Westinghouse
TM 55-2040	Combined Vacuum and Airbrake Equipment for Diesel-Electric Locomotives
TM 55-2210-216-35P	Field and Depot Maintenance Repair Parts and Special Tool Lists
TM 55-4021	Caterpillar Diesel Engines (D397, D386, D375, D364) Industrial, Electrical Set, Locomotive, Marine, Caterpillar Tractor Form 13262-2

5. Lubrication Orders

LO 55-2210-201-20	Locomotive, Diesel-Electric, 56-1/2-, 60-, 63-, 66-inch Gage, 120-ton, Electro-Motive MRS-1 (Domestic and Foreign Service)
LO 55-2210-204-20	Locomotive, Diesel-Electric (General Electric 44-ton BB 88/88, 45-ton BB 90/90, 47-ton BB 94/94, 380-hp, 4GE-733) (Caterpillar D17000)
LO 55-2210-205-20	Locomotive, Diesel-Electric (GE 45-ton BB 90/90, 300-hp, 2GE-733) (Cummins HBI-600)
LO 55-2210-206-20	Locomotive, Diesel-Electric (Electro-Motive, Model GP7L, 120-ton, 1,500-hp)
LO 55-2210-207-20	Locomotive, Diesel-Electric (General Electric, 56-1/2-Gage, 65-ton Engine, Cummins Model HBIS-600)
LO 55-2210-208-20	Locomotive, Diesel-Electric, 56-1/2-inch Gage, 80-ton, 0-4-4-0, Davenport Besler Model 112-5708
LO 55-2210-209-20	Locomotive, Diesel-Electric (GE Models B-B-160/160-4 GHM 833 and B-B-160/160-4 GE 747, 80-ton) (Cummins Engine Models LI-600 and NHBIS-600)
LO 55-2210-211-20	Locomotive, Diesel-Electric, 127-131-ton, 1,000-hp, Std Gage (American Locomotive Model RDSW)
LO 55-2210-212-20	Locomotive, Diesel-Electric (120-ton, Baldwin, 1,000-hp)
LO 55-2210-213-20	Locomotive, Diesel-Electric (ALCO, 100-ton, 660-hp) (ALCO, 115-ton, 1,000-hp)
LO 55-2210-214-20	Locomotive, Diesel-Electric, 56-1/2-inch Gage, 44-ton, 0-4-4-0, 380-hp, Davenport Besler
LO 55-2210-216-20	Locomotive, Diesel-Electric, 56-1/2-inch, 60-inch, 63-inch, and 66-inch Gages, 120-ton, 0-6-6-0, 1,600-hp, GE Model GE 19B238G1 and G2

LO 55-2210-217-20	Locomotive, Diesel-Electric, 56-1/2-inch Gage, 120-ton, 0-4-4-0, 1,200-hp, Fairbanks-Morse Model H12-44
LO 55-2210-218-20	Locomotive, Diesel-Electric, 56-1/2-inch Gage, 23- and 25-ton, 0-4-0 150-hp, Cummins HBI-600 (General Electric Company)

6. Miscellaneous Publications

MIL-B-121	Barrier Material, Greaseproofed, Flexible (Waterproofed)
MIL-B-131C	Barrier Material; Water Vaporproof, Flexible
MIL-C-16173	Corrosion Preventive, Solvent Cutback, Cold Application
MIL-D-3464A	Desiccants Activated (in Bags) for Static Dehumidification and Packaging
MIL-D-3716(2)	Desiccants (Activated) for Dynamic Dehymidification
MIL-P-116C	Preservation, Methods of
MIL-P-3321B	Painting, Railway Motive Power and Work Equipment
TB 55-2200-205-25/1	Installation and Servicing of Journal Lubricating Devices
	DASC 2200-IL, FSG Group 22 Railway Equipment
	AAR Lubrication Manual
	AAR Wheel and Axle Manual
	Management Data List, DASC 2200-ML

GLOSSARY

Section I. DIESEL LOCOMOTIVE TERMS

The following glossary includes terms and names used in this manual and encountered by those personnel whose duties cover the operation and maintenance of diesel-electric locomotives.

Atmospheric pressure — The pressure of the atmosphere measured from absolute zero pressure. At sea level, atmospheric pressure is about 14.7 pounds per square inch, decreasing as the altitude increases.

Axle — A shaft of wrought iron or steel to which a pair of wheels is attached by pressing on with a hydraulic wheel press.

Babbitt metal — An alloy, consisting mainly of tin and copper — largely used for journal box bearings; so called after its inventor, Isaac Babbitt. The term is commonly applied to any white alloy for bearings, as distinguished from the metals or brasses, in which copper predominates.

Burning — Commonly substituted for combustion, as late burning meaning late or slow combustion.

Bushing — A lining for a hole. Usually a metal cylindrical ring which forms a bearing for some other object as a shaft, valve, etc., which is inserted into the hole. Often contracted to bush.

Bypass — A form of valve manually or automatically controlled which, when open, permits a fluid to pass around some part of a mechanism.

Cam — A wheel-like disk attached to a shaft. Only a portion is circular, the remainder protruding beyond the circle. From the irregularity or the contour of the cam, corresponding motion is imparted to a valve by means of a lifter, push rod, and rocker arm.

Camshaft — The shaft which carries the various cams required for the operation of air inlet and exhaust valves.

Cetane number — Cetane number is a specification used for diesel oils which may be compared with octane number in gasoline. Cetane is a hydrocarbon which burns quickly and easily in a diesel. Alpha Methyl Naphthalene is one which has very poor ignition qualities. A blend of the two can be made which has the same ignitibility as almost any commercial fuel, and the percentage of cetane which this blend contains is known as the cetane number of the fuel with which it is being compared. A high cetane number indicates a diesel fuel that will fire or ignite easily.

Clearance — Space that is provided between working parts and/or fixed parts of objects.

Clearance volume — The volume of air space remaining in the cylinder when the piston has reached the end of its upward, or compression stroke.

Combustion — Burning or combustion is the result of the combination of a combustible with oxygen and heat.

Compression — Pressure produced within the cylinder as the piston moves from bottom to top center with all valves closed.

Compression-ignition — Ignition of a fuel charge by the heat generated by compression of the air in the cylinder.

Compressor governor — A device used to regulate the point at which an air compressor cuts in (loading point) and when it cuts off (unloading point).

Crankcase — Lower part of the engine structure in which the crankshaft is mounted.

Crankpin — That part of the crankshaft that is offset to carry the connecting rod.

Crankshaft — The shaft that extends through the length of the engine to which is attached the connecting rods and which gathers the power and delivers it to the flywheel.

Crocus cloth — An abrasive cloth in which jewelers rouge (Garnet stone) is embedded. It is normally used for polishing metal.

Cycle — The complete series of events which occur until the original positions of all moving parts are restored and recurrence starts. In the four-cycle or four-stroke cycle engine, this requires four strokes of the piston, hence the designation; in the two-cycle engine, only two strokes are needed to complete the cycle.

Cylinder — The cylindrical part of the engine in which the piston moves.

Cylinder cock — A small cock screwed into a cylinder to allow any accumulation of water in the cylinder to escape.

Cylinder head — The part which covers and seals the end of the cylinder and usually contains the valves.

Deckplate — A plate used to form a floor or deck over an open space.

Delivery stroke — The stroke of a pump during which the fluid in the pump is forced out of the cylinder.

Engine — A mechanism for converting the energy in steam, air, or other gas under pressure into mechanical energy in the form of motion. Usually restricted to reciprocating engines having a cylinder, reciprocating piston, and means for causing the gas under pressure to expand alternately on each side of the piston, moving it back and forth in the cylinder. Frequently used as meaning the entire locomotive.

Equalizer — A beam connected at each end to a driving or truck spring, or to the end of another similar beam, for the purpose of distributing the weight of an engine to two or more axles, and to prevent an excessive load being thrown upon one axle by reason of inequalities of the track or roadbed. Also known as equalizing lever or beam or equal beam.

Exhaust pyrometer — An instrument to measure temperature of the exhaust by the electrical energy developed at the junction of two dissimilar metals when exposed to heat.

Expansion period — The portion of the power stroke during which the combustion gases exert pressure on the moving piston and expand while the pressure falls.

Foot-pounds (ft-lbs) — Units in which work is measured; is equivalent to the work of raising one pound vertically a distance of one foot or of moving an object one foot against a resistance of one pound.

Four-stroke cycle — An engine in which the intake, compression, power and exhaust events are completed with four strokes of the piston. In a normal engine, this is accomplished within two revolutions of the crankshaft.

Fulcrum — In mechanics, that by which a lever is sustained or the point on which it moves.

Governor — On engines, the governor is a device whereby the speed is held approximately constant regardless of the load or is kept from exceeding a set predetermined speed within the limits of the engine. This is brought about by the governor altering the amount of fuel introduced into the cylinder.

Heat balance — A tabulation showing the percentage of the heat developed by combustion in the engine cylinder, that is: delivered in the form of power at the crankshaft; lost in friction; lost to the cooling water; lost in the exhaust gases and radiation.

Horsepower — The rate of doing work expressed in terms of 33,000 foot-pounds per minute. This means if a weight of 33,000 pounds was moved one foot in 1 minute, there would have been one horsepower of work done, or if one pound was moved 33,000 feet in 1 minute, it would also be one horsepower.

Inertia — Resistance of the body to motion or change in velocity.

Injection pump — A pump used to inject fuel into the injector.

Journal — As referred to a crankshaft, that part which rests in the main bearing shells.

Journal bearing — A block of metal, usually of brass or bronze, which is in contact with a journal on which the load rests. In locomotive building the term, when unqualified, means an engine or truck axle journal bearing.

Journal box — A cast of malleable iron, or cast steel box or case which encloses the journal of a truck axle, the journal bearing and key, and which holds the packing for lubricating the journal. Also called axle box, grease box, housing box, oil box, and pedestal box, or simply box.

Key— A square or rectangular piece of steel straight or tapering from one and to the other used to secure a collar or flywheel to a shaft.

Keyway— A machined slot in a shaft or hub of a wheel to take a steel key.

Knuckle — (AAR couplers) —The rotating coupling hook by means of which coupling is effected when the knuckle is locked by the catch or lock. It must conform to certain contour lines adopted by the AAR.

Knuckle lock — The device which locks the knuckle and prevents it from being released when a coupling has been made.

Knuckle pin — A pivot on which the knuckle of the coupler turns.

Lands — The portions of the piston between the grooves carrying the piston rings.

Lanova system — A modern form of diesel combustion process in which rapid and complete burning of fuel is attained through the controlled turbulence of great intensity.

Lateral motion — A movement sidewise, more particularly meaning, as generally used, a side or swing motion of the bolster of a swing motion truck, as opposed to the end play of an axle under the journal.

Liner — The inner removable part of the cylinder in contact with the piston.

Load — A term used to indicate the output of the engine.

Locomotive — A self-propelled vehicle running on rails and generating or converting energy into motion for the purpose of hauling cars. A locomotive has no space for a revenue load. It may be operated by steam, electricity, gas from volatile oils, or compressed air.

Lubrication — Term applied to the use of oil, grease, or other substance between moving parts of machinery for reducing friction, resistance, and heating caused by motion of the parts in contact.

Lubricator — Any device, as an oilcup or grease cup, for holding a lubricant and supplying it to wearing surfaces.

Manometer — A U-shaped glass tube, usually partly filled with mercury, employed to measure pressure or vacuum.

Mean effective pressure (mep) — The "mean" is another way of saying average. The mep of any engine is the average pressure in the cylinder during the power stroke.

Mechanical efficiency — The ratio of useful work performed by a machine to the energy expended in producing this work.

Mechanical injection — Same as airless injection. Another way of referring to an injection system of a diesel engine that does not use air as a means of carrying the fuel into the combustion chamber.

Muffler — Sometimes referred to as silencer — used to diminish noise either of the intake or exhaust.

Needle valve — A rod consisting of a long fine point to its spindle, the point just fitting into a hole which its motion opens or closes. Needle valves are designed for standard working pressures to control air, gas, gasoline, or other liquids requiring close regulation.

Nitrogen — A gas that makes up approximately four-fifths of the atmospheric air. Nitrogen will unite with certain substances, but it does not give off heat in so doing.

Nozzle — A device containing one or more small openings through which liquids or gases are ejected under pressure.

Outboard bearing — A bearing located at the end of a shaft.

Oxygen — An odorless, colorless, tasteless gas which comprises 20 percent of the atmosphere and is necessary to support life and combustion.

Packing — A material used to seal a joint against leakage or as a method to apply lubricant to a bearing or bearings.

Piston — A cylindrical part of an engine which reciprocates in the cylinder bore and transmits the force exerted upon its crown to the connecting rod and crank.

Piston crown — The top of the piston.

Piston pin — A pin which rests in two bored holes in the piston and passes through the eye of the connecting rod to join the two together flexibly.

Piston pin bearing — The bearing either in the eye of the connecting rod or in the bored bosses of the piston in which the piston pin oscillates.

Piston rings — Rings of cast iron, which float in grooves of the piston, to seal against gas leakage between the piston and cylinder barrel.

Plunger — The piston of a pump, such as a fuel injection pump.

Preignition — In a gas engine, ignition of the charge before the ignition arc or spark occurs. It is usually caused by a carbon deposit in the cylinder which retained enough heat from the previous power stroke to ignite the fuel charge.

Prony brake — A mechanical device for measuring the torque exerted by an engine for the purpose of calculating its brake horsepower.

Relief valve — A valve, similar to a safety valve, that opens at a predetermined pressure.

Ring grooves — Grooves cut in the piston to hold the piston rings.

Rocker arm — A lever, usually mounted on a shaft on the cylinder head, which has one end resting on the valve stem top and the other on a push rod whose motion lifts the rocker arm which, in turn, pushes the valve open.

Rod, connecting — A rod which transmits the reciprocating motion of the piston the circular motion of the crank.

Rpm — Revolutions per minute.

Sandbox — A receptacle for carrying sand to be used to prevent slipping of the driving wheels. It is operated by a pneumatic sander which allows sand to run through the sandpipes to the rail in front of the drivers. The sandbox is located beneath the running boards or under the engine hood.

Seal — Any method used to prevent leakage.

Shaft — A moving member of the engine, supported by bearings end intended to transmit rotary motion.

Skirt, piston — The lower cylindrical portion of the piston.

Sludge — A tar-like formation in oil resulting from mixing of oxidized oil with water and dirt.

Specific gravity — (1) Weight of solid or liquid as compared with equal volume of pure water at 62° F.; (2) Weight of a gas as compared with equal volume of air under the same condition.

Steam generator — A small boiler used to convert water to low-pressure steam for heating purposes.

Steel — A compound of iron usually with small quantities of silicon and manganese and containing between one-half and three percent of carbon. Steel, unlike wrought iron, can be tempered and retains magnetism. Its malleability decreases and fusibility increases with an increase in carbon.

Stroke — The distance that the piston moves from one end of its path to the other end is called the piston stroke.

Supercharging, or pressure charging — This is the supplying of combustion air to an engine at higher than atmospheric pressure; usually 3 to 5 pounds per square inch gage but as high as 30 pounds in some type engines.

Tachometer — An instrument for indicating rotative speed in terms of revolutions per minute.

Thermal efficiency — The ratio of heat transformed into work to the total heat supplied.

Thermocouple — Strips of dissimilar metals joined (usually welded) at one end. When heated at the joint, a small amount of electrical energy is generated in proportion to the temperature, end these currents, when measured by a millivoltmeter with its scale graduated in degrees, indicate temperature.

Thermostat — A control mechanism whose operation is dependent upon the expansion of heated metal or fluid which is converted into movement and force. This, in turn, actuates devices that control electric circuits, valves, etc., and can be set to operate at definite temperatures.

Throttle — A mechanism used on a diesel-electric locomotive in conjunction with the governor which determines the amount of fuel injected into the cylinders and the power and speed developed.

Top dead center (tdc) — This is the farthest point reached by the piston in its upward movement.

Torque — Usually expressed in foot-pounds, torque is the twisting or turning force developed by the rotating shaft of an engine or motor. The pressure or twisting force of a wrench on a nut is also called torque and is expressed in foot-pounds.

Traction motor — An electric motor that drives an individual axle of a locomotive.

Transfer pump — Any pump employed to transfer liquid from one area to another.

Truck — A metal frame carrying journal boxes and supported on one or more pairs of wheels with their axles mounted under a locomotive, and carrying part of the weight of the locomotive. With the exception of a few designs of rigid trailing trucks, all trucks are made to turn about a central pivot or to allow for side displacement to enable the locomotive to round sharp curves.

Turbulence — A high-velocity swirling of air-fuel vapor or a mixture of both within the combustion chamber or cylinder.

Two cycle (properly two-stroke cycle) — An engine operating method utilizing a regularly ropeated series, or cycle, of events, each cycle completed in two strokes of the piston, providing a power impulse per cylinder for each shaft revolution. One stroke includes the last part of the scavenging and all of the compression phases; the other, expansion, exhaust, and the early part of scavenging period.

Valve, spray — A valve which sprays the fuel charge injected into the engine cylinder.

Vanes — Baffles employed to deflect currents of air of gas.

Viscosity — Resistance to flow, measured by a number of systems (Saybolt-Furol, Saybolt-Universal, Engler, Redwood-Admirality, etc.) and rated by the number of seconds required for a definite quantity to flow through a standard orifice under stated test conditions.

Viscosity index — A number given to a certain lubricating oil to indicate the oil's performance under certain temperature variations.

Water jacket — An outer metallic casting forming a space around the cylinder liners to permit the passage of water for cooling purposes.

Wheel — A circular disk, mounted on an axle, serving to support a moving vehicle. Wheels used on railroad equipment are sometimes made of chilled cast iron but are more commonly of wrought steeel.

Wheel flange — The projecting edge or rim of the periphery of a wheel for keeping it on the rail.

Section II. ELECTRICAL TERMS

(Some of these terms are used in connection with diesel-electric transmission.)

Airgap — An air-filled gap in a magnetic or electric circuit in a dynamo or motor; the space between the field magnetic poles and the armature.

Ampere — A unit which indicates the rate of flow of electric current.

Arc — An electrical arc is the visible flow of electrical current between conducting pieces separated by air or other gases.

Arc chutes — Usually a box-like structure made of insulating and heat-resisting materials to confine and direct an electric arc formed when contactors or switches open an electric circuit.

Arc horn — A horn-shaped extension attached to a circuit-making contact of a contactor or switch for the purpose of elongating and extinguishing the arc formed when opening an electric circuit.

Armature — This term is usually applied to mean the rotating part of a direct current generator or motor, but is also applied to mean that part of a contactor or relay which is caused to move by magnetic force.

Auxiliary generator — A generator of electric power which is to be used for driving the auxiliary equipment of diesel motive power.

Bands — A wrapping of high tensile strength wire around the armature of a generator or motor to hold the coils or other parts in place against the centrifugal forces of rotation.

Blowout coil — A coil inserted below the reversing drum for blowing out the electric arc between the contact fingers and the drum strips whenever the circuit is broken.

Brush — A device used for pressing against a rotating part of a generator or motor in order to pass current from the stationary to the rotating portions or vice versa. These brushes are usually made of carbon or graphite.

Carbon — One of the nonmetallic elements. In a prepared form, it may be a brush or electrode.

Carbon pile — A group of carbon disks so arranged that by compressing a stack of these disks the electrical resistance from one end of the stack to the other is reduced. When the pressure on the stack is reduced, the resistance rises. This is one means of obtaining a variable resistance.

Circuit — The course followed by an electric current passing from its source through a succession of conductors and then returning again to its place of origin.

Coil — Successive turns of insulated wire which create a magnetic field when an electric current passes through.

Commutating field — An auxiliary flux developed at the point where the armature coils are short circuited by the brush. It is used to eliminate excessive sparking by helping reverse the current in each short-circuited coil.

Commutating pole — A steel pole piece with a coil for producing a commutating magnetic field.

Commutator — A device used to reverse the direction of electric currents in any circuit.

Compound field winding — A combination of series, shunt, and/or separately excited field coils for magnetizing a field pole.

Condenser — Two electrical conductors, when placed parallel to each other as closely as possible and separated by an insulator, have the characteristic of an electric reservoir and are capable of absorbing and holding considerable energy. A device built especially for this purpose is called a condenser and usually consists of large areas of sheets of metal foil separated by an insulating medium such as mica or paper and rolled into a small space.

Conductor — Any device, wire, bar, or any material which readily conducts electrical current.

Contactor — A device for making or breaking an electrical circuit and usually actuated by the pull of magnetism. In its usual form, it consists of a stationary coil surrounding a steel core and an armature moved by magnetism of the core whenever an electric current flows through the coil. The armature carries a moving contact piece which strikes and completes an electrical circuit through a stationary contact piece. While a relay may accomplish this same function in a similar manner, the term contactor is usually applied where the currents passing through the contact pieces are of appreciable values.

Control generator — A small generator driven by the main diesel engine speed and, thus, to actuate the control system to increase or decrease the electrical load correspondingly.

Controller — A device, usually manually operated, by means of which the operator of the locomotive or rail car can increase or decrease the applied power, make transition, and determine direction.

Cumulative field winding — On a single magnetic circuit encircled by series, shunt, and/or separately excited coils; if all coils tend to magnetize the circuit in the same direction, the windings are said to be cumulative.

Current — The flow of electrical energy in a circuit. *See* ampere, the unit of current.

Differential control — A system of control whereby the loading of the diesel engine is regulated by means of a differential field winding applied to the main generator or to the exciter of the main generator.

Differential field winding — In a combination of series, shunt, and/or separately excited field coils, an arrangement such as one tending to magnetize the field pole in a direction opposite to the magnetization of the others.

Direct current — An electrical power system in which the electrical current flow is continuously in the same direction.

Drawbar pull — The actual pulling power of a locomotive, less the effort necessary to move the locomotive.

Drum — A cylindrical device carrying contact plates and so arranged that by its rotation circuit changes are made.

Eddy current — Local circulating current generated in conductors or machine structures, usually serving no useful purposes.

End windings — That portion of the armature coils of a generator or motor which extends beyond the armature iron at either end.

Energize — To apply electrical voltage to a circuit, coil, or other device.

Excite — To pass current through a coil for the purpose of creating a magnetic field.

Exciter — A generator especially designed to produce the electric current required for exciting another generator.

Field — The region where magnetic forces act—also known as the magnetic field.

Flashover — An arc occurring between two points not supposed to be directly connected, such as from one brush holder to the next brush holder of a motor or generator, or across an insulator separating one conductor from another or from ground.

Fuse — A fusible link connected in a circuit so that when an excessive current flows, the link will melt and will break the electrical circuit.

Generator — A general term given to a machine that transforms mechanical energy into electrical energy.

Ground — A connection from an electrical circuit to a grounded part.

Insulation — Material which does not readily pass electric current. An assembly of materials and devices for insulating a circuit.

Interlock — A secondary electrical contact-making or contact-breaking device applied to a contactor or switch for the purpose of altering the control circuits depending upon whether the switch is open or closed.

Interpole — Commutating pole.

Jumper — A removable electrical connector usually used for bypassing a portion of an electrical circuit. Also a device used between units of a train for coupling or uncoupling electrical circuits carried from unit to unit.

Kilowatt — A unit of power. 1,000 watts. 1.34 horsepower.

Knife switch — A switch consisting of one or more bare hinged blades, making contact edgewise with stationary jaws.

Lead — A conductor leading current to or from an electrical device. Usually applied to flexible wire, cable, etc.

Load control — A system of control whereby the loading of the diesel engine is regulated by the speed of the engine itself, this speed reflecting the load conditions of the engine.

Magnetic blowout — Provision of a magnetic field surrounding the contact jaws of a contactor or switch so that the arc which forms when a circuit is opened is stretched and extinguished. *See* blowout coil.

Magnetic field — Normally means the region where magnetic forces are acting.

Magnetic flux — The average field intensity of a magnet, multiplied by its area.

Magnetic line of force — Indicating the direction of action of magnetic forces.

Megger — An instrument used for the measurement of insulation resistance. Since such resistance to the passage of electrical current is generally in the range of millions of ohms (megohms) the instrument derives its name therefrom.

Megohm — A large unit of resistance— a million ohms.

Motor — An electrical machine having electrical conductors rotating past magnetic poles so that electrical energy may be converted into mechanical energy.

Multiple — As pertaining to electricity, designating a circuit having a number of conductors in parallel. As applied to engines, the operation of more than one motive power unit simultaneously by one operator.

Negative — Usually considered as the point toward which electrical current flows.

Neutral — That zone on the commutator of a generator or motor where the voltage between bars is at minimum. This zone is normally stationary in respect to the field poles even though the commutator is rotating.

Ohm — The unit of electrical resistance. An electrical conductor is said to have a resistance of one ohm if a current of one ampere flows when one volt is impressed across the conductor.

Ohm's law — Volts = Amperes x Ohms.

Parallel — Side by side. A method of connecting an electrical system in which all of the positive poles or terminals are connected to one conductor and all of the negative poles to another conductor.

Pigtail — A flexible conductor of short length attached to a contact brush for conducting electricity to or from the device.

Pole — Usually a projection of steel provided with a coil for producing magnetism in a motor or generator. A conductor or lead or a circuit acted upon by a switch.

Pole piece — The steel portion of a magnetic pole.

Positive pole — Usually considered as the point of source from which electrical current originates or flows.

Receptacle — Usually a stationary device housing electrical terminals so arranged that electrical connections may be made to these terminals by inserting a plug or jumper head. Normally used for connecting external circuits to a locomotive or rail car for battery charging or for multiple operation of motive power units. Also the base for electric lamp bulbs.

Regulator — An automatic or hand-operated device whose function is to regulate the voltage of a circuit, the output of a given machine, or to maintain other conditions within prescribed limits.

Relay — An electrical device which operates under one set of predetermined electrical conditions in other parts of the circuit or other electrical circuits. Relays may be of various types, the title usually being indicative of their functions, such as voltage relay, reverse current relay, transition relay, overload relay, regulating relay, etc.

Residual magnetism — When a piece of iron or steel is magnetized and then the magnetizing force is removed, some magnetic effect is still retained by the metal. This known as its residual magnetism.

Resistance — The property of a conductor or material which opposes the flow of current when voltage is applied and which converts electrical energy into heat. The unit of resistance is the ohm.

Resistor — An assembly of conductors having relatively high resistance characteristics built to connect in a circuit as desired to limit or control the current flow.

Reverser — A control device used for altering the electrical connections of traction motors to obtain reverse movement of a motive power unit. This is usually of the drum type.

Rheostat — A resistor arranged for convenient variation of the resistance values.

Saturation — The total amount of magnetic force that may be permanently imparted to the core of a magnet.

Season — To alternately heat and cool and tighten a commutator assembly so that actual heating and cooling of service cycles will not allow the assembly to loosen or distort and thus change its cylindrical shape.

Series circuit — The connection of two or more pieces of electrical apparatus in succession so that the flow of current is first through one and then through the others in turn. For instance, if two motors are connected in series with a source of power, current first flows through No. 1 motor and then through No. 2 motor before returning to its source.

Series field — A field winding connected in series with the armature of the machine itself or in series with the armature of a main generator.

Series motor — A type of motor in which the field coils are connected in series with the motor armature. This motor is self-protecting to some extent since a rise in current through the armature is accompanied by the same rise in the field. Since motor torque depends upon armature current and field strength, a relatively small rise in current results in a large increase in torque.

Short circuit—To short a circuit means to introduce a relatively low resistance path in place of the normal higher resistance path. A short circuit usually refers to an accidental and possibly a damaging bypassing of such normal circuit resistance.

Short field—An arrangement of a traction motor field whereby the number of turns connected in the circuit may be reduced to weaken the field strength. This tends to increase the motor speed.

Shunt—(1) A device for diverting a portion of the current from a part of an electrical circuit.

(2) A piece of electrical apparatus used in connection with a meter or instrument so that the main current passes through the shunt with only a small portion passing through the meter or instrument.

(3) To shunt a portion of an electrical circuit means to connect a shunt around it. This is usually applied to the field of a traction motor.

Note. Perhaps no electrical term is used with as many meanings as the word shunt. Many electrical men often refer to any field winding of low ampere capacity and many turns as a shunt field even though it may be separately excited. Then there are field shunt (not shunt field), brush shunt, switch shunt, shunt transition, and many other uses too numerous to mention or define.

Shunt field—The field of a motor or generator which is energized by being connected directly between the positive and the negative terminals of the machine.

Shunted field—A field around which a shunt has been connected to divert a portion of the current normally passing through the field. This is usually for the purpose of increasing traction motor speed.

Solenoid—An electric coil, usually of many turns, used for the generation of a magnetic flux.

Spider—A permanent support for an armature assembly, also for a commutator assembly, so that the alinement of insulation and windings need not be disturbed in replacing an armature shaft.

Split pole control—A system of differenertial field control which follows the principles embodied in all differential control exciters except that two rows of field poles are required to accomplish the results obtained by the single row of poles in the machine.

Switch—A device for opening and closing an electrical circuit. The name usually describes the construction or purpose, such as knife switch, toggle switch, pneumatic switch, magnetic switch, battery switch, cutout switch, selector switch, etc.

Torque control—The first system of load control, wherein the engine is loaded to its full permissible torque by gaging the rise or fall in engine speed. A control generator reflects engine speed and causes a load regulator to operate to increase the electrical load if the engine speed is high and vice versa.

Traction motor—An electric motor that drives an individual axle of a locomotive.

Tractive effort—The torque in pounds developed at the rim of the wheels divided by the total train weight in tons. It depends upon the rate of acceleration, grade, car friction, and air resistance.

Tractive force—The force exerted at the rims of the driving wheels of a motive-power unit for propulsion.

Tractive power—The power developed at the rims of the drivers of a motive-power unit. Very frequently misused to mean tractive force. Tractive power involves both traction and speed, whereas tractive force may be independent of speed.

Trainline—Electrical circuits passing from one vehicle to another of a train.

Transition—A change from one system of electrical connections to another. Usually applied to the change from series connection of traction motors to parallel connections.

Unit switch—A term describing pneumatically-operated switches for use in the main power circuits of railway vehicles.

Unloading point—Diesel engines may be

kept fully loaded over a wide range of train speeds by an electrical transmission system. However, when the generator reaches its maximum voltage, there is a tendency for the engine to become slightly unloaded as the train speed increases unless alterations are made in the motor connections. This is called the unloading point or unloading speed.

Volt — The unit of electrical pressure. A term used in place of electromotive force.

Watt — This is the unit of electrical power and equals one volt multiplied by one ampere. To determine the power of a circuit, multiply the volts across the circuit by the amperes flowing (in direct current circuits). 746 watts equals 1 horsepower.

Weight transfer compensation — When tractive force is applied to the rims of the drivers for moving a locomotive or rail car, the resultant forces tend to lift weight from the forward drivers and increase the weight on the rear ones. This is called weight transfer. Since the maximum tractive force which may be exerted by a motive power unit is limited by the slipping point of the wheels on the rails, it follows that if all traction motors develop the same tractive force, the total is limited by the most lightly weighted pair of drivers. By weakening the fields of the forward traction motors and passing increased current through the rear motors, the differential in weight is sometimes compensated for. This is called weight transfer compensation.

Winding — The system of electrical conductors within a given machine or piece of apparatus.

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Active Army:

DCSOPS (2)
DCSLOG (2)
COA (1)
CRD (1)
ACSI (1)
CORC (1)
ACSFOR (2)
CNGB (1)
CofEngrs (2)
CofSptS (2)
USCONARC (10)
USAMC (2)
USACDCTA (2)
LOGCOMD (2)
USAMB (2)
USAMOCOM (2)
USAMEC (5)
Armies (5)
Instl (1)
TOAD (2)
USATC Mb1 Shop Tms (2)
USATSCH (50)
Units org under fol TOE:
55-201 (2)
55-202 (2)
55-203 (2)
55-225 (2)
55-226 (2)
55-228 (10)
55-247 (10)

NG: None.
USAR: None.
For explanation of abbreviations used, see AR 320-50.

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