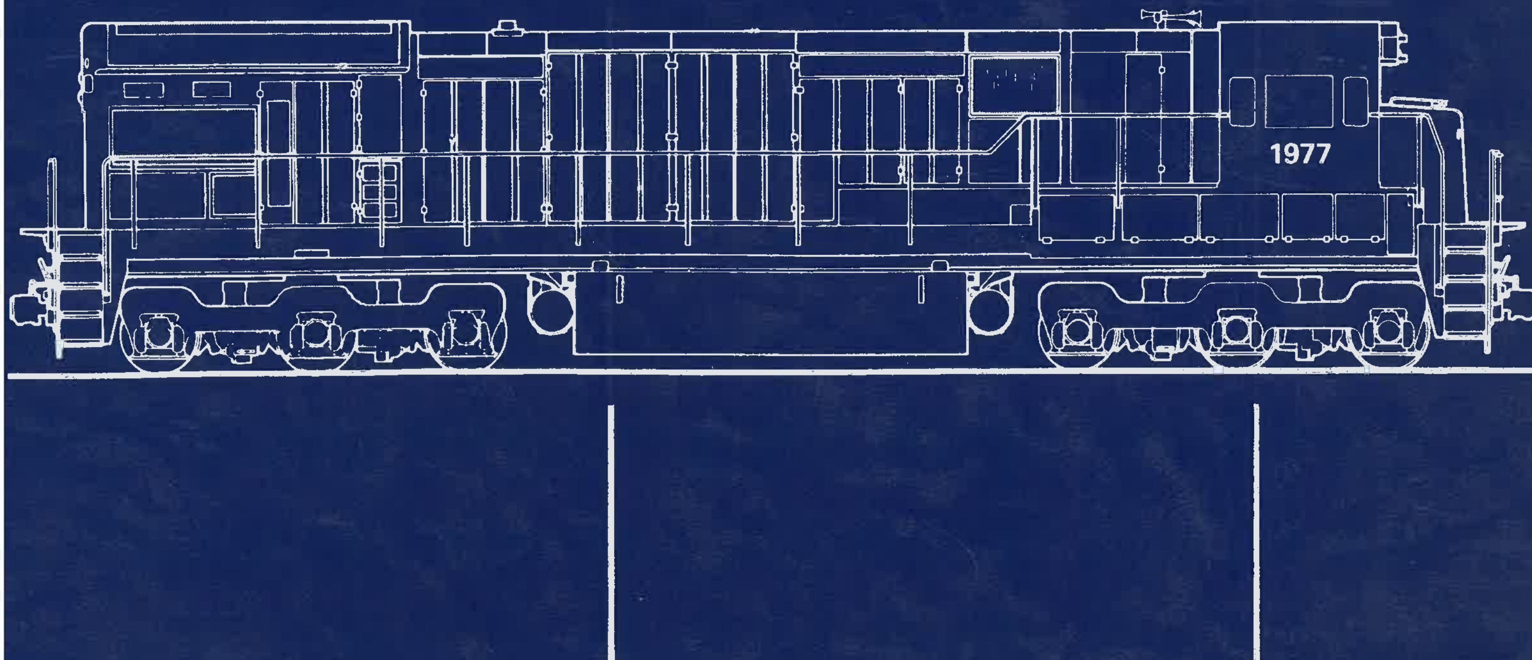
Locomotive Service Manual

Running Maintenance and Trouble-Shooting

for

Series-7

Road Locomotives



GENERAL ELECTRIC

GEK-30150
First Edition
August, 1978

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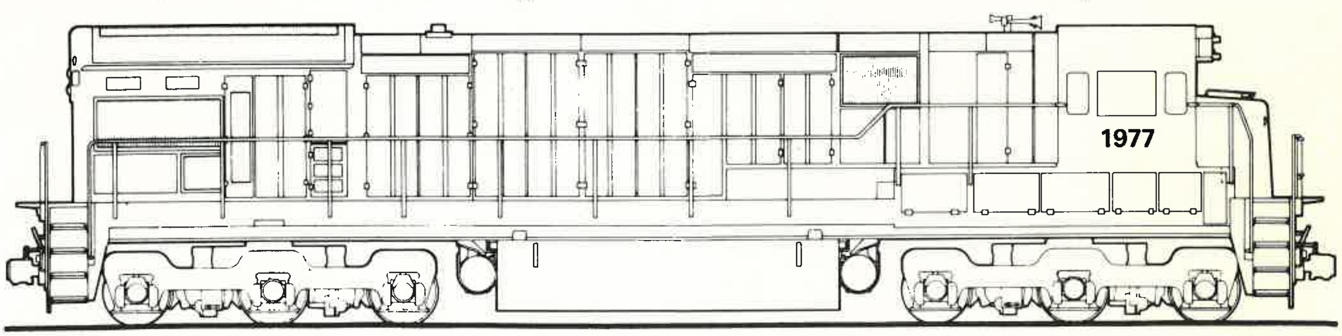

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FOREWORD

This manual is for personnel performing running maintenance on General Electric's Series-7 (built since January, 1977) Locomotives. Running maintenance consists of such work as terminal servicing, minor repair and adjustments, interchanging small components, or any work which will restore the locomotive to service with a minimum of time and repair equipment.

Care has been taken in compiling the material to include those items and methods that will be of the greatest use to the maintainer in his daily activities. The manual includes service information pertaining to major equipments and systems of the standard Series-7 Locomotive. Variations will exist between different models of locomotives and between railroad customers. Instructions on specific customer modifications are not included here but are part of the maintenance manuals furnished to the customer.

The manual is divided into 13 sections. Each section will be revised periodically to include applicable customer comments and engineering changes. We welcome any comments on the accuracy and thoroughness of this manual. This will enable us to provide you, the customer, with the best and latest information. Please forward all comments to General Electric Co., Maintenance Engineering and Education, 2901 East Lake Road, Erie, PA, 16531.

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LOCOMOTIVE SERVICE MANUAL

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INTRODUCTION

This section presents general information for Series-7 Locomotives. For more detailed data, refer to the overall maintenance manual furnished with the applicable model of locomotive.

SERIES-7 LOCOMOTIVES

General Electric's standard line of locomotives is shown in Fig. I-1. The Company has made a change in locomotive nomenclature, abandoning the traditional U-designation for an identification system felt to be more meaningful. The change in nomenclature applies across the standard domestic line.

As in the past, the letter still indicates the number of axles i.e., "B" is the standard two-axle two-motor truck, and "C" indicates a three-axle three-motor truck. The number following the truck identification represents the horsepower input for traction. The last number, in this case, "7," indicates the first model year i.e., 197"7."

The Series-7 retains the standard locomotive underframes and diesel engines. The 7FDL8 engine for the 1800 hp class; the 7FDL12 engine for the 2250 and 2750 hp class; and the 7FDL16 for the 3000, 3300 and 3600 hp class.

The 7FDL8 is an 8-cylinder engine, the 7FDL12 is a 12-cylinder engine and the 7FDL16 is a 16-cylinder engine.

GENERAL DATA

Table I-I lists the general data for each Series-7 locomotive model.

CONVERSION FACTORS

U.S. WEIGHTS AND MEASURES

Measures of Length

1 mile = 1760 yards = 5280 feet.
1 yard = 3 feet = 36 inches.
1 foot = 12 inches.
1 mil = 0.001 inch.
1 fathom = 2 yards = 6 feet.
1 rod = 5.5 yards = 16.5 feet.
1 hand = 4 inches.
1 span = 9 inches.
1 micro-inch = one millionth inch or 0.000001 inch.
(1 micron = One millionth meter = 0.00003937 inch.)

Surveyor's Measure

1 mile = 8 furlongs = 80 chains.
1 furlong = 10 chains = 220 yards.
1 chain = 4 rods = 22 yards = 66 feet = 100 links.
1 link = 7.92 inches.

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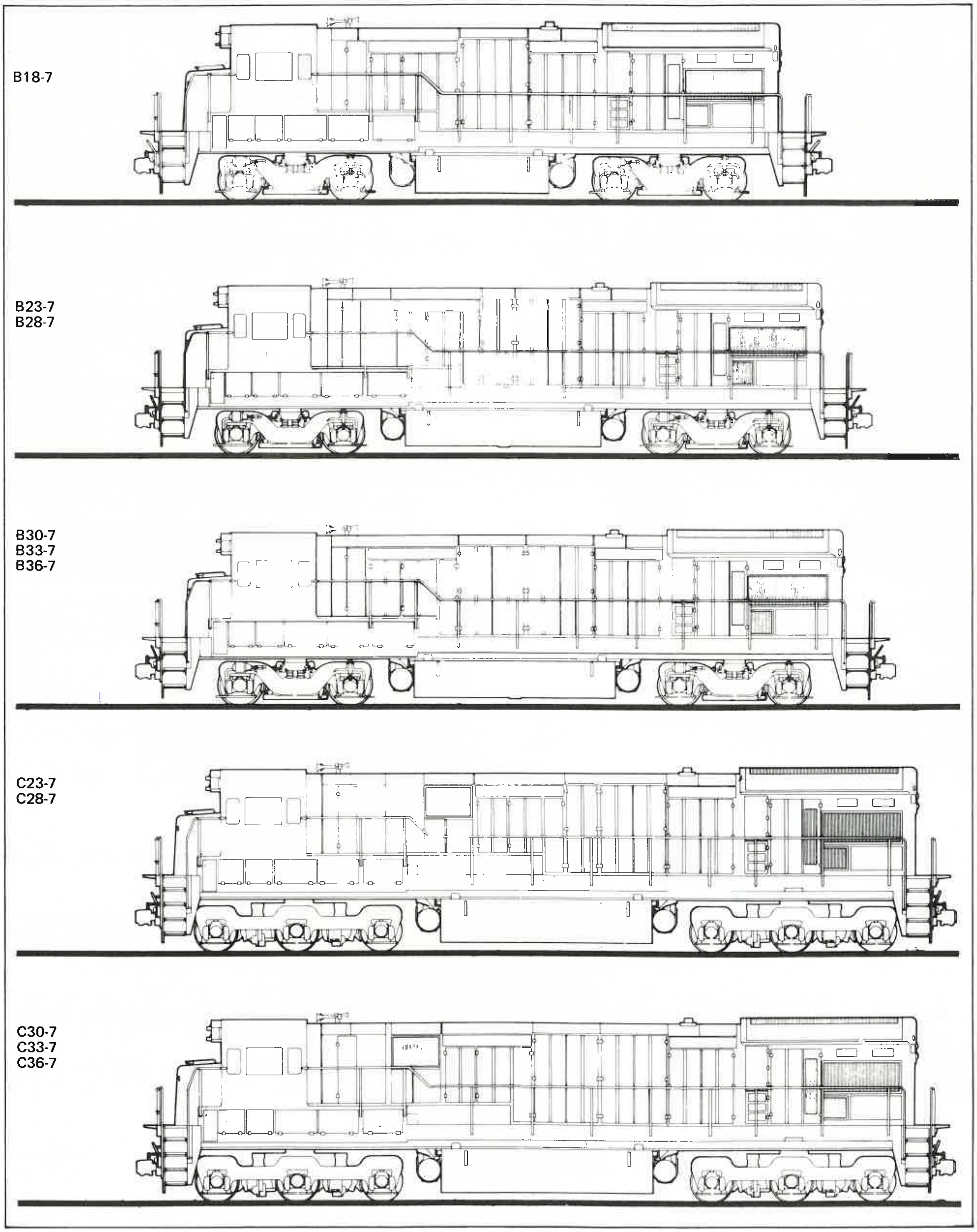

FIG. I-1, E-24520

FIG. I-1. SERIES-7 LOCOMOTIVES.

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TABLE I-I, GENERAL DATA

	Model								
	B18-7	B23-7	C23-7	B28-7	C28-7	B30-7	C30-7	B36-7	C36-7
Horsepower (Net)	1800	2250	2250	2750	2750	3000	3000	3600	3600
Type (ARR Symbol)	B-B	B-B	C-C	B-B	C-C	B-B	C-C	B-B	C-C
Engine	GE-FDL8	GE-FDL12	GE-FDL12	GE-FDL12	GE-FDL12	GE-FDL16	GE-FDL16	GE-FDL16	GE-FDL16
Major Dimensions									
Length	56 ft.-8 in.	62 ft.-2 in.	67 ft.-3 in.	62 ft.-2 in.	67 ft.-3 in.	62 ft.-2 in.	67 ft.-3 in.	62 ft.-2 in.	67 ft.-3 in.
Width	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.	10 ft.-3-1/4 in.
Height	14 ft.-9-1/4 in.	14 ft.-9-1/4 in.	15 ft.-4-1/4 in.	14 ft.-9-1/4 in.	15 ft.-4-1/4 in.	14 ft.-9-1/4 in.	15 ft.-4-1/4 in.	14 ft.-9-1/4 in.	15 ft.-4-1/4 in.
Length Between Bolster Centers	30 ft.-8 in.	36 ft.-2 in.	40 ft.-11 in.	36 ft.-2 in.	40 ft.-11 in.	36 ft.-2 in.	40 ft.-11 in.	36 ft.-2 in.	40 ft.-11 in.
Truck Wheel Base	9 ft.-0 in.	9 ft.-0 in.	13 ft.-7 in.	9 ft.-0 in.	13 ft.-7 in.	9 ft.-0 in.	13 ft.-7 in.	9 ft.-0 in.	13 ft.-7 in.
Minimum Curve									
Locomotive Alone	150 ft. or 39°	150 ft. or 39°	273 ft. or 21°	150 ft. or 39°	273 ft. or 21°	150 ft. or 39°	273 ft. or 21°	150 ft. or 39°	273 ft. or 21°
Coupled to Train	250 ft. or 23°	250 ft. or 23°	273 ft. or 21°	250 ft. or 23°	273 ft. or 21°	250 ft. or 23°	273 ft. or 21°	250 ft. or 23°	273 ft. or 21°
Drive									
Traction Motors	Four GE-752	Four GE-752	Six GE-752	Four GE-752	Six GE-752	Four GE-752	Six GE-752	Four GE-752	Six GE-752
Wheel Diameter	40 in.	40 in.	40 in.	40 in.	40 in.	40 in.	40 in.	40 in.	40 in.
Weight (Typical)									
Minimum	230,600 lb.	253,000 lb.	359,000 lb.	253,000 lb.	359,000 lb.	259,000 lb.	366,000 lb.	259,800 lb.	366,600 lb.
Maximum	268,000 lb.	280,000 lb.	420,000 lb.	280,000 lb.	420,000 lb.	280,000 lb.	420,000 lb.	280,000 lb.	420,000 lb.
Supplies									
Fuel Min./Max.	1200/2150 gal.	2150/3250 gal.	3250/4000 gal.	2150/3250 gal.	3250/4000 gal.	2150/3250 gal.	3250/4000 gal.	2150/3250 gal.	3250/4000 gal.
Cooling Water	335 gal.	350 gal.	350 gal.	350 gal.	350 gal.	365 gal.	365 gal.	365 gal.	365 gal.
Lubricating Oil	245 gal.	300 gal.	300 gal.	300 gal.	300 gal.	380 gal.	380 gal.	380 gal.	380 gal.
Governor Oil	2 qt.	2 qt.	2 qt.	2 qt.	2 qt.	2 qt.	2 qt.	2 qt.	2 qt.
Sand	60 cu. ft.	60 cu. ft.	60 cu. ft.	60 cu. ft.	60 cu. ft.	60 cu. ft.	60 cu. ft.	60 cu. ft.	60 cu. ft.

Square Measure

1 square mile = 640 acres = 6400 square chains.
1 acre = 10 square chains = 4840 square yards = 43,560 square feet.
1 square chain = 16 square rods = 484 square yards = 4356 square feet.
1 square rod = 30.25 square yards = 272.25 square feet = 625 square links.
1 square yard = 9 square feet.
1 square foot = 144 square inches.

An acre is equal to a square, the side of which is 208.7 feet.

Measure Used for Diameters and Areas of Electric Wires

1 circular inch = area of circle 1 inch in diameter = 0.7854 square inch.
1 circular inch = 1,000,000 circular mils.
1 square inch = 1.2732 circular inch = 1,273,239 circular mils.

A circular mil is the area of a circle 0.001 inch in diameter.

Cubic Measure

1 cubic yard = 27 cubic feet.
1 cubic foot = 1728 cubic inches.

The following measures are also used for wood and masonry:

1 cord of wood = 4 x 4 x 8 feet = 128 cubic feet.
1 perch of masonry = 16-1/2 x 1-1/2 x 1 foot = 24-3/4 cubic feet.

Liquid Measure

1 U.S. gallon = 0.1337 cubic foot = 231 cubic inches = 4 quarts = 8 pints.
1 quart = 2 pints = 8 gills.
1 pint = 4 gills.
1 British Imperial gallon = 1.2009 U.S. gallon = 277.42 cubic inches.
1 cubic foot = 7.48 U.S. gallons.

Measures of Weight (Avoirdupois or Commercial Weight)

1 gross or long ton = 2240 pounds.
1 net or short ton = 2000 pounds.
1 pound = 16 ounces = 7000 grains.
1 ounce = 16 drachms = 437.5 grains.

Measures of Pressure

1 pound per square inch = 144 pounds per square foot = 0.068 atmosphere = 2.042 inches of mercury at 62 degrees F = 27.7 inches of water at 62 degrees F = 2.31 feet of water at 62 degrees F.
1 atmosphere = 30 inches of mercury at 62 degrees F = 14.7 pounds per square inch = 2116.3 pounds per square foot = 33.95 feet of water at 62 degrees F.
1 foot of water at 62 degrees F = 62.355 pounds per square foot = 0.433 pound per square inch.
1 inch of mercury at 62 degrees F = 1.132 foot of water = 13.58 inches of water = 0.491 pound per square inch.

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METRIC SYSTEM OF MEASUREMENT

In the metric system of measurements, the principal unit for length is the meter; the principal unit for capacity, the liter; and the principal unit for weight, the gram. The following prefixes are used for subdivisions and multiples: milli = 1/1000; centi = 1/100; deci = 1/10; deka = 10; hecto = 100; kilo = 1000. In abbreviations, both the subdivisions and the multiples are used with a small or lower case letter.

All the multiples and subdivisions are not used commercially. Those ordinarily used for length are kilometer, meter, centimeter and millimeter; for capacity, square meter, square centimeter, and square millimeter; for cubic measures, cubic meter, cubic decimeter (liter), cubic centimeter, and cubic millimeter. The most commonly used weights are the kilogram and gram.

Measures of Length

10 millimeters (mm)	= 1 centimeter (cm).
10 centimeters	= 1 decimeter (dm).
10 decimeters	= 1 meter (m).
1000 meters	= 1 kilometer (km).

Square Measure

100 square millimeters (mm^2)	= 1 square centimeter (cm^2).
100 square centimeters	= 1 square decimeter (dm^2).
100 square decimeters	= 1 square meter (m^2).

Surveyor's Square Measure

100 square meters (m^2)	= 1 are (a).
100 ares	= 1 hectare (ha).
100 hectares	= 1 square kilometer (km^2).

Cubic Measure

1000 cubic millimeters (mm^3)	= 1 cubic centimeter (cm^3).
1000 cubic centimeters	= 1 cubic decimeter (dm^3).
1000 cubic decimeters	= 1 cubic meter (m^3).

Dry and Liquid Measure

10 milliliters (ml)	= 1 centiliter (cl).
10 centiliters	= 1 deciliter (dl).
10 deciliters	= 1 liter (l).
100 liters	= 1 hectoliter (hl).

1 liter = 1 cubic decimeter = the volume of 1 kilogram of pure water at a temperature of 39.2 degress F.

Measures of Weight

10 milligrams (mg)	= 1 centigram (cg).
10 centigrams	= 1 decigram (dg).
10 decigrams	= 1 gram (g).
10 grams	= 1 dekagram (dag).
10 dekagrams	= 1 hectogram (hg).
10 hectograms	= 1 kilogram (kg).
1000 kilograms	= 1 (metric) ton (t).

Metric and English Conversion Table

Linear Measure

1 kilometer = 0.6214 mile.	1 mile = 1.609 kilometers.
1 meter = 39.37 inches.	1 yard = 0.9144 meter.
1 meter = 3.2808 feet.	1 foot = 0.3048 meter.
1 meter = 1.0936 yards.	1 foot = 304.8 millimeters.
1 centimeter = 0.3937 inch.	1 inch = 2.54 centimeters.
1 millimeter = 0.03937 inch.	1 inch = 25.4 millimeters.

Square Measure

1 square kilometer = 0.3861 square mile = 247.1 acres.
1 hectare = 2.471 acres = 107,639 square feet.
1 are = 0.0247 acre = 1076.4 square feet.
1 square meter = 10.764 square feet = 1.196 square yards.
1 square centimeter = 0.155 square inch.
1 square millimeter = 0.00155 square inch.

1 square mile = 2.5899 square kilometers.
1 acre = 0.4047 hectare = 40.47 ares.
1 square yard = 0.836 square meter.
1 square foot = 0.0929 square meter = 929 square centimeters.
1 square inch = 6.452 square centimeters = 645.2 square millimeters.

Cubic Measure

1 cubic meter = 35.315 cubic feet = 1.308 cubic yards.
1 cubic meter = 264.2 U.S. gallons.
1 cubic centimeter = 0.061 cubic inch.
1 liter (cubic decimeter) = 0.0353 cubic foot = 61.023 cubic inches.
1 liter = 0.2642 U.S. gallon = 1.0567 U.S. quarts.

1 cubic yard = 0.7646 cubic meter.
1 cubic foot = 0.02832 cubic meter = 28.317 liters.
1 cubic inch = 16.38706 cubic centimeters.
1 U.S. gallon = 3.785 liters.
1 U.S. quart = 0.946 liter.

Weight

1 metric ton = 0.9842 ton (of 2240 pounds) = 2204.6 pounds.
1 kilogram = 2.2046 pounds = 35.274 ounces avoirdupois.
1 gram = 0.03215 ounce troy = 0.03527 ounce avoirdupois.
1 gram = 15.432 grains.

1 ton (of 2240 pounds) = 1.016 metric ton = 1016 kilograms.
1 pound = 0.4536 kilogram = 453.6 grams.
1 ounce avoirdupois = 28.35 grams.
1 ounce troy = 31.103 grams.
1 grain = 0.0648 gram.

1 kilogram per square millimeter = 1422.32 pounds per square inch.
1 kilogram per square centimeter = 14.223 pounds per square inch.
1 kilogram-meter = 7.233 pounds-foot.
1 pound per square inch = 0.0703 kilogram per square centimeter.
1 calorie (kilogram calorie) = 3.968 Btu (British thermal unit).

POWER AND HEAT EQUIVALENTS

1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2545 Btu (British thermal unit) = 2.64 pounds of water evaporated at 212 F = 17 pounds of water raised from 62 to 212 F.
1 kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,655,200 foot-pounds = 3,600,000 joules = 3415 Btu = 3.54 pounds of water evaporated at 212 F = 22.8 pounds of water raised from 62 to 212 F.
1 horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2545 Btu per hour = 42.4 Btu per minute = 0.71 Btu per second = 2.64 lbs. of water evaporated per hour at 212 F.
1 kilowatt = 1000 watts = 1.34 horsepower = 2,655,200 foot-pounds per hour = 44,200 foot-pounds per minute = 737 foot-pounds per second = 3415 Btu per hour = 57 Btu per minute = 0.95 Btu per second = 3.54 pounds of water evaporated per hour at 212 F.
1 watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 Btu per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 3.54 pounds of water evaporated per hour at 212 F.
1 Btu = 1052 watt-seconds = 778 foot-pounds = 0.252 kilogram-calorie = 0.000292 kilowatt-hour = 0.000393 horsepower-hour = 0.00104 pound of water evaporated at 212 F.
1 foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 Btu = 0.0000005 horsepower-hour.
1 joule = 1 watt-second = 0.000000278 kilowatt-hour = 0.00095 Btu = 0.74 foot-pound.

TEMPERATURE CONVERSION TABLE

Thermometer Scales

There are three thermometer scales in general use: the Fahrenheit (F), which is generally used in the English speaking countries; the Centigrade (C) or Celsius, which is used in several continental countries and in scientific work; and the Réaumur (R), which is used to some extent on the European continent.

In the Fahrenheit thermometer, the freezing point of water is marked at 32 degrees on the scale and the boiling point, at atmospheric pressure, at 212 degrees. The distance between these two points is divided into 180 degrees. On the Centigrade scale, the freezing point of water is at 0 degrees and the boiling point at 100 degrees. On the Réaumur scale, the freezing point is at 0 degrees and the boiling point at 80 degress. The following formulas may be used for converting temperatures given on any one of the scales to the other scales:

Degrees Fahrenheit =

$$\frac{9 \text{ x degrees C}}{5} + 32 = \frac{9 \text{ x degrees R}}{4} + 32.$$

Degrees Centigrade =

$$\frac{5 \text{ x (degrees F} - 32)}{9} = \frac{5 \text{ x degrees R}}{4}$$

Degrees Réaumur =

$$\frac{4 \text{ x degrees C}}{5} = \frac{4 \text{ x (degrees F} - 32)}{9}$$

Table I-II is for converting degrees Centigrade into degrees Fahrenheit. The tables can, of course, be conveniently used in the reverse order.

Absolute Temperature and Absolute Zero

A point has been determined on the thermometer scale, by theoretical considerations, which is called the absolute zero and beyond which a further decrease in temperature is inconceivable. This point is located at −273.2 degrees Centigrade or 459.7 degrees Fahrenheit. A temperature reckoned from this point, instead of from zero on the oridinary thermometers, is called absolute temperature. Absolute temperature in degrees C is known as "degrees Kelvin" or the "Kelvin scale" (K) and absolute temperature in degrees F is known as "degrees Rankine" or the "Rankine scale" (R).

Degrees Kelvin = degrees C + 273.2

Degrees Rankine = degrees F + 459.7

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TABLE I-II, COMPARISON BETWEEN CENTIGRADE AND FAHRENHEIT

Deg. C	Deg. F	Deg. C	Deg. F	Deg. C	Deg. F	Deg. C	Deg. F	Deg. C	Deg. F	Deg. C	Deg. F
–40	–40.0	8	46.4	56	132.8	104	219.2	152	305.6	200	392.0
–39	–38.2	9	48.2	57	134.6	105	221.0	153	307.4	201	393.8
–38	–36.4	10	50.0	58	136.4	106	222.8	154	309.2	202	395.6
–37	–34.6	11	51.8	59	138.2	107	224.6	155	311.0	203	397.4
–36	–32.8	12	53.6	60	140.0	108	226.4	156	312.8	204	399.2
–35	–31.0	13	55.4	61	141.8	109	228.2	157	314.6	205	401.0
–34	–29.2	14	57.2	62	143.6	110	230.0	158	316.4	206	402.8
–33	–27.4	15	59.0	63	145.4	111	231.8	159	318.2	207	404.6
–32	–25.6	16	60.8	64	147.2	112	233.6	160	320.0	208	406.4
–31	–23.8	17	62.6	65	149.0	113	235.4	161	321.8	209	408.2
–30	–22.0	18	64.4	66	150.8	114	237.2	162	323.6	210	410.0
–29	–20.2	19	66.2	67	152.6	115	239.0	163	325.4	211	411.8
–28	–18.4	20	68.0	68	154.4	116	240.8	164	327.2	212	413.6
–27	–16.6	21	69.8	69	156.2	117	242.6	165	329.0	213	415.4
–26	–14.8	22	71.6	70	158.0	118	244.4	166	330.8	214	417.2
–25	–13.0	23	73.4	71	159.8	119	246.2	167	332.6	215	419.0
–24	–11.2	24	75.2	72	161.6	120	248.0	168	334.4	216	420.8
–23	– 9.4	25	77.0	73	163.4	121	249.8	169	336.2	217	422.6
–22	– 7.6	26	78.8	74	165.2	122	251.6	170	338.0	218	424.4
–21	– 5.8	27	80.6	75	167.0	123	253.4	171	339.8	219	426.2
–20	– 4.0	28	82.4	76	168.8	124	255.2	172	341.6	220	428.0
–19	– 2.2	29	84.2	77	170.6	125	257.0	173	343.4	221	429.8
–18	– 0.4	30	86.0	78	172.4	126	258.8	174	345.2	222	431.6
–17	+ 1.4	31	87.8	79	174.2	127	260.6	175	347.0	223	433.4
–16	3.2	32	89.6	80	176.0	128	262.4	176	348.8	224	435.2
–15	5.0	33	91.4	81	177.8	129	264.2	177	350.6	225	437.0
–14	6.8	34	93.2	82	179.6	130	266.0	178	352.4	226	438.8
–13	8.6	35	95.0	83	181.4	131	267.8	179	354.2	227	440.6
–12	10.4	36	96.8	84	183.2	132	269.6	180	356.0	228	442.4
–11	12.2	37	98.6	85	185.0	133	271.4	181	357.8	229	444.2
–10	14.0	38	100.4	86	186.8	134	273.2	182	359.6	230	446.0
– 9	15.8	39	102.2	87	188.6	135	275.0	183	361.4	231	447.8
– 8	17.6	40	104.0	88	190.4	136	276.8	184	363.2	232	449.6
– 7	19.4	41	105.8	89	192.2	137	278.6	185	365.0	233	451.4
– 6	21.2	42	107.6	90	194.0	138	280.4	186	366.3	234	453.2
– 5	23.0	43	109.4	91	195.8	139	282.2	187	368.6	235	455.0
– 4	24.8	44	111.2	92	197.6	140	284.0	188	370.4	236	456.8
– 3	26.6	45	113.0	93	199.4	141	285.8	189	372.2	237	458.6
– 2	28.4	46	114.8	94	201.2	142	287.6	190	374.0	238	460.4
– 1	30.2	47	116.6	95	203.0	143	289.4	191	375.8	239	462.2
0	32.0	48	118.4	96	204.8	144	291.2	192	377.6	240	464.0
+ 1	33.8	49	120.2	97	206.6	145	293.0	193	379.4	241	465.8
2	35.6	50	122.0	98	208.4	146	294.8	194	381.2	242	467.6
3	37.4	51	123.8	99	210.2	147	296.6	195	383.0	243	469.4
4	39.2	52	125.6	100	212.0	148	298.4	196	384.8	244	471.2
5	41.0	53	127.4	101	213.8	149	300.2	197	386.6	246	474.8
6	42.8	54	129.2	102	215.6	150	302.0	198	388.4	248	478.4
7	44.6	55	131.0	103	217.4	151	303.8	199	390.2	250	482.0

Measures of the Quantity of Heat

The unit of quantity of heat used in the English speaking countries is the British thermal unit, which is the quantity of heat required to raise the temperature of one pound of pure water one degree F. (American Standard abbreviation, Btu; conventional British symbol, B.Th.U.). The French thermal unit or kilogram calorie, is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C. One kilogram calorie = 3.968 British thermal units = 1000 gram calories.

The number of foot-pounds of mechanical energy equivalent to one British thermal unit is called the mechanical equivalent of heat, and equals 778 foot-pounds. One foot-pound equals 0.001285 heat unit.

TORQUE VALUES
(Medium Carbon and Alloy Steel Bolts)

INTRODUCTION

Use the torque values in Table I-III as a guide to insure satisfactory tightening of the bolts, studs and their nuts where a specific value is NOT given in Table I-I, General Data of the instructions, or on a maintenance data plate on the equipment part being maintained.

BOLT IDENTIFICATION

Bolts may be identified in the following manner:

MEDIUM CARBON STEEL:

Three radial dashes on head

ALLOY STEEL:

Six radial dashes on head

or "X" stamped on head

TABLE I-III, TORQUE VALUES

Bolt Diameter	Threads Per Inch	Torque Values*			
		Medium Carbon (SAE Grade 5)		Alloy Steel (SAE Grade 8)**	
		Lb.-Ft.	N·m	Lb.-Ft.	N·m
1/4	20	5-8	7-11	10-12	14-16
	28	5-8	7-11	10-12	14-16
5/16	18	12-15	16-20	18-21	24-28
	24	12-15	16-20	20-23	27-31
3/8	16	20-25	27-34	30-36	41-49
	24	25-28	34-38	34-40	46-54
7/16	14	35-40	47-54	50-56	68-76
	20	40-45	54-61	60-65	81-88
1/2	13	55-60	75-81	80-90	108-122
	20	60-70	81-95	95-105	129-142
9/16	12	75-80	102-108	110-123	149-167
	18	90-100	122-136	130-145	176-197
5/8	11	105-115	142-156	152-169	206-229
	18	125-140	169-190	185-205	251-278
3/4	10	185-205	251-278	285-315	386-427
	16	220-245	298-332	340-370	461-502
7/8	9	300-330	407-447	440-490	597-664
	14	340-380	461-515	510-565	691-766
1	8	440-490	597-664	685-735	929-997
	12	530-570	719-773	790-865	1071-1173
1-1/8	7	620-690	841-936	935-1040	1268-1410
	12	750-830	1017-1125	1115-1240	1512-1681
1-1/4	7	890-990	1206-1342	1250-1360	1695-1844
	12	1040-1160	1410-1573	1600-1750	2169-2373
1-3/8	6	1160-1290	1573-1749	1745-1940	2366-2630
	12	1420-1580	1925-2142	2125-2360	2881-3200
1-1/2	6	1570-1740	2129-2359	2300-2600	3118-3525
	12	1800-2000	2440-2712	2600-3020	3525-4095

*Read the following information before using this table.
**Includes socket head capscrews.

I

LUBRICATION

To get maximum benefit from applied torque, the threads and the underside of the bolt head should be clean from dirt, rust areas and scale from heat treating.

Bolts should be lubricated with a high-pressure lubricant such as graphite in oil or white lead in oil (mixed approximately five parts machine oil to one part graphite or white lead, by volume). Lubriplate* (Part 147X1614), Molykote** (Part 147X1143), Dag 210*** (Part 147X1613) or anti-seize compound (Part 147X1640) may also be used. Always lubricate both the threads and washer face of bolts and nuts.

NOTE: *Hardened, flat washers are recommended for medium carbon bolts and are mandatory for alloy steel bolt applications.*

NONSTEEL APPLICATIONS

When aluminum, copper or other soft metals are being bolted together, care must be taken to use larger washers, smaller bolts, or lower torques in order to prevent deformation of the softer materials. The softer metals also have more of a tendency to relax with time; retorquing at least once is recommended.

If using an extension on the torque wrench, refer to TORQUE WRENCH APPLICATIONS section.

CAUTION: *The Torque Values Table gives approximate maximum and minimum values that should be applied to the bolts of the size and material indicated. These values take only bolt strength into consideration and are applicable for steel-to-steel joints. When material is softer than steel, such as brass, aluminum, plastic, etc., thread stripping is a possibility if the table values of torque are used. These values may also be excessive for many gasketed joints, since extrusion of the gasket may result.*

Also consider the following when using the tables:

1. *Torque wrenches are a possible source of error and should be checked often. If out of calibration more than ± 5%, they should be adjusted.*
2. *Dry (unlubricated) assemblies of bolts and nuts may require up to 20% additional torque. If threads are not clean, the values may be higher yet.*
3. *Well-rolled and lubricated bolts going into smooth threads in a tapped hole could require as much as 20% less torque than that shown in the table. Cadmium plating will also reduce the charted torque.*

TORQUE WRENCH APPLICATIONS

INTRODUCTION

To insure satisfactory performance of mechanical equipment and to avoid costly failures, it is important to tighten all nuts on vital bolts and studs according to values given in the appropriate instructions. When a torque wrench is not available, it may be assumed a man can exert a pull of about 125 pounds on a wrench handle which, when multiplied by the wrench length in feet, gives the torque produced in lb.-ft.

USE OF ADAPTERS

It is often necessary to use adapters with a torque wrench to reach inaccessible bolts or nuts. When adapters are used, the reading of the torque wrench dial is not the actual torque exerted. The additional torque exerted on the nut or bolt (over that shown on dial) depends on:

1. Length of the adapter
2. Angle at which adapter is positioned on wrench.

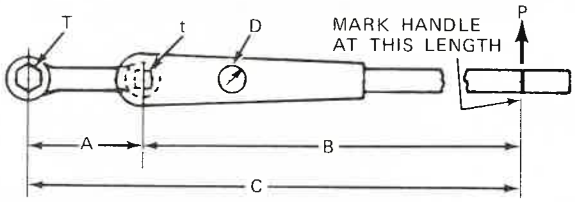
See Figs. I-2 and I-3 for calculation of correction factor to be applied to dial readings.

NOTE: *It is important the pull on the torque wrench handle be concentrated at the position marked "P" in Figs. I-2 and I-3. A shift in this position will cause considerable error in the effective torque at the end of the adapter. It is also very important the threads of both parts be clean, free of burrs, and properly lubricated. The contact face of a nut or bolt must also be lubricated with the same lubricant.*

*Product of Fiske Bros. Refining Co., Newark, N.J.
**Registered trademark of Dow Corning Corp.
***Acheson Colloids Co., Port Huron, Mich.

FIG. I-2, E-11813A

A – ADAPTER LENGTH
B – LENGTH BETWEEN SQUARE DRIVE OF TORQUE WRENCH AND LOCATION ON HANDLE WHERE PULL IS CONCENTRATED
C – TOTAL EFFECTIVE LENGTH OF WRENCH
P – PULL (FORCE EXERTED) ON HANDLE
T – EFFECTIVE TORQUE ON NUT OR BOLT
t – TORQUE INDICATED ON WRENCH DIAL



$C = A + B$
$T = P \times C$
$t = P \times B$
$\frac{T}{C} = \frac{t}{B}$
$t = T \times \frac{B}{C}$
$T = t \times \frac{C}{B}$

EXAMPLE:
WHAT IS CORRECT DIAL READING WHEN USING 6-IN. EXTENSION IN STRAIGHT POSITION FOR A 350 LB.-FT. TORQUE ON A 3-FT. TORQUE WRENCH?

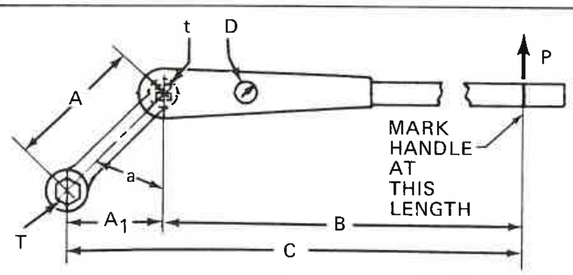
A = 0.5 FT (6 IN.)
B = 3 FT.
T = 350 LB.-FT. (DESIRED TORQUE)

THEN
$$t = T \times \left(\frac{B}{C = A + B}\right) = 350 \times \left(\frac{3}{3 + 0.5}\right)$$

t = 300 LB.-FT. (TORQUE INDICATED ON WRENCH DIAL D)

FIG. I-2. USING TORQUE WRENCH WITH ADAPTER APPLIED IN STRAIGHT POSITION.

FIG. I-3, E-11814A



ALL THE SAME FORMULAE APPLY AS FOR THE STRAIGHT ADAPTER, IN THE STRAIGHT POSITION, EXCEPT C = B + A_1. ALSO NOTE WHEN ANGLE "A" BECOMES 0 (OR ADAPTER IS AT RIGHT ANGLES TO THE TORQUE WRENCH), B AND C ARE EQUAL AND T = t (NO CORRECTION NEEDED FOR DIAL READING).

FIG. I-3. TORQUE WRENCH WITH ADAPTER APPLIED AT AN ANGLE.

TABLE I-IV
ENGLISH TO METRIC CONVERSIONS

Lb.-Ft. (Pound-Feet)	N·m (Newton-Meters)	kgm or mkp (kilogram meters or kilopond meters)
Conversions		
1.0000	1,3558	0,1382
0.7376	**1,0000**	0,1020
7.2330	9,8066	**1,0000**
Values (rounded to second decimal place)		
1.00	1,36	0,14
2.00	2,71	0,28
3.00	4,07	0,41
4.00	5,42	0,55
5.00	6,78	0,69
6.00	8,13	0,83
7.00	9,49	0,97
8.00	10,85	1,11
9.00	12,20	1,24
10.00	13,56	1,38
20.00	27,12	2,76
30.00	40,67	4,15
40.00	54,23	5,53
50.00	67,79	6,91
60.00	81,35	8,29
70.00	94,91	9,68
80.00	108,46	11,06
90.00	122,02	12,44
100.00	135,58	13,82
200.00	271,16	27,65
300.00	406,74	41,48
400.00	542,33	55,30
500.00	677,91	69,13
600.00	813,49	82,95
700.00	949,07	96,78
800.00	1 084,65	110,60
900.00	1 220,24	124,43
1000.00	1 355,82	138,25

EXAMPLE:

175 lb.-ft. = ? N·m
From Conversions:
175 X 1.3558 = 237,265 N·m ← ANSWER
From Table:

5 lb.-ft.	=	6,78 N·m
70 lb.-ft.	=	94,91 N·m
100 lb.-ft.	=	135,58 N·m
175 lb.-ft.	=	237,27 N·m ← ANSWER

I

NOTES:

NOTES:

TRANSPORTATION SYSTEMS BUSINESS DIVISION

ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

INSPECTIONS AND CHECKS

II

CONTENTS

CONTENTS (Cont'd.)

INTRODUCTION

This section covers inspections and checks on a diesel-electric locomotive. Inspection is a critical examination to detect any problems such as hanging wires, anything that is loose and other damages. Specific inspection intervals are determined by each railroad. The items included in this manual may fall under the one-month, three-month, six-month or twelve-month inspection schedule depending on local procedures. The only tools needed for inspecting most items are a flashlight and a rag.

There are two important distinctions among checks. The first is a functional check; performing a function to determine if the item is functional and ready for operation. This includes looking at the dipstick, gages, dials, meters, the oil and water levels, etc. The other is an operational check; determining if a piece of equipment is operating under operating conditions: for example, determining if the air compressor provides compressed air.

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GENERAL ELECTRIC

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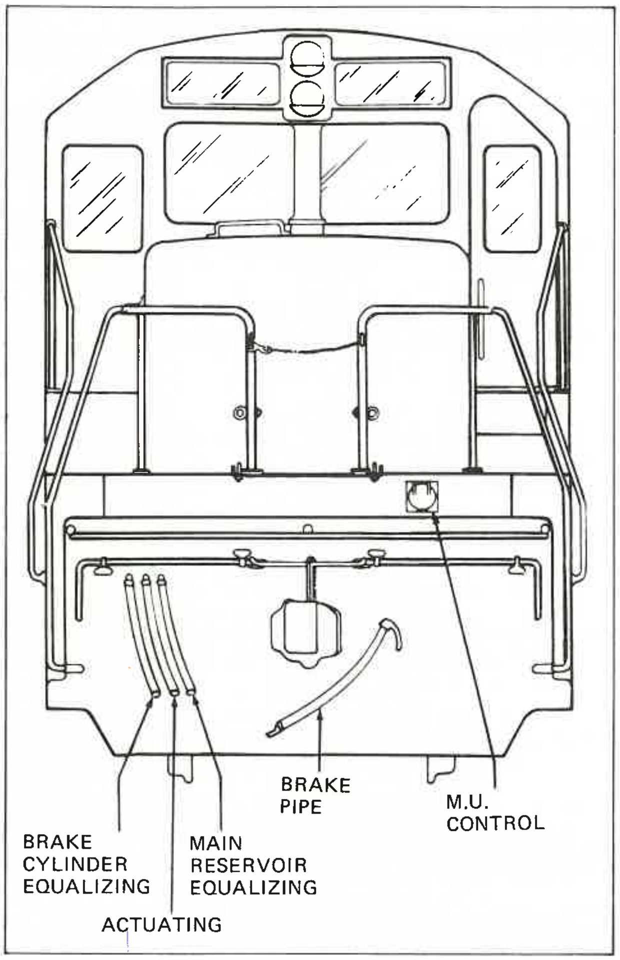


FIG. II-1. LOCOMOTIVE END CONNECTIONS.

A test is different from a check in that it is measuring the operational parameters of equipment under operating conditions. It should be noted that test information is not included in this section. Refer to the Trouble-Shooting section.

EQUIPMENT AND APPARATUS LOCATION

EQUIPMENT LOCATION

Locomotive End Connections

The locomotive end connections are shown in Fig. II-1.

Electrical Equipment Compartments

The Series-7 Locomotives have standardized on two electrical equipment compartments, Fig. II-2, to house control equipment and to provide for the maximum separation of high and low voltages.

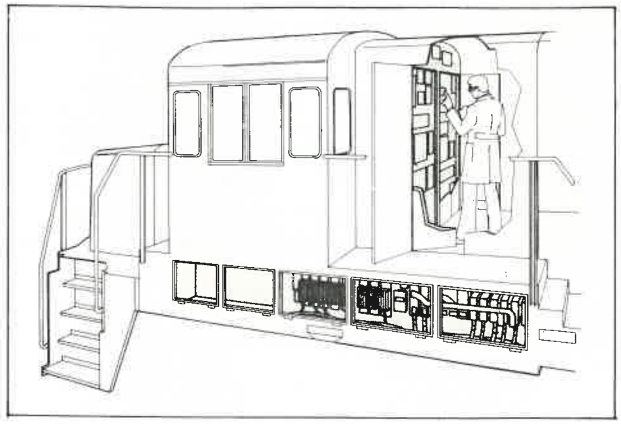


FIG. II-2. ELECTRICAL EQUIPMENT COMPARTMENTS (LOWER AND UPPER).

Lower Compartment

All high-voltage heat-emitting power equipment such as contactors, reverser and braking switch remain in the lower control compartment, Fig. II-2. This arrangement features adequate space for customer options plus improved ventilation.

Upper Compartment

All low-voltage, low-heat producing control components are located in the upper compartment, Fig. II-2, providing a spacious area for component maintenance. The compartment also contains a secondary air filter to protect these components. Fig. II-3 presents the upper compartment equipment arrangement.

No. 2 End Equipment Arrangement

The Series-7 Locomotives, Fig. II-4, have five significant modifications to improve reliability and availability, and to reduce maintenance and operating costs.

1. The compressor has been moved from the radiator compartment into a walled-off section of the engine room where it breathes warm air. This new environment isolates the unit from road dust, eliminates oil and oil vapor from the radiator compartment and lessens the chance of winter freeze-up.

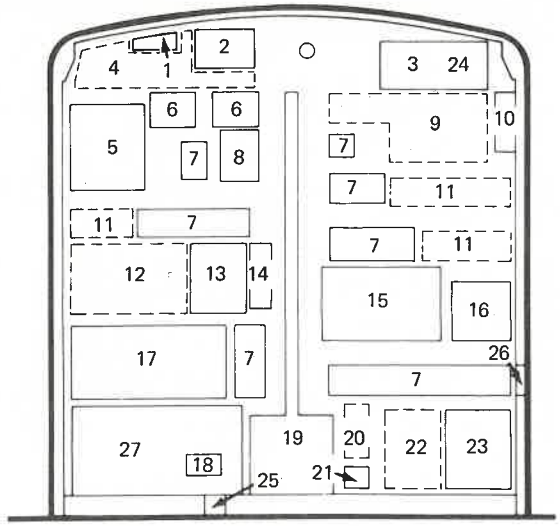
2. The water tank, with improved pressure retention, has been redesigned using copper bearing steel to eliminate flake rust. The new rectangular tank no longer supports the oil cooler, thus reducing the tendency to crack.

FIG. II-1, E-11821

FIG. II-2, E-24521

FIG. II-3, E-24522

FIG. II-4, E-24523



REF.	DESCRIPTION
1	EXCITATION THYRECTOR
2	EXCITATION RESISTOR PANEL
3	BATTERY CHARGING RESISTORS
4	OPTIONAL RESISTOR AREA
5	ANNUNCIATOR PANEL (OPTIONAL RELAY AREA BEHIND)
6	SWITCH AREA
7	CONTROL AND PROTECTION RELAYS
8	LATCHING CONTROL AND PROTECTION RELAYS
9	OPTIONAL CONTROL DEVICES
10	REVERSE CURRENT DIODE
11	OPTIONAL CONTROL AND PROTECTION RELAYS
12	OPTIONAL LOCKED AXLE PANEL
13	VOLTAGE REGULATOR
14	DIODE AREA
15	WHEELSLIP PANEL
16	TRANSITION PANEL
17	EXCITATION PANEL
18	75 VDC RECEPTACLE
19	TERMINAL BOARDS
20	OPTIONAL GROUND RELAY DEVICES
21	GROUND RELAY
22	OPTIONAL CONTACTORS
23	STARTING CONTACTORS
24	COOLING AIR-OUT
25	COOLING AIR-IN
26	GROUND CUT-OUT SWITCH
27	OPTIONAL CONTROL DEVICE AREA

FIG. II-3. ELECTRICAL CONTROL COMPARTMENT EQUIPMENT ARRANGEMENT.

3. The oil filter has been repositioned to permit self-draining – the dirty oil must flow out. Ten filter elements are now utilized instead of eight to increase the time between necessary filter changes.

4. The oil cooler is self-supporting and is now mounted to allow easy draining, etc. With a simplified piping arrangement, the unit is now easier to drain and clean, and has greater resistance to plugging.

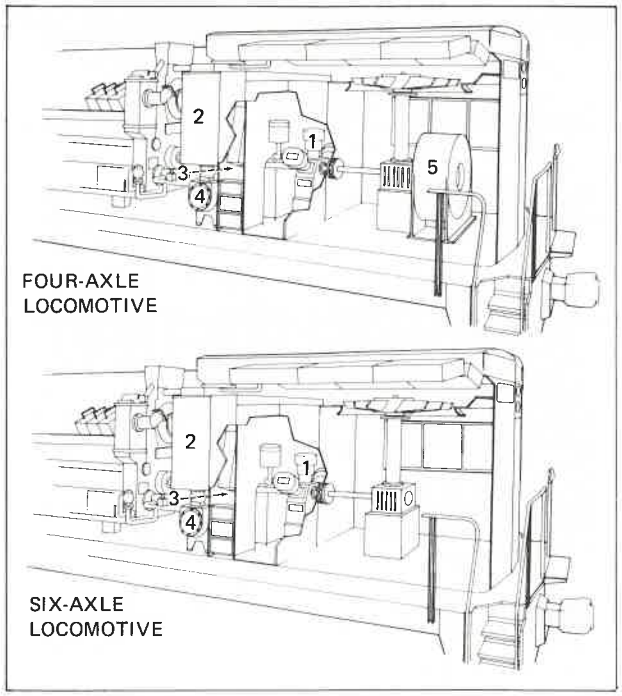


FIG. II-4. NO. 2 END EQUIPMENT ARRANGEMENT.

5. In the four-axle locomotive, the equipment blower has been moved into the radiator compartment to make room for the AAR cab modifications and the new location for the low-voltage control compartment.

APPARATUS LOCATION

The apparatus location is shown in Fig. II-5.

TRIP INSPECTION, SET-UP AND SERVICING

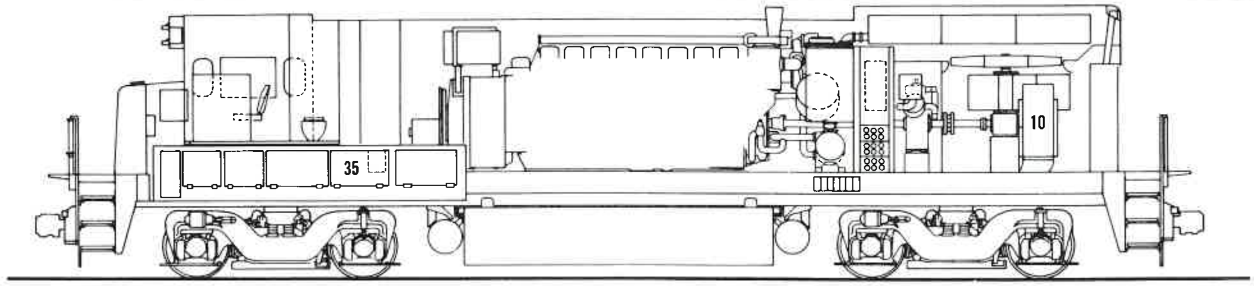
DESCRIPTION

"Trip Inspection, Set-Up and Servicing" refers to the procedure to be followed each time a locomotive or a multiple-unit consist of locomotives is serviced and set-up for its next assignment.

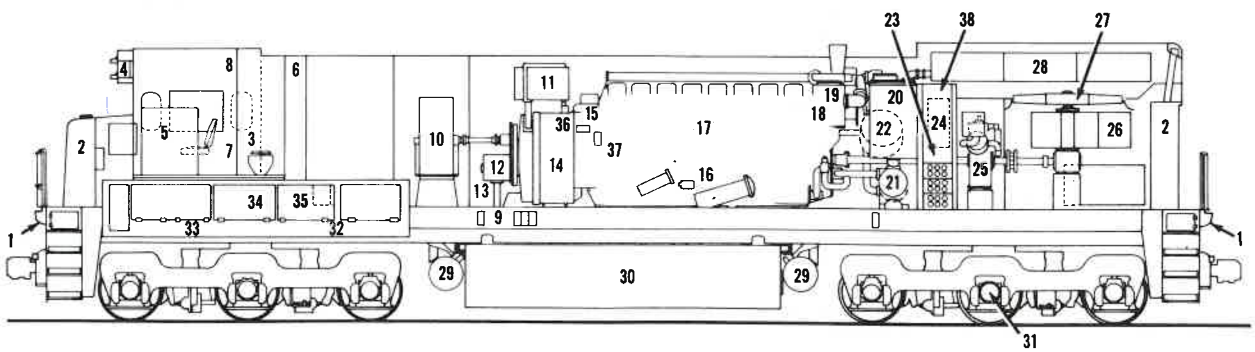
"Inspection" is the visual checking of components on the locomotive for signs indicating possible system problems such as leaks, incorrect valve positions and loose, damaged or broken parts.

"Set-Up" is the proper positioning of switches, circuit breakers, cut-out cocks and valves for direction and type of service the locomotive is to be applied on next assignment.

"Servicing" includes the checking of, and if low, the adding to fuel oil, engine lubricating oil, cooling water, sand and supplies for any other systems.



REF.	DESCRIPTION	REF.	DESCRIPTION
1	MULTIPLE-UNIT CONNECTOR	20	COOLING-WATER STORAGE TANK
2	SAND BOX	21	LUBE-OIL COOLER
3	TOILET (WHEN FURNISHED)	22	LUBE-OIL FILTER
4	HEADLIGHT AND NUMBER BOXES	23	ENGINE AIR FILTERS (INERTIAL)
5	OPERATING CONTROLS	24	ENGINE AIR CLEANERS (PAPER)
6	UPPER CONTROL COMPARTMENT	25	AIR COMPRESSOR
7	WATER COOLER (WHEN FURNISHED)	26	DYNAMIC BRAKE GRIDS (WHEN FURNISHED)
8	ENGINE CONTROL PANEL	27	RADIATOR FAN
9	EQUIPMENT AIR FILTERS (INERTIAL)	28	RADIATOR
10	EQUIPMENT BLOWER	29	AIR RESERVOIR
11	RECTIFIER	30	FUEL TANK
12	AUXILIARY GENERATOR	31	AXLE ALTERNATOR
13	EXCITER (RIGHT SIDE)	32	BATTERY (RIGHT SIDE)
14	TRACTION GENERATOR	33	AIR-BRAKE EQUIPMENT (RIGHT SIDE)
15	GOVERNOR	34	LOWER CONTROL COMPARTMENT (LEFT SIDE)
16	FUEL-OIL TRANSFER PUMP, STRAINER AND FILTER	35	CONTROL COMPARTMENT FILTER
		36	CRANKCASE OVER-PRESSURE SWITCH (RIGHT SIDE)
17	DIESEL ENGINE	37	ENGINE OVERSPEED GOVERNOR'S RESET
18	INTERCOOLER	38	ENGINE AIR FILTER SERVICE INDICATOR (RIGHT SIDE)
19	TURBOCHARGER		



NOTE: RIGHT AND LEFT SIDE DESIGNATIONS ABOVE ASSUME SHORT CAB "F" END.

FIG. II-5. APPARATUS LOCATION (FOUR-AXLE AND SIX-AXLE LOCOMOTIVE).

FIG. II-5, E-23500

Proper performance of these trip inspection, set-up and servicing procedures could reduce the number of road failures by recognizing and correcting faults before the locomotive is released for further service.

The trip inspection, set-up and servicing procedures are divided into two groups:

1. Electrical items
2. Mechanical items.

ELECTRICAL ITEMS

Included in this group are electrical items on a General Electric locomotive that should be checked during a trip inspection, set-up and servicing procedure.

Assume in all cases the engine is idling and the locomotive independent air brakes are properly set.

The following inspection sequence assumes maintenance personnel board the locomotive at the cab end, enter the cab, proceed along the right-side of the locomotive and then exit the locomotive at the rear and, if in multiple-unit consist, proceed to the next locomotive.

Operator's Control Console

For Lead or Trail operation the proper positioning of the three-handle Master Controller on the operator's control console, Fig. II-6, is:

FIG. II-6, E-25103

FIG. II-7, E-25104

FIG. II-8, E-25105

II

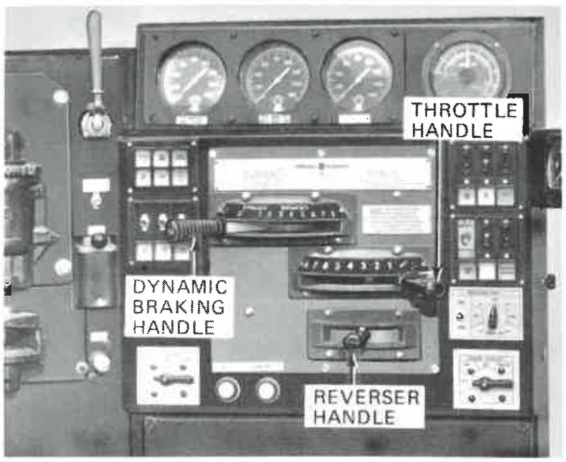


FIG. II-6. OPERATOR'S CONTROL CONSOLE.

1. Throttle handle in IDLE position on the Lead unit (in OFF position on Trail units).
2. Dynamic Braking handle in OFF position.
3. Reverse handle removed. (Depending on local operating procedure, it is assumed the operator will insert the Reverse handle when he is ready to operate the locomotive.)

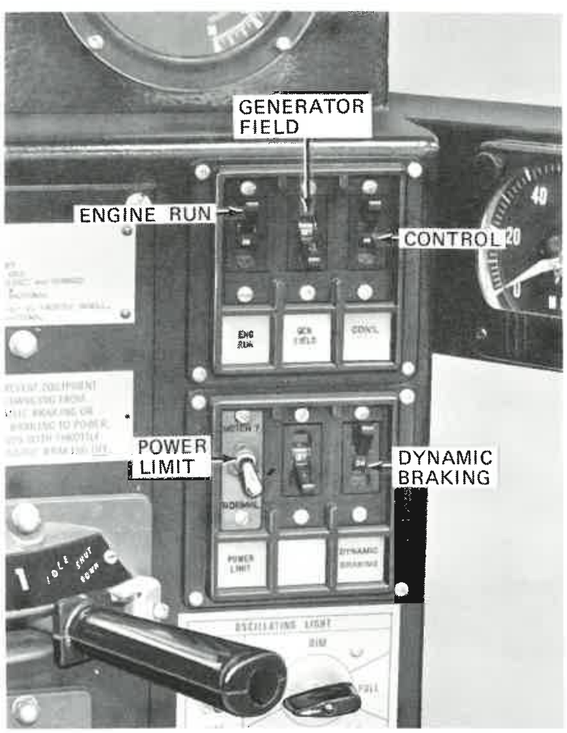


FIG. II-7. OPERATOR'S CONTROL CONSOLE CIRCUIT-BREAKER PANEL.

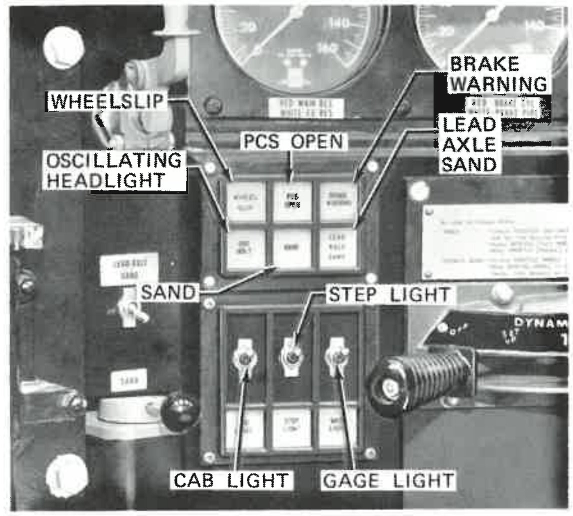


FIG. II-8. INDICATING LIGHT AND SWITCH PANEL.

Circuit Breakers

Position the circuit breakers, Fig. II-7, when operating as follows:

Circuit Breaker	Lead Unit	Trail Unit
ENGINE RUN	ON	OFF
GENERATOR FIELD	OFF	OFF
CONTROL	ON	OFF
POWER LIMIT	NORMAL (OFF)	NORMAL (OFF)
DYNAMIC BRAKE	ON	OFF

For safety reasons, the Generator Field circuit breaker on the Lead locomotive is left in the OFF position until the operator desires power to move the locomotive and/or train.

On the Lead locomotive, the operator should move the Power Limit circuit breaker to NOTCH 7 position only while the locomotive is under power, with the Master Controller Throttle handle in Notch 8 and with the locomotive encountering excessive wheelslip. Placing this breaker in NOTCH 7 will reduce the power output of the Lead locomotive only. The Power Limit breaker should be returned to the NORMAL (off) position as soon as the rail condition will permit full power operation on the Lead locomotive.

Indicating Lights

Assure that none are lit, Fig. II-8, when the locomotive is at standstill and the engine is at IDLE. For example: A lit WHEELSLIP light would indicate a malfunction which should be corrected.

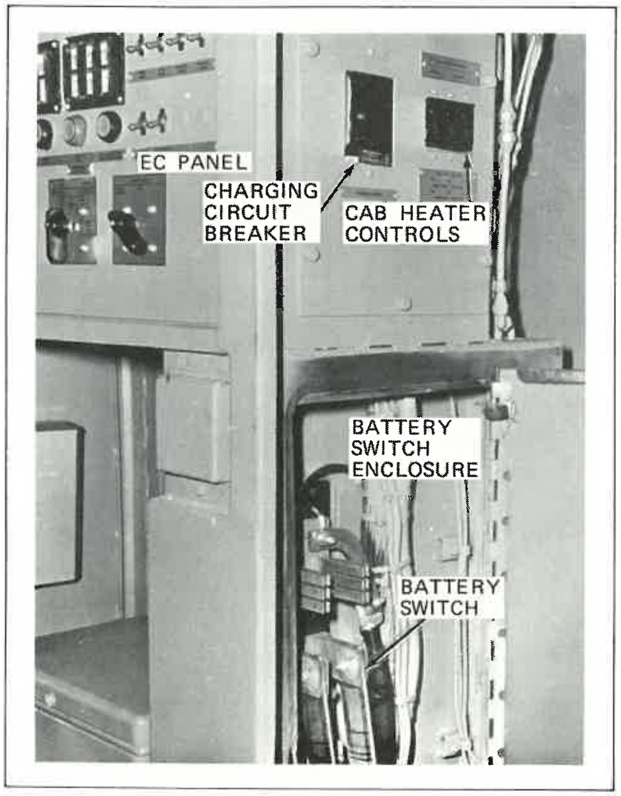


FIG. II-9. ENGINE CONTROL PANEL SHOWING BATTERY SWITCH AND CHARGING CIRCUIT BREAKER.

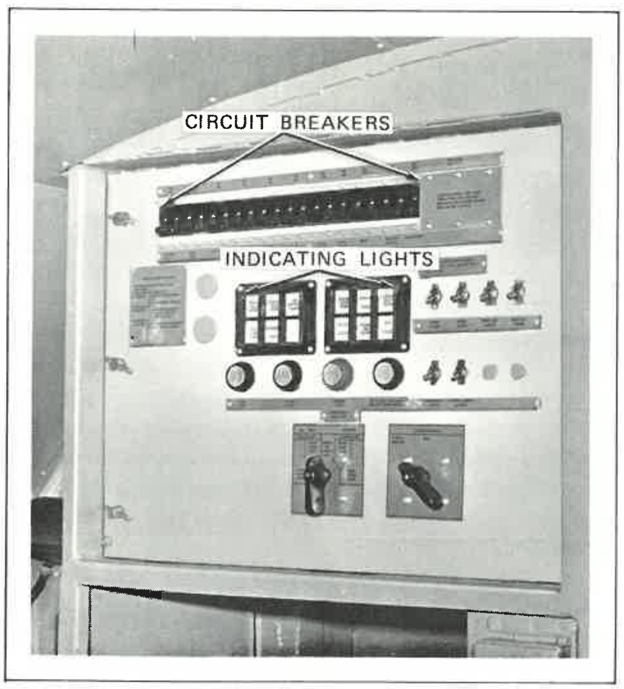


FIG. II-10. ENGINE CONTROL PANEL SHOWING CIRCUIT BREAKERS AND INDICATING LIGHTS.

Light Switches

Those on the Switch Panel should be positioned according to the railroad instructions.

Engine Control Panel

Battery Switch

The Battery switch, Fig. II-9, must be CLOSED on all locomotives in the multiple-unit consist.

NOTE: *The polarities of the blades on the Battery switch are not always consistent. On most General Electric locomotives, the left blade is negative and the right blade is positive.*

Charging Circuit Breaker

This breaker, Fig. II-9, must be ON at all times while locomotives are in service.

Circuit Breakers

Position the breakers, Fig. II-10, according to the directions on the instruction strip mounted above the circuit breakers. The instruction strip gives the proper position of each breaker for Lead or Trail operation.

Indicating Lights

Set the Engine Control switch to the START/ISOLATE position.

NOTE: *On some locomotives several of the indicating lights are de-energized when the Engine Control switch is set at the RUN position.*

Assure no indicating lights, Fig. II-10, are lit since a light would signify a problem exists on the locomotive, which must be investigated and should be corrected before the locomotive is released for further service.

NOTE: *If any malfunction lights are lit, refer to the ENGINE SYSTEMS MONITOR (ESM) section and review the ESM Diagnostic Chart.*

Set-Up Switches

Position the M-U Headlight switch, Fig. II-11, according to the direction and position of the locomotive in the consist. The switch instruction plate describes the available positions.

Set the Engine Control switch in the RUN position to place the locomotive "On Line" for normal operation. The switch is shown in the START/ISOLATE position.

FIG. II-9, E-25106

FIG. II-10, E-25107

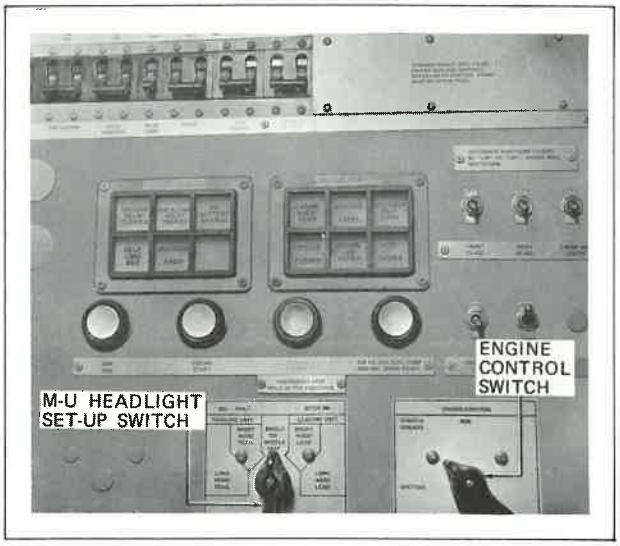


FIG. II-11. ENGINE CONTROL PANEL SHOWING SET-UP SWITCHES.

FIG. II-11, E-25108

NOTE: *The SPOTTER position on this switch is a customer option to provide battery power for movement of the locomotive in the shop using one traction motor.*

Annunciator Panel

Check for lit malfunction lights on the Annunciator Panel, Fig. II-12, located within the control compartment. Resolve the malfunction problem.

After resolving the problem, place the Reset Toggle switch to the RESET position. Test for any burned-out light bulbs by pushing the LAMP TEST push-button. Replace any burned-out bulbs.

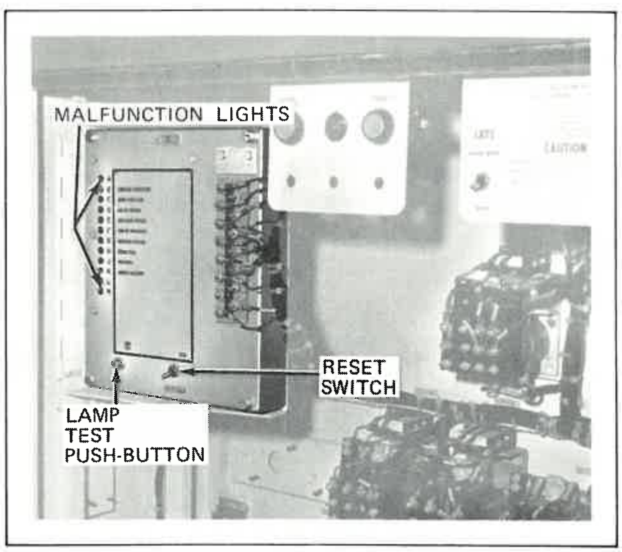


FIG. II-12. ANNUNCIATOR PANEL.

FIG. II-12, E-25109

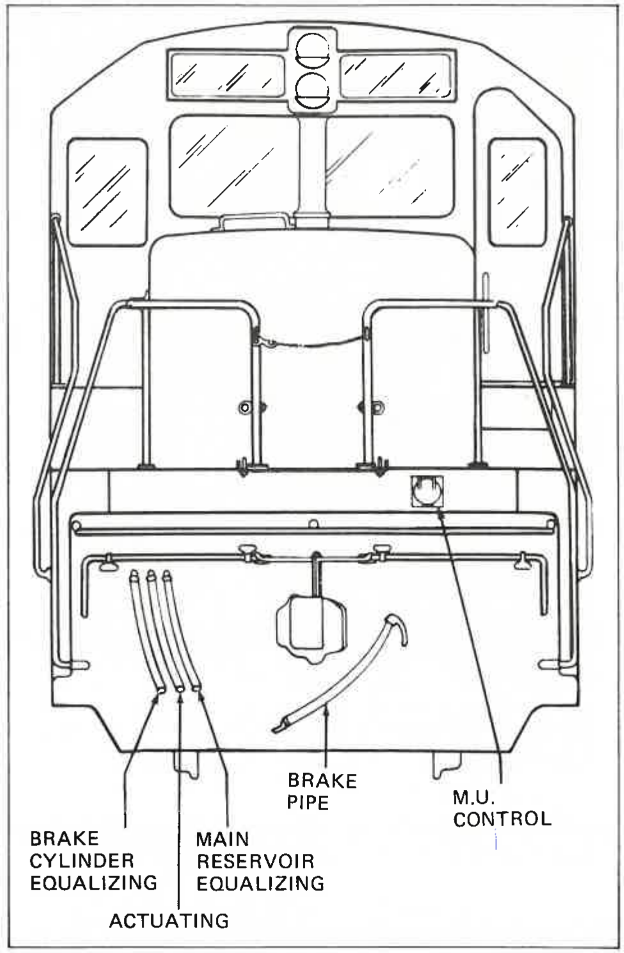


FIG. II-13. MULTIPLE UNIT (M-U) JUMPERS.

FIG. II-13, E-11821

NOTE: *If any malfunction lights are lit, refer to the ENGINE SYSTEMS MONITOR (ESM) section and review the ESM Diagnostic Chart.*

Multiple-Unit Jumper

Check that the jumpers, Fig. II-13, between locomotives of the consist are properly secure in their receptacles and properly suspended to prevent chafing or damage.

MECHANICAL ITEMS

Description

Included in this group are mechanical items on a General Electric locomotive that should be checked during a trip inspection, set-up and servicing procedure.

Assume in all cases the engine is idling and the locomotive independent air brakes are properly set.

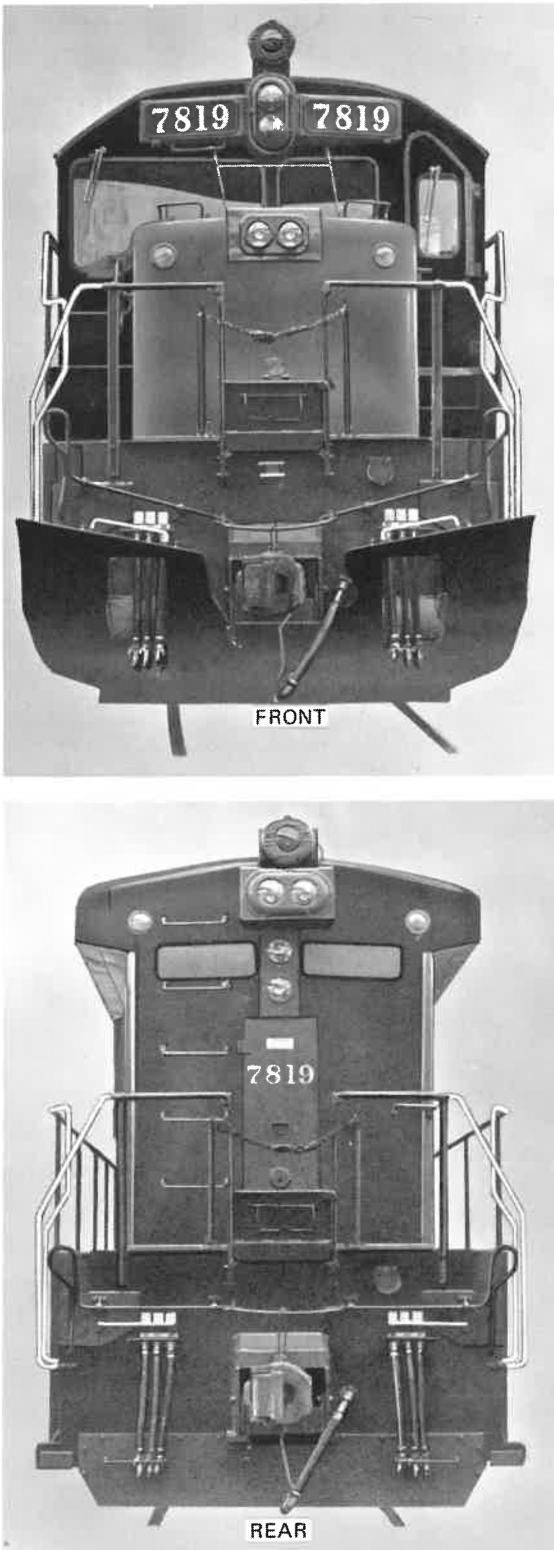


FIG. II-14. LOCOMOTIVE ENDS.

FIG. II-14, E-25110

The following inspection sequence assumes maintenance personnel board the locomotive at the cab end, enter the cab, proceed along the right-side of the locomotive, along the left-side and then exit the locomotive at the rear and, if in multiple unit consist, proceed to the next locomotive. To check devices below platform level on the return from the rear of the consist, refer to "Ground Level Inspection."

Locomotive Ends

Perform the following:

1. Check for damage or irregularities to the end of the locomotive, Fig. II-14.
2. Check the condition of the coupler and uncoupling levers.
3. Check M-U air hoses between locomotives of a consist for proper connection. Assure the hoses are not cross-connected.
4. Check the cut-out cocks on the brake pipe and M-U hoses (behind end frame) to insure they are fully OPEN between locomotives and properly positioned on end locomotives.

Sand Traps

The sand trap Shut-Off handle, Fig. II-15, should be in the OPEN position. Sand delivery hoses should be smooth, not collapsed and properly clamped. The trap clean-out flange must be in place and tight.

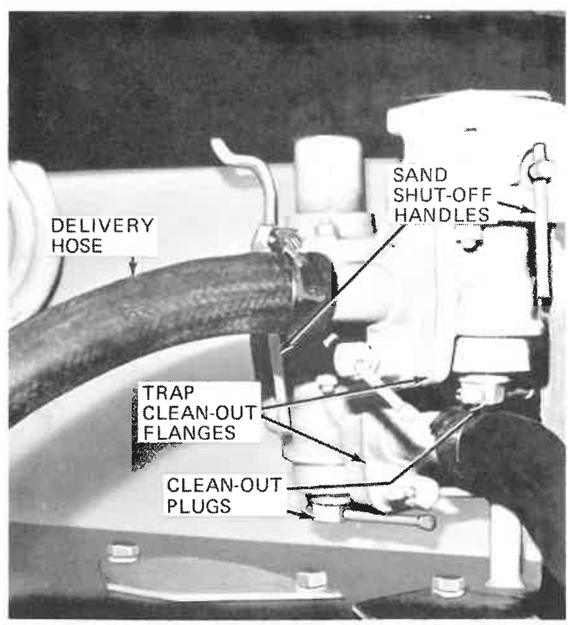


FIG. II-15. SAND TRAPS.

FIG. II-15, E-25111

FIG. II-16, E-25112

FIG. II-17, E-25113

FIG. II-18, E-25114

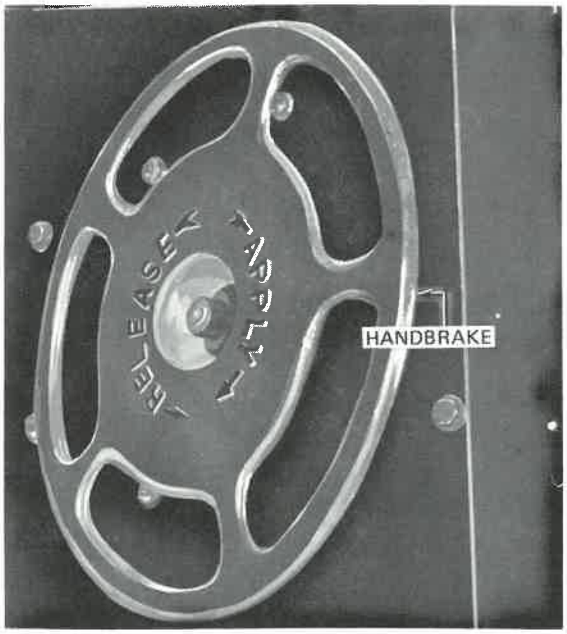


FIG. II-16. HANDBRAKE.

Air supply cut-out cocks to the sand traps must be OPEN.

NOTE: *Air supply cut-out cocks are usually located near the ceiling of the sand trap compartment just inside the spring-loaded step door.*

Handbrake

Local railroad operating procedures determine when the handbrake, Fig. II-16, is to be applied or released.

On three-axle C trucks, check that the handbrake chain trips the brake cylinder Quick-Release valve located on the right-side of the Lead truck. Air should be heard as it is released from the brake cylinder. The quick-release feature releases air pressure from the brake cylinder on one axle to insure the mechanical handbrake is holding the locomotive. Only in this way, if air pressure bleeds-off the brake cylinder, will the handbrake still hold the brake shoes firmly against the wheel.

Engine Control Panel Gages

Check the Engine Control Panel gages, Fig. II-17, with engine at IDLE. The gages should read:

Turbo Air Pressure	–	zero (0)
Fuel Oil Pressure	–	40 psi
Lube Oil Pressure	–	between 15 and 25 psi

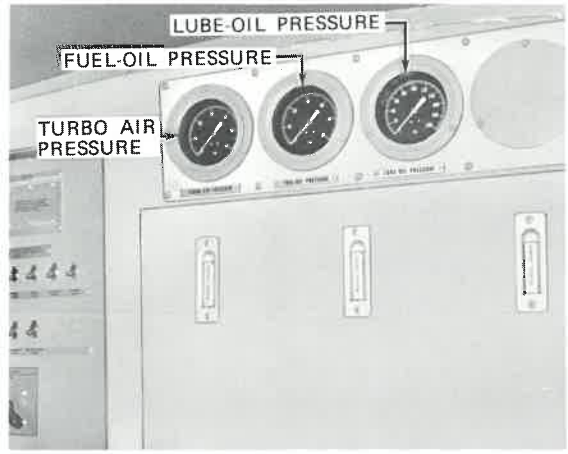


FIG. II-17. ENGINE CONTROL PANEL GAGES (SHOWN AT ZERO; ENGINE SHUTDOWN).

NOTE: *Maximum turbo air pressure occurs only at Notch 8 with the engine producing full horsepower. Maximum turbo air pressure will range between 20 and 32 psi depending on the particular model of locomotive. Turbo air pressure is negligible in Notches 1 through 5, even under load.*

Air Brake Gages

Check that the air brake gages, Fig. II-18, on the operator's control console are indicating the proper values. The main-air reservoir gage normally should indicate 130 to 140 psi on the Lead locomotive.

Trail units in a consist equipped with special two-stage compressor governor control should normally have 135 to 145 psi main-air reservoir pressure indicated on the gage.

FIG. II-18. AIR BRAKE GAGES (SHOWN AT ZERO; ENGINE SHUTDOWN).

II

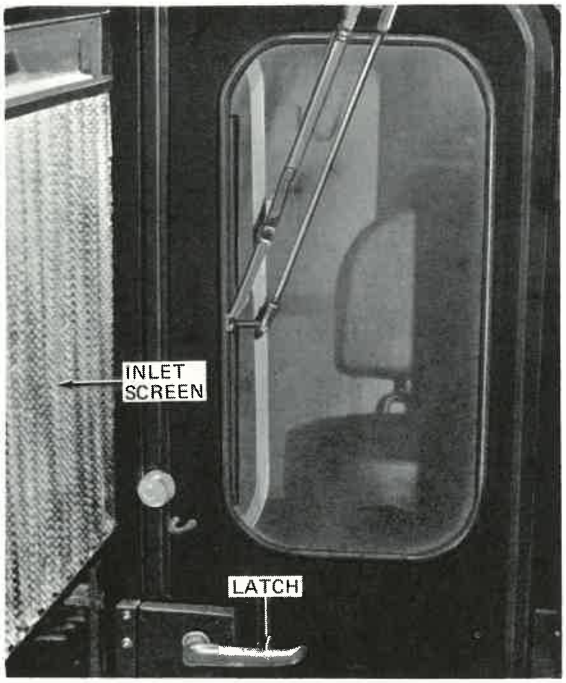


FIG. II-19. CAB DOORS AND AIR INLET SCREENS.

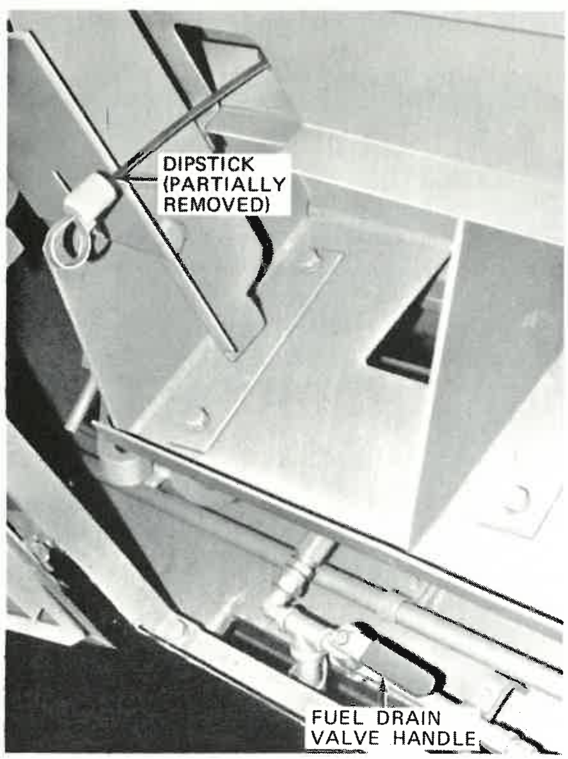


FIG. II-20. ENGINE DIPSTICK AND FUEL DRAIN-VALVE HANDLE.

Cab Doors and Air Inlet Screens

The cab door latch, Fig. II-19, must hold the door closed and the door must seal properly.

Remove accumulated debris from the outside of equipment blower, engine air intake, and radiator-cab inlet air screens.

Also, check the wipers for proper pressure against the windshield.

Engine Oil Level

Check the diesel-engine lubricating oil supply with the engine at IDLE. The dipstick, Fig. II-20, located on the side of the engine is marked LOW - FULL. The oil level should be above the LOW mark, but not above the FULL mark. DO NOT OVERFILL. Excess oil can cause a crankcase overpressure shutdown.

The floor-mounted, fuel drain-valve handle, Fig. II-20, is on the fuel filter tank drain valve. The spring return valve is normally held closed. If fuel pressure build-up is restricted due to air trapped in the lines, opening the spring return valve may release trapped air and restore proper fuel pressure. Open the valve with the fuel pump running, then check that it closes properly.

Check for Engine Leaks

While checking the engine oil level, Fig. II-21, also check the engine for leaks or any unusual condition. For example: This could possibly be a melted intake air manifold section or a broken fuel rack linkage. These conditions must be repaired before dispatching the locomotive for road service.

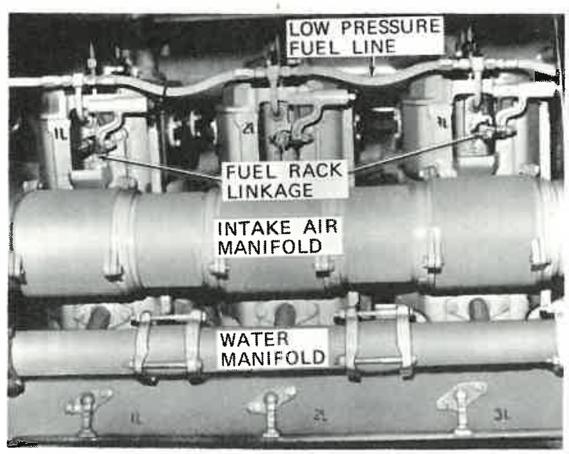


FIG. II-21. ENGINE DETAILS.

FIG. II-19, E-25115

FIG. II-20, E-25116

FIG. II-21, E-25117

FIG. II-22, E-25118
FIG. II-23, E-25119
FIG. II-24, E-25120

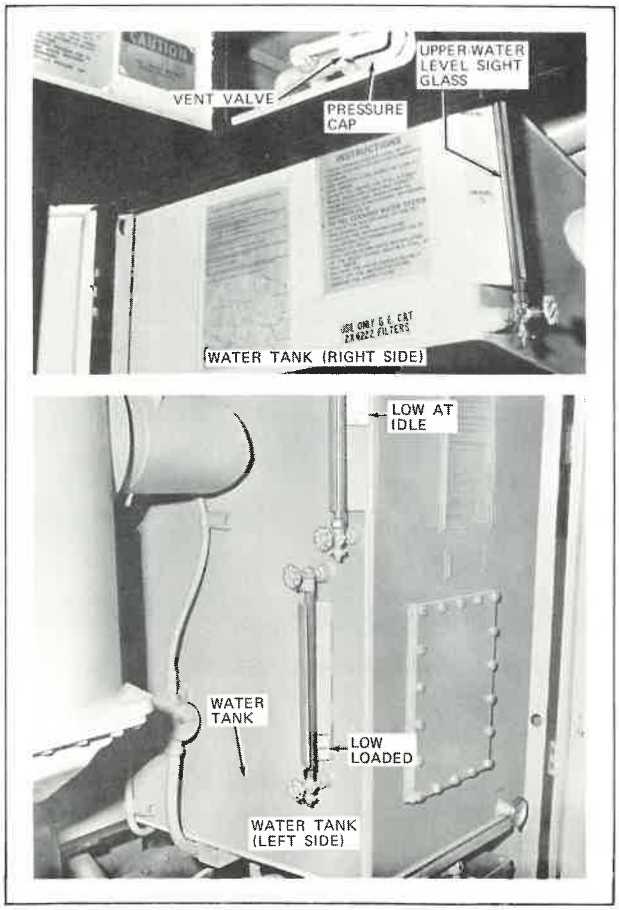


FIG. II-22. WATER STORAGE TANK.

Engine Cooling Water Supply

The water storage tank, Fig. II-22, contains the cooling water for the diesel engine. With the engine at IDLE, the level in the water tank sight glass should be above the LOW AT IDLE mark on the tank indicating plate. Be sure both the top and bottom sight glass valves are open.

While checking the water level, inspect around the tank area for leaks. Serious leaks may require repair before the locomotive is released for service.

If water must be added, inspect the entire cooling system for leakage, especially around the radiator area. Also, check that the water pressure cap is on tight. Instructions for adding water and adding water-treatment compound are mounted on the storage tank.

NOTE: *The LOW AT IDLE reading can be obtained on either side of the storage tank. The LOW LOADED mark is located only on the left-side of the storage tank.*

Check for Leaks

While checking the engine cooling-water supply, also check the water system drain valve, Fig. II-23, to assure it is completely closed.

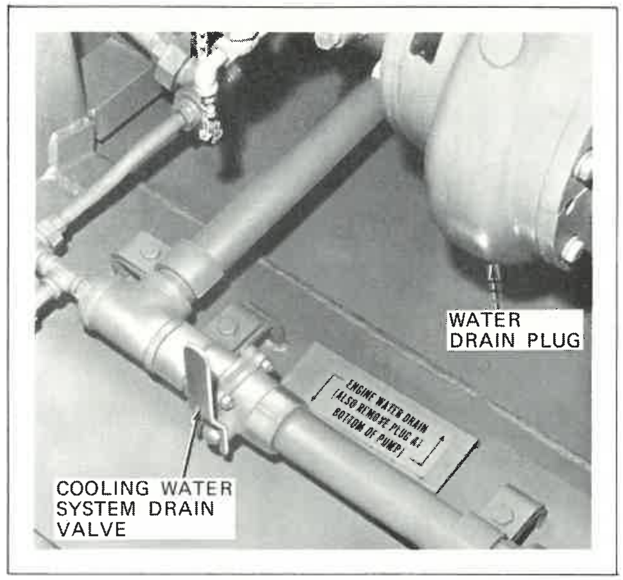


FIG. II-23. COOLING-WATER SYSTEM DRAIN VALVE.

A drain valve slightly open may result in a total loss of the cooling water.

NOTE: *Engine water and air compressor water drain through one valve.*

Also, check the water pump area for water, oil and fuel leaks.

Engine Governor

Check the engine governor oil, Fig. II-24, with the engine in IDLE. The Series-7 Locomotive governor uses the

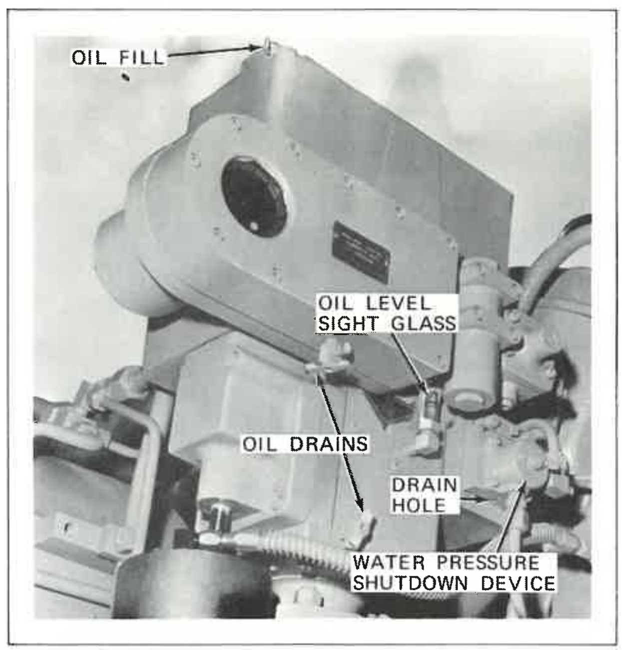


FIG. II-24. ENGINE GOVERNOR.

II

single-line type sight glass. The single line indicates the maximum oil level with the engine at IDLE.

Oil will be visible in the sight glass with the engine shutdown. Usually, the governor will appear overfilled in the shutdown condition.

Tests have been conducted that have shown that an overfilled or underfilled governor can sometimes cause engine "hunting." Hunting is not a desirable condition.

Also, check the engine water-pressure shutdown diaphragm drain hole. Water leaking from this hole indicates a failed diaphragm. The diaphragm should be changed to avoid a possible future road shutdown.

Ground Level Inspection

After the on-board inspection has been completed, perform a ground level inspection, Fig. II-25, by walking around the entire consist and check items such as:

1. Trucks
   a. Brake shoes
   b. Brake cylinders and levers
   c. Handbrake equipment
2. Fuel tank for damage or leaks.
3. Locomotive sump drains for leakage. Leakage from the drains may be a result of system leakage on-board the locomotive. These leakages should be investigated.
4. Air reservoirs for damage or leaks.
5. Hanging equipment or material from the locomotive to the roadway.

MECHANICAL INSPECTION

AIR COMPRESSOR

Check compressor crankcase oil level, Fig. II-26, using the dipstick. The level should be between the two groove marks on the dipstick with the locomotive Throttle handle at IDLE.

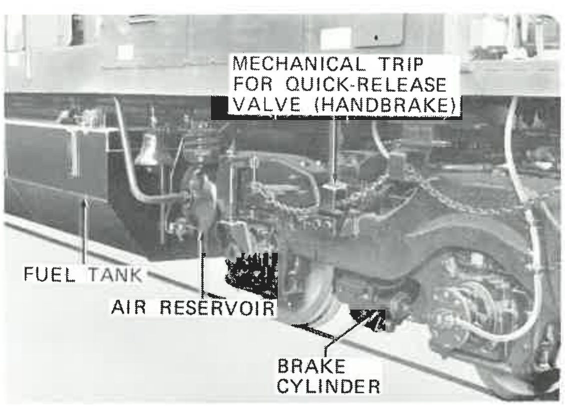


FIG. II-25. GROUND LEVEL INSPECTION.

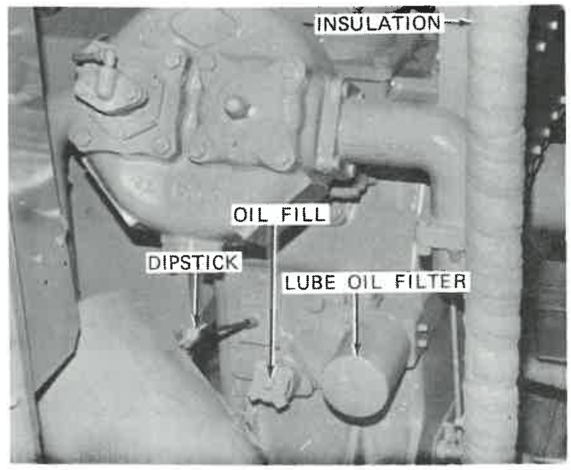


FIG. II-26. AIR COMPRESSOR.

FIG. II-25, E-25121

FIG. II-26, E-24483

Inspect the air compressor and immediate area for compressor oil or cooling water leaks.

Check that compressor water-piping insulation material is securely applied.

LUBE-OIL DRAIN VALVE

The drain valve, Fig. II-27, must be in the CLOSED position (turned fully clockwise).

RADIATOR FAN GEAR BOX

Check the gear box oil level, Figs. II-28 and II-29, with the engine shut down. The oil should be up to the lip of the

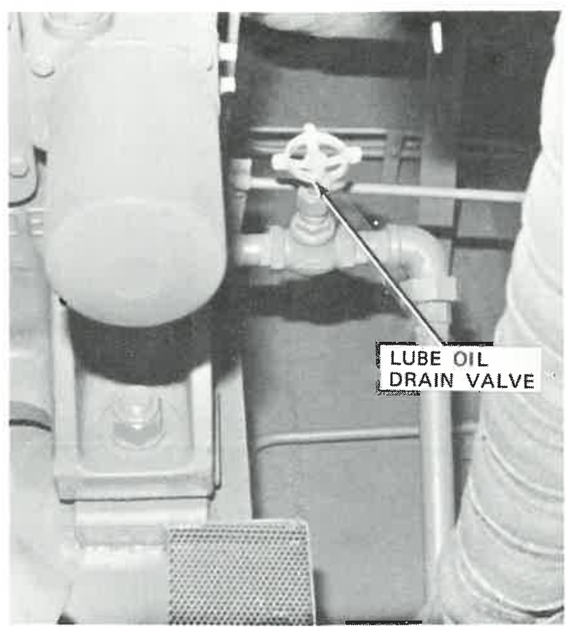


FIG. II-27. LUBE-OIL DRAIN VALVE.

FIG. II-27, E-24484

FIG. II-28, E-24485 FIG. II-29, E-12825A FIG. II-30, E-24486 FIG. II-31, E-24487

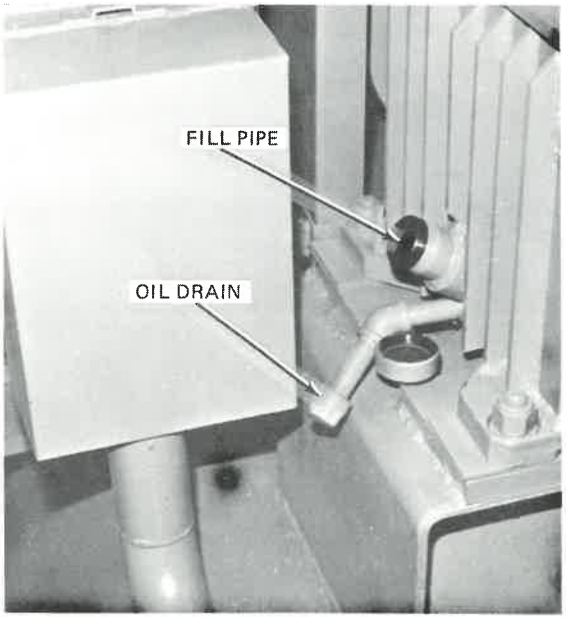


FIG. II-28. RADIATOR FAN GEAR BOX.

fill pipe. (No dipstick is provided.) Inspect the gear box area for oil leaks.

Check for water treatment stains on, and around, the gear box. These stains might indicate a radiator leak.

NOTE: *Engine cooling water does not normally flow through the radiators at IDLE. Pressurization of the water system may be required to locate radiator leaks.*

GENERATOR GEAR UNIT LUBRICATING OIL

The generator gear unit dipstick, Fig. II-30, is marked on one side for the correct oil level with the engine running at IDLE; the other side indicates the correct oil level with the engine shut down.

The oil drain is located about 12 in. below the dipstick. The drain plug is not shown.

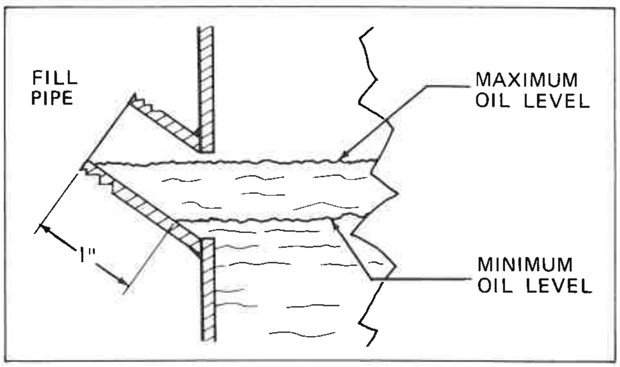


FIG. II-29. OIL LEVEL.

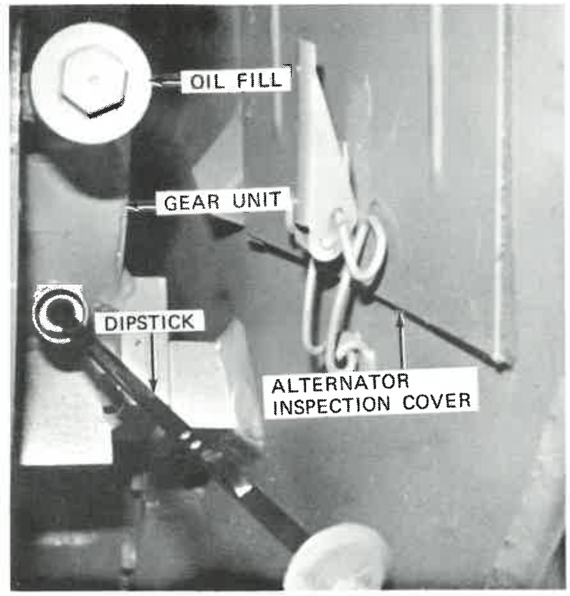


FIG. II-30. GENERATOR GEAR UNIT.

Check that the alternator inspection covers are correctly applied.

FUEL SYSTEM

Inspect the fuel pump, strainer, relief valve, regulator and related piping, Fig. II-31, for leaks. Replace filter elements as designated. Check transfer-pump motor brushes for proper length. The fuel regulator is set to give 40 psi at IDLE on the gage located in the operator's cab.

The fuel-relief valve is set at 75 psi to prevent excessive pressure in the fuel system.

ENGINE LUBRICATING OIL-PUMP AREA

Inspect oil-pump area piping for leaks, Fig. II-32.

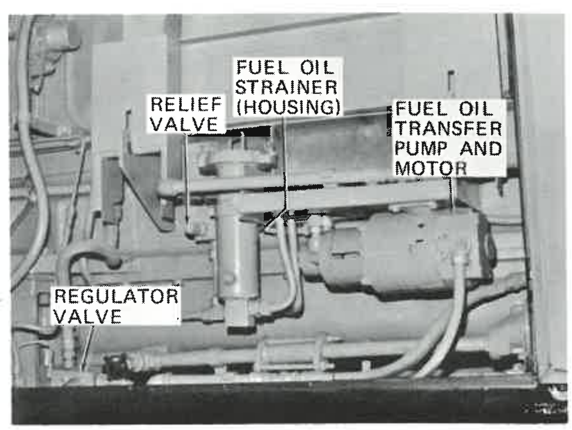


FIG. II-31. FUEL SYSTEM AREA.

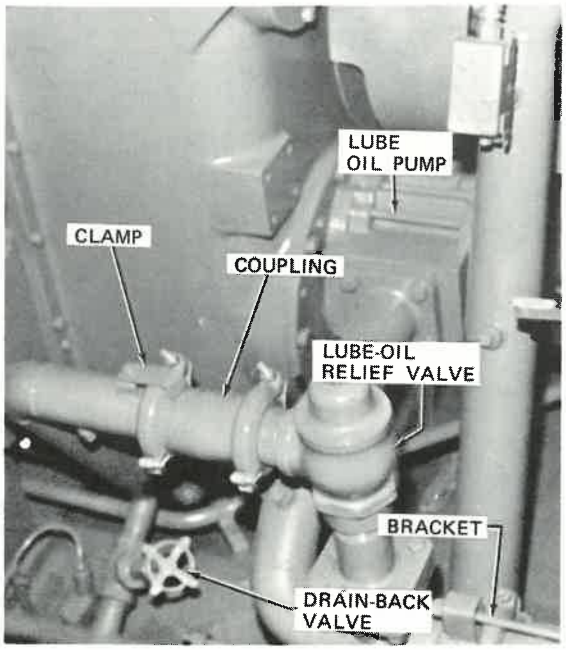


FIG. II-32. ENGINE LUBRICATING OIL-PUMP AREA.

Check that oil filter tank drain-back valve is CLOSED.

Check that the Dresser coupling brackets and clamps are secure. Without the clamps, normal engine vibration can cause the couplings to move on the piping. Excessive movement could cause major leakage and a road failure.

The oil relief valve opens at 135-140 psi to prevent excessive lube-oil system pressures.

OIL DRAIN VALVES

Close crankcase and filter drain valves, Fig. II-33, for normal operation.

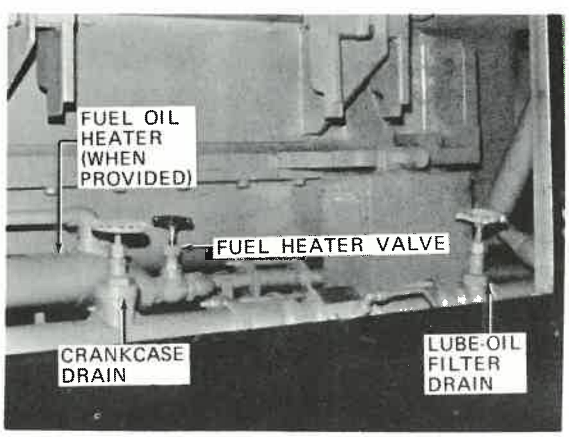


FIG. II-33. OIL DRAIN VALVES.

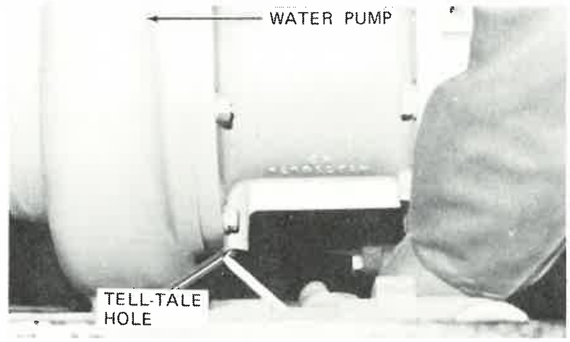


FIG. II-34. WATER PUMP AREA.

For summer operation, close fuel heater water valve.

For winter operation, open fuel heater water valve.

Inspect the engine block for oil, water or fuel leakage from the cylinder area.

WATER PUMP

Leakage from the water pump tell-tale hole, Fig. II-34, indicates a defective pump seal. The pump should be replaced or the seal renewed. In most cases engine cooling water will be leaking from the tell-tale hole indicating a defective water seal. If the oil-seal becomes defective, oil will also come out the tell-tale hole.

NEVER PLUG THE TELL-TALE DRAIN HOLE. With this drain plugged, a defective water pump seal would permit water to contaminate the engine crankcase oil.

Leakage from the tell-tale hole may be permitted for a short while after starting a cold engine. However, if the leakage continues after the engine has reached operating temperature, the seal may be defective.

CHECK FOR LEAKS

Inspect low and high-pressure fuel oil tubing, piping and hoses, Fig. II-35.

Inspect the water manifold that feeds the cooling water into the cylinders.

Inspect the intake air manifold for leaks or irregularities. A leak might be detected visually by an exposed air-manifold O-ring. This could indicate a loose manifold section.

ENGINE COOLING-WATER RETURN MANIFOLD

Inspect each elbow between the cylinder water-return port and the water-return manifold for leaks, Fig. II-36.

FIG. II-32, E-24488

FIG. II-33, E-24489

FIG. II-34, E-24491

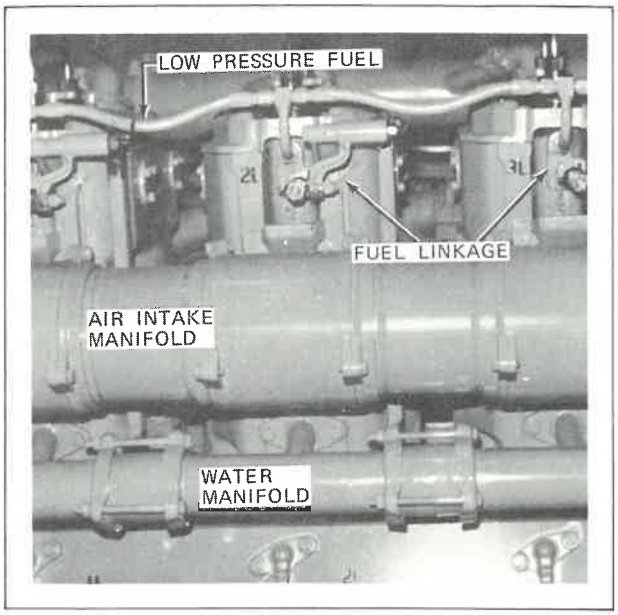


FIG. II-35. ENGINE DETAILS FOR MECHANICAL INSPECTION.

Exhaust Manifold

Check the condition of the exhaust manifold, Fig. II-36. Check for missing or loose bolts, or connections. With the engine idling, manifold leaks can be detected by pulling out the corresponding fuel-injection pump rack. This overfuels (the cylinder causing black smoke that escapes through any manifold leaks). Excessive carbon deposits on the engine may indicate a leaking manifold.

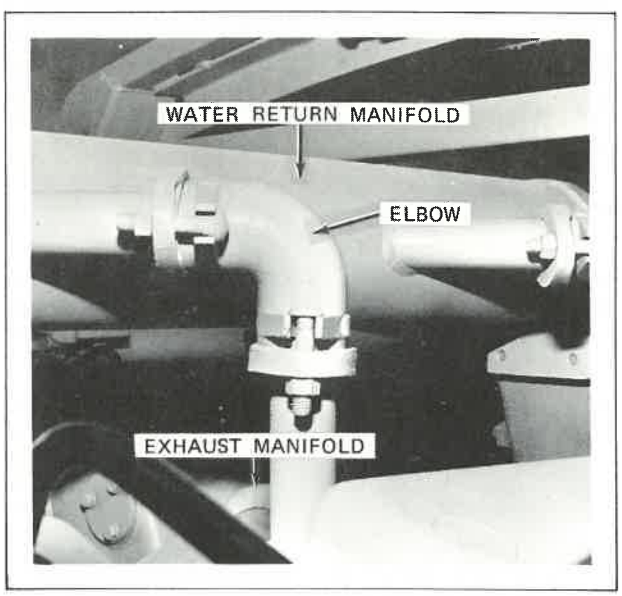


FIG. II-36. ENGINE COOLING-WATER RETURN MANIFOLD.

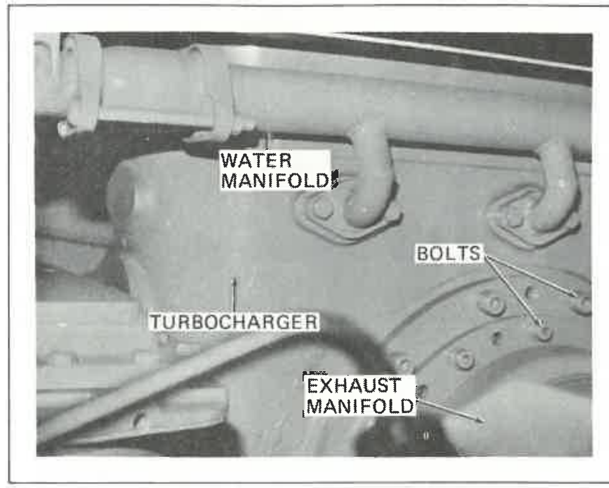


FIG. II-37. TURBOCHARGER AREA.

All leaks should be corrected. Excessive leakage can reduce the turbocharger speed which reduces engine horsepower output.

TURBOCHARGER

Check the cooling-water return manifold, Fig. II-37, for leaks.

Check the exhaust manifold to turbocharger connection for exhaust leaks, Fig. II-37. Check that all clamping bolts are in place and tight.

EXHAUST-STACK ASPIRATOR HOSE

Inspect the flexible metal-aspirator hose connections, Fig. II-38. Replace any broken metal hose.

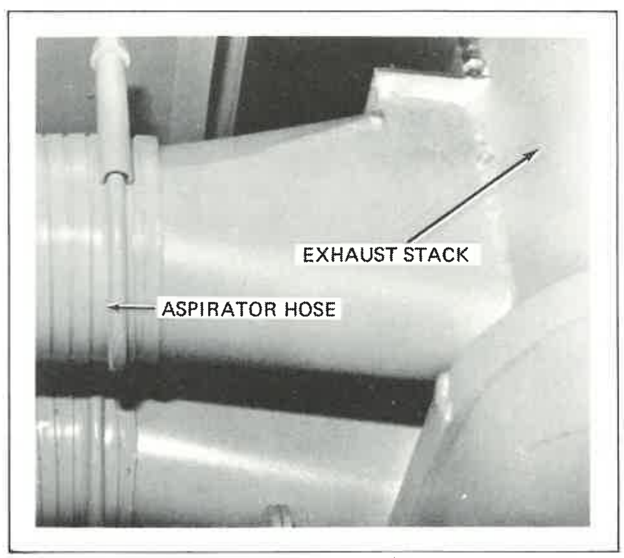


FIG. II-38. EXHAUST-STACK ASPIRATOR HOSE.

FIG. II-35, E-24492
FIG. II-36, E-24493
FIG. II-37, E-24494
FIG. II-38, E-24495

II

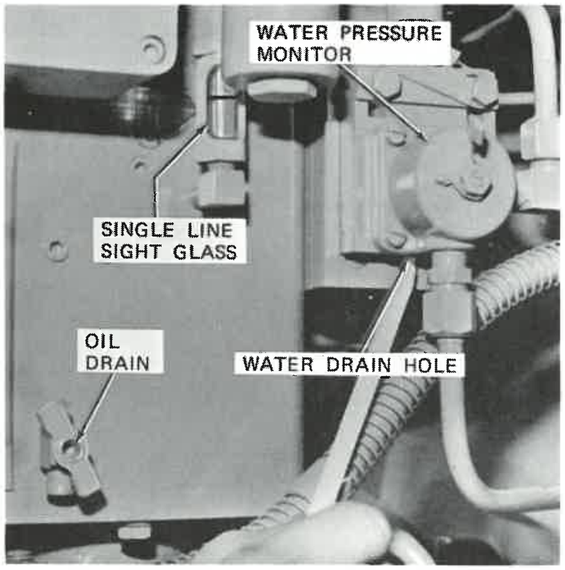


FIG. II-39. ENGINE GOVERNOR AREA.

The hoses can be partially viewed from the locomotive walkways. The hinged hatch covers should be lifted for a complete inspection.

NOTE: *Broken aspirator hose will partially disable the engine intake air-cleaning system.*

ENGINE GOVERNOR

Oil Level

Engine governor oil is checked with the engine at IDLE. The governor sight glass is a single-line sight glass, Fig. II-39: One line is etched on the glass. The single line indicates the maximum oil level.

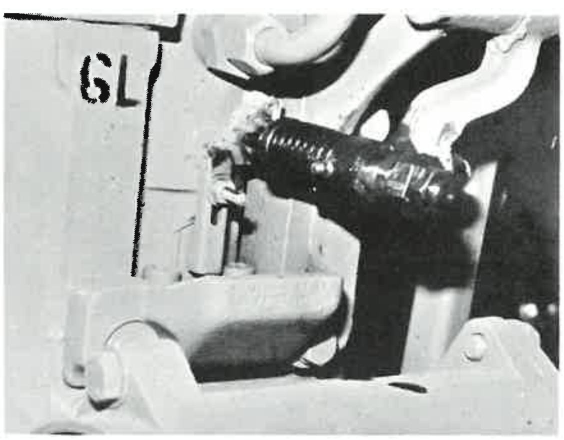


FIG. II-40. INJECTION FUEL-PUMP LINKAGES.

NOTE: *Tests show that an overfilled or underfilled governor can cause undesired engine heating.*

Governor oil must be clean and of the proper type. Replace dirty oil. Do not use engine crankcase oil in the governor.

Check For Leaks

Check the governor oil and water piping for leaks.

Inspect the engine cooling-system water-pressure monitor/shutdown device, Fig. II-39. Water leakage from the drain hole would indicate a defective water diaphragm. Replace defective diaphragm.

INJECTION FUEL-PUMP LINKAGES

Inspect Linkage, Fig. II-40, for binding or excessive looseness.

Add grease to fitting only when the linkage is in the IDLE, or higher position. If lubricated at the shutdown position, grease will not enter the groove.

UPPER CYLINDER EQUIPMENT

Inspect valve stems, springs, bell crank, push rods, rocker arms and tappet adjustment nuts, Fig. II-41, for proper lubrication and any irregularity.

With the engine at IDLE, observe oil flow from the rocker arms. Listen for any abnormal sounds that might indicate worn parts.

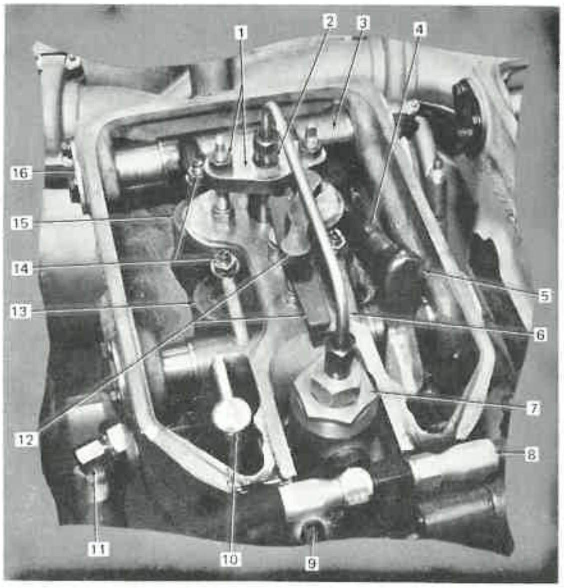
CRANKCASE

With the engine shut down and the crankcase doors removed, Fig. II-42, inspect:

1. Main bearing and rod cap-side clearances for evidence of heat or bearing wear.
2. Lower cylinder liners. Broken lower liners may indicate a bent rod.
3. Main or connecting rod. Nicks or gouges in the rod may result from a bent rod that is hitting the cylinder liner.
4. Camshaft lobes for wear.
5. Crosshead rollers for wear.
6. Camshaft bearings. Look for irregularities.
7. Internal engine-frame ledges. An accumulation of metal bearing material on these ledges may indicate a failed main or rod bearing.

FIG. II-39, E-24496A

FIG. II-40, E-24497



REF.	DESCRIPTION
1	FUEL-INJECTOR NOZZLE CLAMP BAR AND HARDWARE
2	FUEL-INJECTOR NOZZLE
3	EXHAUST-VALVE ROCKER ARM
4	EXHAUST-VALVE CROSSOVER PUSH ROD
5	BELL CRANK
6	HIGH-PRESSURE FUEL LINE
7	FUEL-INJECTION PUMP
8	FUEL HEADER LINE
9	INJECTION-PUMP MOUNTING BOLT
10	INLET-VALVE ROCKER ARM
11	COMPRESSION RELEASE PLUG
12	CYLINDER-COVER CLAMP BAR AND HANDLE
13	INLET-VALVE SPRING
14	VALVE TAPPET ADJUSTMENTS
15	EXHAUST-VALVE SPRING
16	ROCKER-SHAFT RETAINER PLATE

FIG. II-41. UPPER CYLINDER EQUIPMENT.

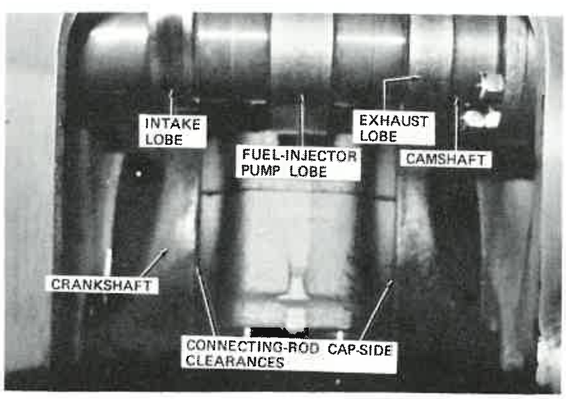


FIG. II-42. CRANKCASE AREA.

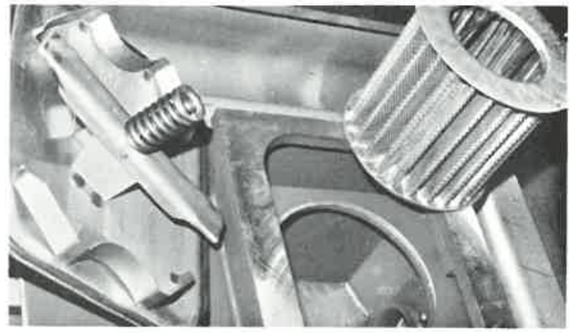


FIG. II-43. LUBE-OIL SUCTION STRAINER.

8. Opposite-side liner and rod. If the inspection is being made through a right-side door, parts of the left-side cylinder liner and rod can also be observed from this point.
9. Oil pan. Check for foreign material that may indicate a failure.

LUBE-OIL SUCTION STRAINER

The oil pan suction-strainer basket, Fig. II-43, should be removed and cleaned at each oil change or after an internal engine failure.

The purpose of the 26-mesh strainer is to keep harmful particles out of the engine lube-oil pump.

Anytime the cover is removed to service the basket, check the cover seal gasket to insure it is in good condition and properly located to prevent any possibility of sucking air when oil level is below upper surface. Otherwise, a leaking gasket can be the cause of low oil pressure (LOP) engine shutdowns.

WATER TANK

Check for evidence of leaks from the fill-cap neck and pressure-relief piping, Fig. II-44. Excessive water treatment stains might indicate a leak.

Check that the relief valve, Fig. II-44, over the cap operates properly. The purpose of the relief valve is to vent the tank pressure to prevent personal injury when the fill cap is removed.

Check that the cap can be tightened properly. A loose fill cap can cause a low water-pressure shutdown in some high-ambient temperature situations.

ENGINE AIR-FILTER SERVICE INDICATOR

Check the service indicator, Fig. II-45, to determine the condition of the paper air-filters. If the service indicator is

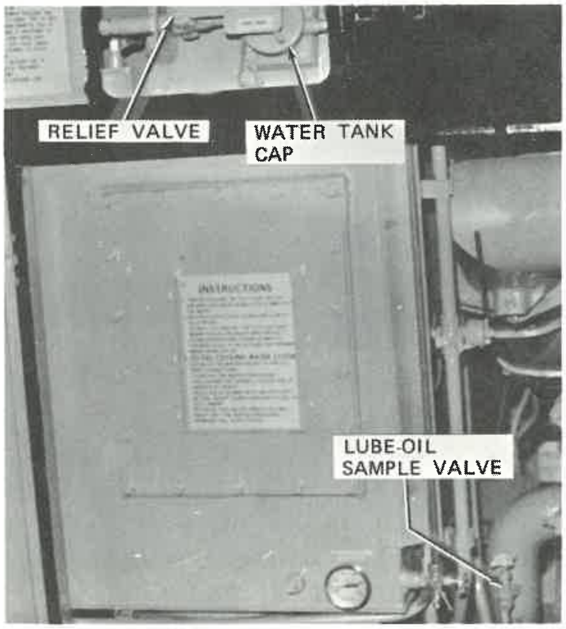


FIG. II-44. WATER TANK.

FIG. II-44, E-24501

showing a red band in its "window," the filters should be changed. It is recommended that the service indicator be changed when the filters are changed. If the service indicator is not changed, it should be reset by pushing the RESET on the indicator.

The access door clamps must be tight and secured to hold the door closed. Bent doors or deteriorated seals must be repaired to prevent unfiltered air from bypassing the plastic air cleaners.

AIR-FILTER SERVICE INDICATOR

The indicator was photographed showing the red band, indicating the engine paper air-filters should be changed, Fig. II-46.

The red band becomes visable when a vacuum of 12-in. H_2O is applied to the indicator.

It is recommended that the service indicator be changed when the air filters are changed.

PLASTIC AIR-CLEANERS

Check that the engine intake plastic air-cleaners, Fig. II-47, are all in place and properly positioned. The cleaners can be viewed through the screen without opening the filter door. The right and left-side engine air intakes each require three (3) plastic air-cleaner elements.

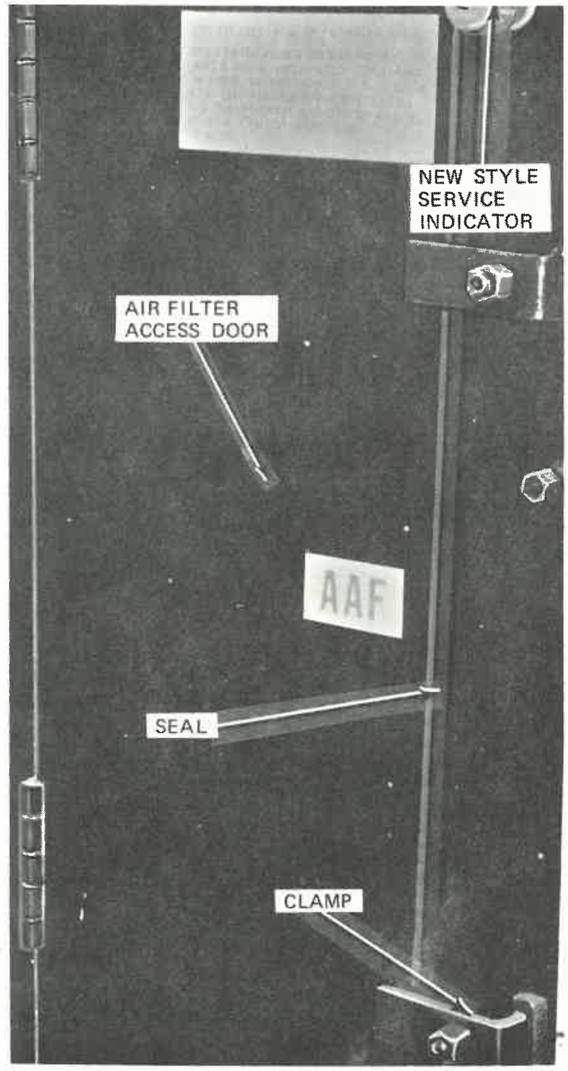


FIG. II-45. ENGINE AIR-FILTER SERVICE INDICATOR.

FIG. II-45, E-24502

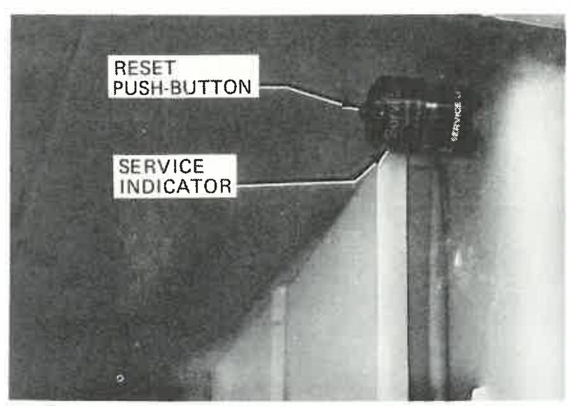


FIG. II-46. SERVICE INDICATOR.

FIG. II-46, E-22356A

FIG. II-47, E-24504

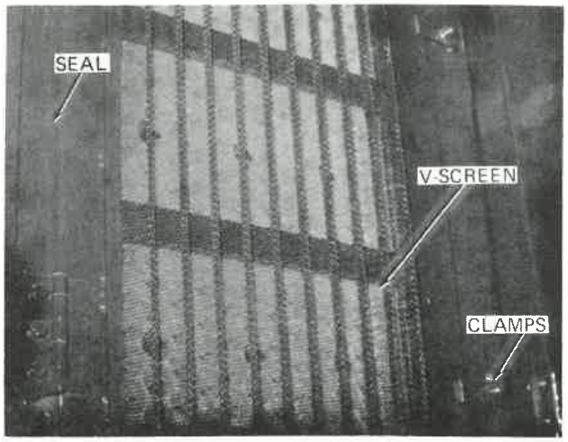


FIG. II-47. PLASTIC AIR-CLEANERS.

FIG. II-48, E-24505

The door clamps over the plastic cleaners must be tight and hold the door closed securely. Bent doors or deteriorated seals must be repaired to prevent uncleaned air from bypassing the air cleaners and prematurely plugging the paper air filters.

Remove any debris that may be plugging the inlet V-screen, Fig. II-47. Debris may include paper, leaves, ice or snow.

PLASTIC AIR-CLEANERS – CORRECT INSTALLATION

When the paper air filters must be changed, check the plastic air-cleaners for proper installation, Fig. II-48. The plastic cleaner-element clamping frame has three indexing probes to insure proper installation of the plastic elements. The indexing probes will not fit into place if the air-inlet spinners in the plastic element are in the wrong position.

The plastic air-cleaners normally never need to be renewed or cleaned. Rain and snow should keep these cleaners dirt-free. If a 1/32-in. dirt build-up does occur in the plastic cleaner, remove the cleaner and clean out the dirt.

PLASTIC AIR-CLEANER DIRT DISCHARGE

FIG. II-49, E-24506

When the paper air filters must be changed, check that the plastic air-cleaner element dirt-discharge openings match the openings in the bulkhead wall, Fig. II-49. The discharge openings are only on one end of the plastic cleaner elements.

If the plastic air-cleaner elements are installed wrong, dirt will have no way to escape and will plug the plastic air-cleaner.

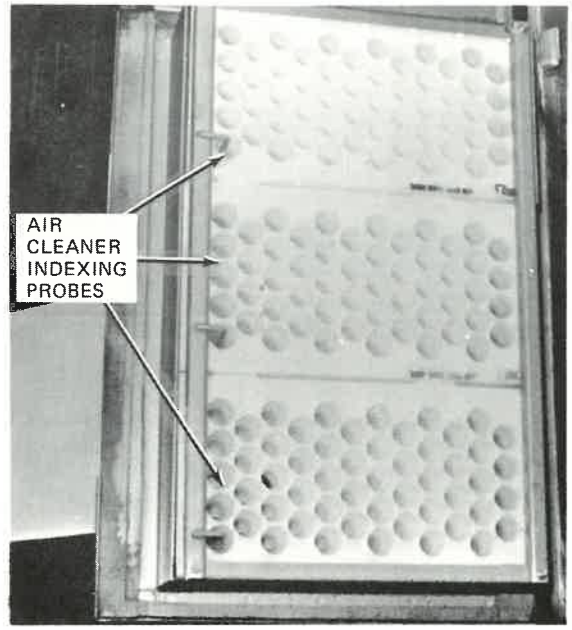


FIG. II-48. PLASTIC AIR-CLEANERS — CORRECT INSTALLATION.

DIRT-EDUCTOR CHECK VALVE

To test the check valve, Fig. II-50, grasp the rollpin in the shaft end and twist the shaft back and forth through a 15-degree arc. A clanging noise should be heard at each end of the arc. View is from walkway on left-side of the locomotive.

A check valve stuck in the CLOSED position will prevent proper operation of the engine plastic air-cleaner.

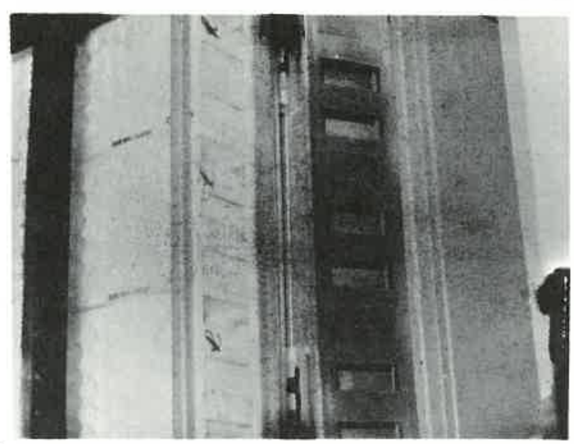


FIG. II-49. PLASTIC AIR-CLEANERS DIRT DISCHARGE.

II

FIG. II-50. DIRT-EDUCTOR CHECK VALVE.

A check valve stuck in the OPEN position can allow exhaust gas from the engine stack to flow backward and overheat the plastic air cleaners. This will be most severe at idle and the first few throttle notches.

The check valve is located on the air compressor side of the engine hood (radiator cab wall).

TURBO-AIR ELBOWS

Combustion air leaking from turbo elbows, Fig. II-51, can cause low horsepower, excessive smoke and possible turbo damage.

Check for proper application of studs and locknuts.

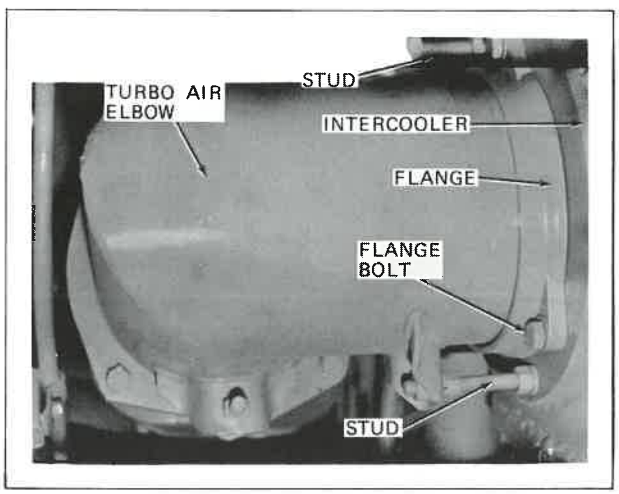


FIG. II-51. TURBO-AIR ELBOWS.

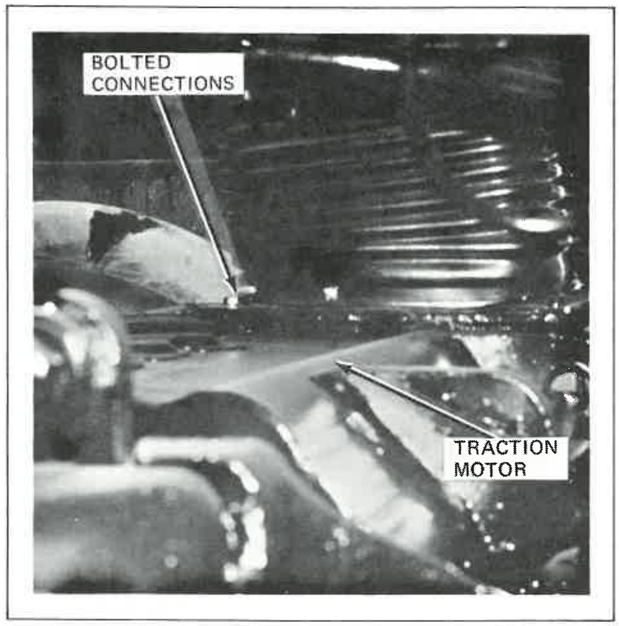


FIG. II-52. TRACTION MOTOR AIR DUCTS.

Check for proper application of flange bolts.

Check for cracks in the elbow pipe. Look for evidence of blown-out O-rings. Damaged O-rings can sometimes be observed hanging out from the flanges.

Vibration due to loose studs and flanges causes the O-rings to wear which results in air leaks.

Notch 8 NO-LOAD will produce enough turbo air so severely leaking O-rings can easily be detected by holding a hand near the escaping air. Less severe leaks can only be detected at full turbo pressure, Notch 8, FULL-LOAD.

TRACTION MOTOR AIR DUCTS

Inspect for damaged or torn flexible, rubber connections on traction motor air ducts, Fig. II-52.

Inspect the bolted connections to the traction motor. This connection should have four bolts.

A loss of ventilating air to the traction motor would affect proper cooling of the motor. Lack of proper cooling could damage the traction motor.

RADIATORS

View of the radiators, Fig. II-53, from inside the radiator cab with engine shut down.

Inspect for leaks and plugged radiators; the corner areas of the radiator must receive close inspection. Corner areas tend to become plugged before the center sections. Look for oil and/or dirt build-up.

FIG. II-50, E-24507

FIG. II-51, E-24508

FIG. II-52, E-24509

FIG. II-53, E-24510

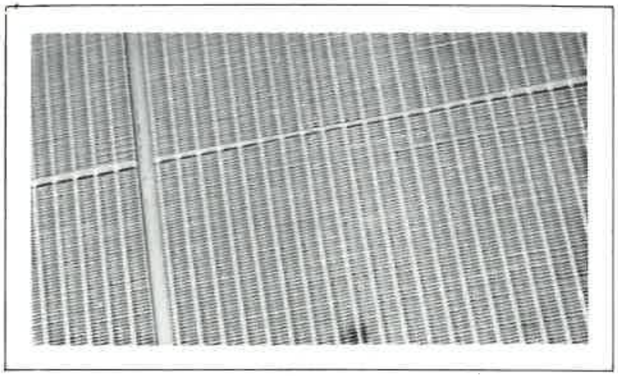


FIG. II-53. RADIATORS — CLOSE-UP VIEW.

Plugged radiators can result in inadequate cooling, hot engine alarms on the road, top liner cylinder leaks and damaged braking grids.

Pay particular attention to stains from water treatment. Remember radiators are normally filled with cooling water only when the engine temperature is above 184 F. Thus wet spots may be evident only immediately following a high-temperature shutdown.

FIG. II-54, E-24511

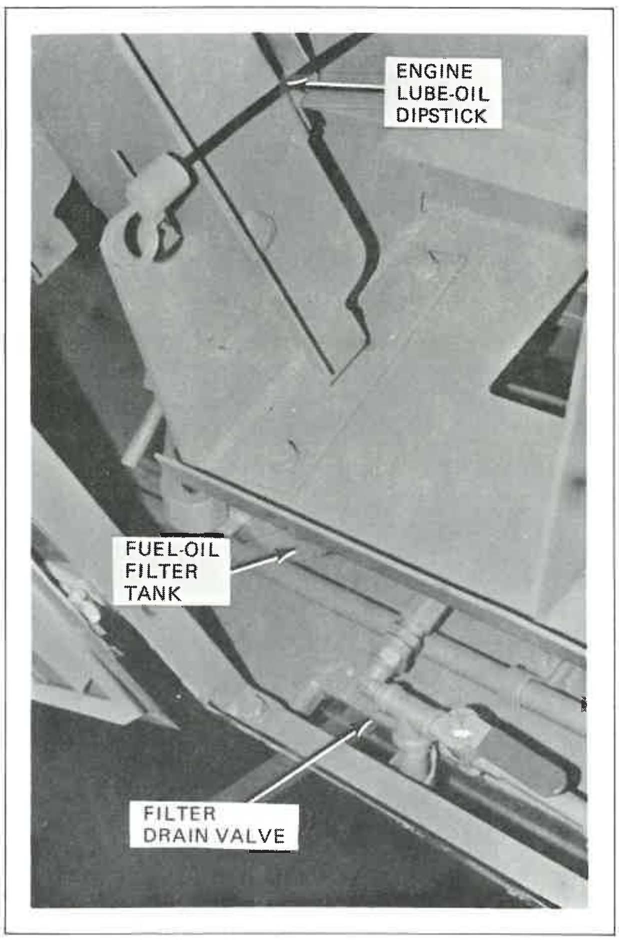


FIG. II-54. FUEL-FILTER DRAIN VALVE.

Suggest self-loading the locomotive to raise cooling water temperature sufficiently to flood both banks of radiators (two-step control). Never pressurize the cooling water system above 20 psi since it may damage the water tank and the radiators.

FUEL-FILTER DRAIN VALVE

This valve, Fig. II-54, drains the fuel-filter tank when replacing the filter element. When the fuel filter is changed, a small amount of fuel and dirt remains at the bottom of the tank. Holding the spring-loaded drain valve open will drain the residue from the filter tank into the locomotive fuel tank. If this is not done, dirty fuel oil can get past the filter and plug the fuel injectors and score the pumps.

When changing fuel filters on locomotives without the drain valve, remove the filter-tank drain plug to drain the tank.

If fuel pressure is restricted due to air trapped in the lines, opening the spring-loaded valve may release trapped air and restore proper fuel pressure. Open valve with fuel pump running, then reclose.

Dipstick

Do not intermix dipsticks, Fig. II-54, between locomotives due to differences in calibration. This could result in crankcase overpressure (COP) trips if overfilled, and low oil pressure shutdowns if underfilled.

FUEL STRAINER

Clean the fuel strainer, Fig. II-55, each time the fuel-filter element is changed. Also remove the plug in the strainer tank and drain all residue.

FIG. II-55, E-24512

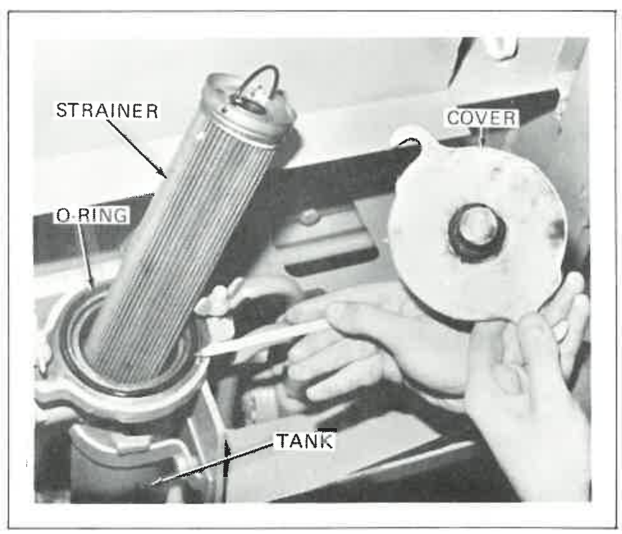


FIG. II-55. FUEL STRAINER.

Check the condition of the strainer tank O-ring before replacing the cover. Replace if necessary.

Refill the strainer tank with clean fuel or light oil to prime the system before starting the fuel pump.

ENGINE CYLINDER HATCHES

Close latches on the engine cylinder hatches, Fig. II-56. This prevents the hatches from vibrating and also allows proper latching of the side doors.

SANDING EQUIPMENT

Check the sand traps for proper operation, Fig. II-57. Most traps have quick-disconnects on outlet and sand shut-off valves to permit rodding the outlet hose if necessary.

Be sure sand is dry, otherwise it will not flow freely and will plug the traps.

Check all hoses, hose connections and hose clamps. Check that sandpipe is aligned and has proper rail clearance. The sand should be directed to the contact point of the wheel flange and the rail head.

AIR-RESERVOIR AUTOMATIC DRAIN VALVES (AIR ACTUATED)

Check that the drain valve, Fig. II-58, is in the ON position.

Operation of the valve can be checked by cycling the air-compressor governor system.

NOTE: *Reservoir drains in the CLOSED position will cause moisture to collect in the reservoir instead of being discharged. This moisture in the air system can cause malfunction or deterioration of the air brake equipment.*

Elbow is included in discharge port to direct discharge away from track ballast; in case locomotive is standing in same location for sometime, otherwise it may blast a hole in the ballast.

ENGINE SYSTEMS MONITOR

DESCRIPTION

The Engine Systems Monitor (ESM) is a protective system that electrically, mechanically and automatically identifies improper locomotive conditions. Its function is to provide over-the-road reliability, avoid unnecessary

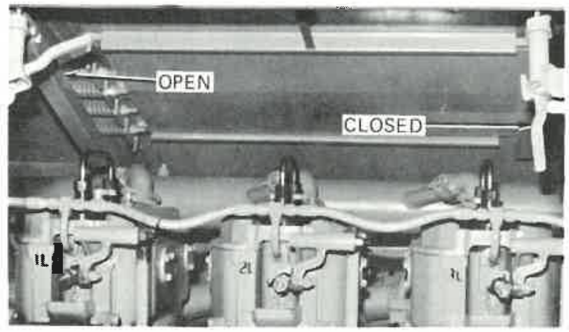


FIG. II-56. ENGINE CYLINDER HATCHES.

FIG. II-56, E-24513

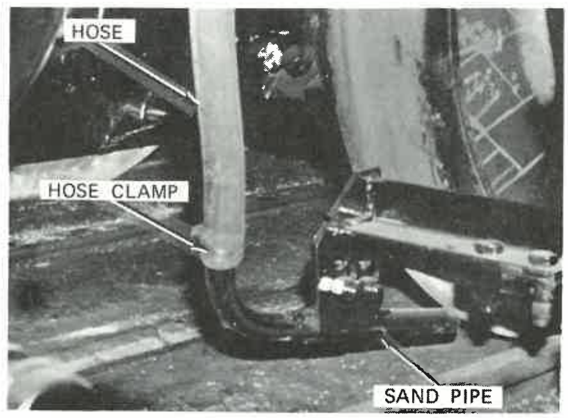


FIG. II-57. SANDING EQUIPMENT.

FIG. II-57, E-24514

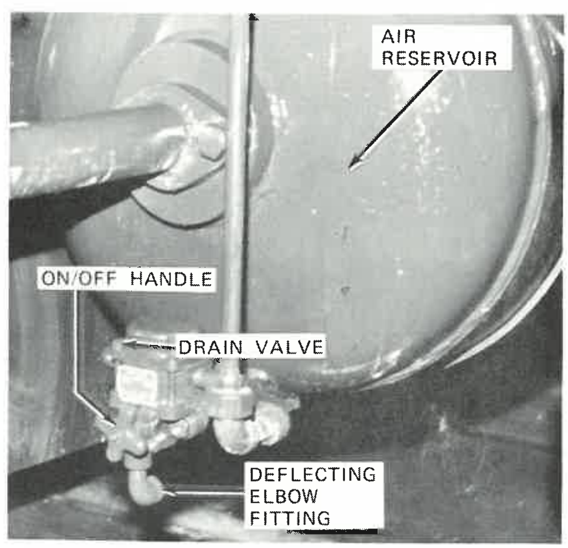


FIG. II-58. AIR-RESERVOIR AUTOMATIC DRAIN VALVES (AIR ACTUATED).

FIG. II-58, E-24515

shutdowns and reduce secondary failures. These objectives are accomplished by indicating when and what kind of maintenance work is required before the faulty condition causes a shutdown or road failure. Under most conditions, ESM will keep the diesel engine running although load and speed may be reduced to match the unit's capabilities.

When a problem occurs, malfunction indicating lights on the Engine Control Panel in the operator's cab will be lit, either singly or in combination, to advise the crew and maintenance personnel that a problem has developed. Also, malfunction indicating lights on an Annunciator Panel located within the control compartment will be lit. By observing the indicating lights, comparing their pattern shown on the ESM Diagnostic Chart, Fig. II-59, and checking the most probable cause, maintenance personnel can quickly analyze and correct the problem.

ESM DIAGNOSTIC CHART

The ESM Diagnostic Chart, Fig. II-59, presents a listing of indicating lights and system conditions including the most probable cause(s) of the problem.

When one or more ESM indicating lights on the Engine Control (EC) Panel are lit, one or more indicating lights on the Annunciator Panel also will be lit. By comparing those illuminated with the chart, maintenance personnel can identify which line of the chart applies to the problem.

For example: If the NO BATTERY CHARGE, ANNUNCIATOR PANEL and CRANKCASE OVER-PRESSURE lights are lit, Line No. 1 applies. Note that the EC PANEL LIGHTS column for Line No. 1 is divided into two sections. The top section lists the lights that are lit for a specific problem and alerts the train crew that some action may have to be taken. The bottom section lists the ANNUNCIATOR PANEL light which alerts the maintenance personnel that a problem had occurred and further investigation is warranted. In this case, the action to be taken by the train crew is to reset the Crankcase Over Pressure (COP) switch (see ENGINE CONDITION column) in accordance with recommended railroad procedures.

The CRANKCASE OVER PRESSURE light on the Annunciator Panel (see ANNUNCIATOR PANEL column) will remain lit after COP is reset to indicate that the locomotive experienced a crankcase overpressure problem. After the maintenance personnel has resolved the overpressure problem, the light on the Annunciator Panel can be turned-off by lifting-up the spring-loaded, RESET Toggle switch on the Annunciator Panel.

The ENGINE CONDITION column lists the various possible engine modes such as shutdown, idling or running.

The MOST PROBABLE CAUSE column lists the causes in descending order of probability. Thus, too high oil level in the crankcase would be considered the most probable cause; a plugged crankcase breather screen would be the least likely cause.

It should be noted that order of severity generally increases from Line No. 1 through Line No. 10. If an indication on one of the upper lines is ignored, expect progression to one of the lower.

The ESM Diagnostic Chart also has a column titled HOLD RELAY. This column lists the Engine Temperature Holding Relay (ETHR) and the Governor Shut Down Holding Relay (GSDHR). The ETHR relay will pick-up if the engine experiences an engine overtemperature condition. This condition is usually caused by high lube oil temperature, or low water pressure which causes the water temperature to increase above normal operating temperature. The GSDHR relay will pick-up if the engine experiences a very low oil pressure and/or very low water pressure condition, and the governor will then shut down the engine.

FUNCTIONAL CHECKS

DESCRIPTION

A functional check of the locomotive can be performed using the TM14 Test Kit.

The TM14 Test Kit, Fig. II-60, is a portable, externally-powered, static-component device which is used to check and calibrate wheelslip/slide detection, speedometer, transition and speed-sensing systems on locomotives.

The TM14 Test Kit has a list of condensed operating instructions attached to its cover for quick reference, Fig. II-61.

CALIBRATION

The TM14 Test Kit calibration procedure consists of two self-checks. There are no adjustments to make. Perform the following self-check steps each time the test kit is used.

1. See Fig. II-62 for Range/Function switch location and move switch to CHECK position.
2. Connect a 24 to 74 vdc source to d-c input on test kit. A nonremovable cord with clip leads is provided, Fig. II-60.

NOTE: *Any d-c voltage between 24 and 74 volts will operate this test kit.*

II

FIG. II-59, E-25038

ENGINE SYSTEMS MONITOR DIAGNOSTIC CHART

LINE NO.	EC PANEL LIGHTS (Throttle at IDLE)	CONTROL COMP. LIGHTS — ANNUNC. PANEL	CONTROL COMP. LIGHTS — HOLD REL.	ENGINE CONDITION (Unless Manually Shut Down)	CHECK EQUIPMENT LISTED FOR MOST PROBABLE CAUSE
1	NO BATT. CHARGE ANNUNC. PANEL CR'CASE OVER PR.	CRANKCASE OVERPRESS.	HOT ENG. / GOV. SH'DOWN	**SHUTDOWN:** will not crank until COP is reset. Indicates engine had excess crankcase pressure.	Too high oil level in crankcase, piston blow-by, plugged crankcase breather screen.
	ANNUNC. PANEL			**RUNNING:** indicates COP switch has tripped and been reset.	
2	ANNUNC. PANEL ENGINE AIR FILTER	ENGINE PAPER FILTER	HOT ENG. / GOV. SH'DOWN	**IDLING:** will not load. Indicates engine paper air filters excessively dirty.	Dirty engine paper air filters, blockage in primary air cleaners, debris obstructing engine air intake screens.
	ANNUNC. PANEL			**RUNNING:** may take full load. Indicates Engine Paper Filter Switch and Relay has tripped and been reset.	
3	ANNUNC. PANEL	LOW OIL PRESS.	HOT ENG. / GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low oil pressure.	Low oil level, dirty oil filter, open filter tank drain-back valve (C), dirty lube oil cooler – oil side, dirt in crankcase oil strainer, faulty lube oil relief valve, dirty fuel filter or strainer, failed (slipping) bonded pump drive, electrical bogging or overloading governor.
4	ANNUNC. PANEL	LOW OIL PRESS. LUBE OIL TEMP.	HOT ENG. / GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low oil pressure and high oil temperature.	Very dirty, almost plugged lube oil cooler – oil side. Also check all equipment listed on Lines 3 and 9. A more severe condition likely exists.
5	NO BATT. CHARGE ANNUNC. PANEL GOV. SHUTDOWN	LOW OIL PRESS.	HOT ENG. / GOV. SH'DOWN	**SHUTDOWN:** will not crank until reset. Indicates engine experienced very low oil pressure.	All equipment listed on Line 3. A more severe condition likely exists. Also investigate engine for failed lube oil pump.
6	ANNUNC. PANEL	LOW WATER PRESS.	HOT ENG. / GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low water pressure.	Low water level, cooling system not pressurized, dirty lube oil cooler – water side, water tank or lube oil cooler inlet screen plugged, dirty fuel filter or strainer, failed (slipping) bonded pump drive, governor.
7	ANNUNC. PANEL	LOW WATER PRESS. LUBE OIL TEMP.	HOT ENG. / GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low water pressure and high oil temperature.	Very dirty, almost plugged lube oil cooler – water side. Also check all equipment listed on Line 6 and 9. A more severe condition likely exists.
8	NO BATT. CHARGE ANNUNC. PANEL GOV. SHUTDOWN	LOW WATER PRESS.	HOT ENG. / GOV. SH'DOWN	**SHUTDOWN:** will not crank until reset. Indicates engine experienced very low water pressure.	All equipment listed on Line 6. A more severe condition likely exists. Also investigate engine for failed water pump.
9	ANNUNC. PANEL	LUBE OIL TEMP.	HOT ENG. / GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced high oil temperature.	Dirty radiators, plugged air inlet screens, excessive braking current, faulty control of water temperature, dirty lube oil cooler – either side, excess horsepower output. *(May also be caused by very high ambient temperature or by tunnel operation.)*
10	ENGINE OVERTEMP. ANNUNC. PANEL		HOT ENG. / GOV. SH'DOWN	**IDLING:** will not load. Indicates engine experienced very high water temperature.	Severe cooling system-related problem. If the system checks OK, test LOT switch. It may not be indicating that a high lube oil temperature has occurred. If LOT switch is found faulty, proceed to Line 11.
11	ENGINE OVERTEMP. ANNUNC. PANEL	LUBE OIL TEMP.	HOT ENG. / GOV. SH'DOWN	**IDLING:** will not load. Indicates engine experienced very high oil or oil and water temperature.	All equipment listed on Line 9. A more severe condition likely exists. Also inspect for failed fan drive.
12	ENGINE OVERTEMP. ANNUNC. PANEL	LOW WATER PRESS.	HOT ENG. / GOV. SH'DOWN	**IDLING:** will not load. Indicates engine experienced low water pressure and very high water temperature.	Low water level.
13	OVERLOAD RELAY TRIPPED ANNUNC. PANEL	GENERATOR OVERLOAD	HOT ENG. / GOV. SH'DOWN	**IDLING:** will not load. Indicates main alternator experienced a surge of current. Reset GOLR to make unit operable.	Traction motors for signs of flashover; motors for shorted fields, busbars, or leads; bus bars and cables at main alternator and rectifier panels for loose connections; current limit adjustment in excitation panel; failure of ACCR; single-phasing of alternator; GOLR for defects; alternator field connections and busbars for a short circuit.
	ANNUNC. PANEL			**RUNNING:** may take full load. Indicates GOLR has tripped and been reset.	
14	GROUND RELAY TRIPPED ANNUNC. PANEL	GROUND RELAY	HOT ENG. / GOV. SH'DOWN	**IDLING:** will not load. Indicates power circuits have experienced a ground.	Electrical power equipment for evidence of a flashover, intermittent ground, or continuing ground.
	ANNUNC. PANEL			**RUNNING:** may take full load. Indicates GR has tripped and been reset.	
15	ANNUNC. PANEL HOT DIODES	HOT DIODES	HOT ENG. / GOV. SH'DOWN	**IDLING:** will not load. Indicates one or more rectifier panels have experienced excessive temperature.	Main alternator for loose or missing covers, accumulation of debris on blower intake screens, inoperative blower, failed diodes in rectifier panels, single-phased alternator.
	ANNUNC. PANEL			**RUNNING:** may take full load. Indicates one or more hot diode detectors have tripped and relay has been reset.	
16	REDUCED EXCIT. ANNUNC. PANEL	REDUCED EXCITATION	HOT ENG. / GOV. SH'DOWN	**RUNNING:** will not take full load. Indicates problem in Excitation Panel causing operation in Reduced Excitation mode.	Excitation panel for proper cards in correct locations. Each card for dirty, bent, or broken contact pins. Faulty card. Allied circuits for loose or broken wires or components, including feedback connections from rectifier panels and ACCR to excitation panel. Make sure alternator is not single-phased. Make sure governor plug connection and wiring is correct.
	ANNUNC. PANEL			**RUNNING:** will take full load. Indicates some period of operation in Reduced Excitation mode, and switch on MD card has been reset.	

FIG. II-59. ENGINE SYSTEMS MONITOR DIAGNOSTIC CHART.

FIG. II-60, E-23515

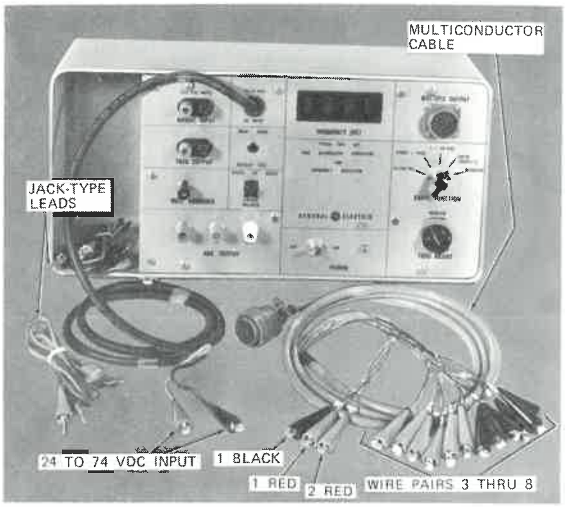


FIG. II-60. TM14 TEST KIT.

NOTE: *Observe polarity. Red is positive; black is negative. Reverse polarity will trip the test kit Circuit Breaker. The Reset button pops out in the TRIPPED position, Fig. II-62.*

3. Move the test kit Power switch to ON. The red indicating light next to the Power switch will indicate power being supplied to the test kit.

4. Push the Display Test button and hold. Read 8888 on the Frequency (Hz) display. Release button.

NOTE: *Failure to read 8888 may indicate a failed display digit.*

5. With the Range/Function switch still in the CHECK position, read 4000 ± 1 on the Frequency (Hz) display.

NOTE: *Failure to read 4000 ± 1 may indicate a malfunction of the test kit internal counter circuitry.*

6. Self-check completed. Place test kit Power switch in the OFF position. If the self-checks given in Steps 4 and 5 do not produce the required results, obtain repair service for this test kit. Do not attempt to use this test kit if it is not operating properly. Incorrect values and settings may result.

II

CAUTION: *The TM14 Test Kit is designed as a multi-purpose test instrument which can produce a wide range of frequencies. Do not use frequencies higher than those needed to test a specific apparatus. Excessive output frequency from the test kit may damage some equipment. When operating the Range/Function switch, set the Freq. Adjust knob to the minimum (CCW) position and turn the test kit Power switch off. This will reduce the possibility of producing excessive output frequency during range changes.*

FIG. II-61, E-23516

CONDENSED OPERATING INSTRUCTIONS FOR 17TM14 TEST SET
FOR FURTHER INFORMATION SEE GEK-61414.

A. SETUP

1. CONNECT POWER LEADS (24 TO 74 VDC). OBSERVE POLARITY. RED IS POSITIVE. REVERSE POLARITY TRIPS CIRCUIT BREAKER.
2. POWER SWITCH "ON". OBSERVE POWER LAMP "ON".
3. PUSH "DISPLAY TEST" – READ 8888
4. "RANGE/FUNCTION" SWITCH TO "CHECK" – READ 4000 1 ON DISPLAY

B. SIMULATE 17MM24 AXLE ALTERNATOR (UP TO SIX TOTAL)

1. USE LEADS R3-B3, R4-B4, R5-B5, R6-B6, R7-B7, R8-B8 (ONE PAIR FOR EACH 17MM24 REPLACED)
2. SET FREQUENCY RANGE DESIRED (10-100 HZ, 100 HZ-1 KHZ, 1-10 KHZ)
3. ADJUST FREQUENCY WITH "FREQ. ADJUST". READ FREQUENCY ON DIGITAL DISPLAY
4. TO SIMULATE ONLY ONE 17MM24 USE "FREQ. OUTPUT" TERMINALS.

C. SIMULATE 17MM54 AXLE ALTERNATOR

1. DISCONNECT THE LEADS (RED/+15; BLUE/Vo; WHITE/COMMON) FROM THE 17MM54 AND CONNECT THESE LEADS TO CORRESPONDING TERMINAL POSTS ON THE TEST SET (LEADS PROVIDED).
2. SET RANGE AND FREQUENCY DESIRED – READ FREQUENCY ON DISPLAY

D. MONITOR

APPLY SIGNAL TO "SIGNAL INPUT" TERMINALS AND PLACE "RANGE/FUNCTION" IN "MONITOR". READ FREQUENCY ON DIGITAL DISPLAY

E. NULL REFERENCE

SEE OPERATING INSTRUCTIONS GEK-61414.

FIG. II-61. CONDENSED OPERATING INSTRUCTIONS (ATTACHED TO INSIDE COVER).

II

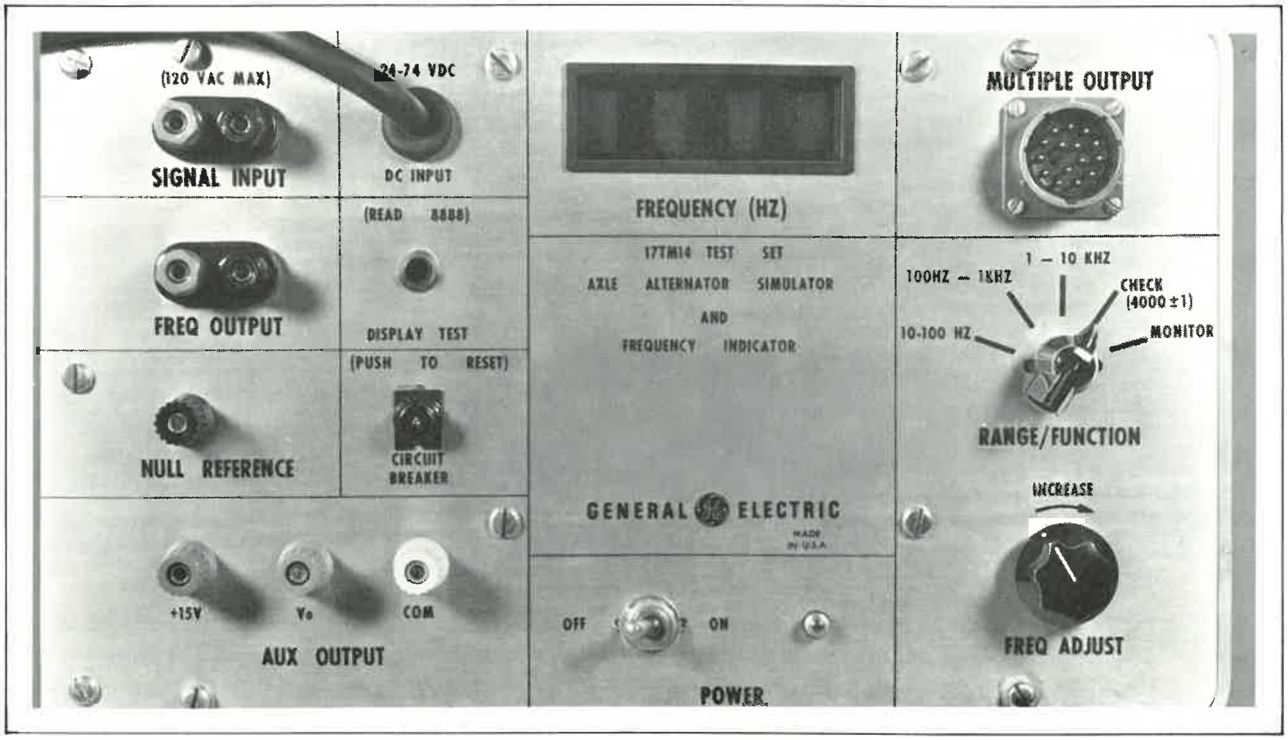


FIG. II-62. TM14 TEST KIT FRONT PANEL.

FIG. II-62, E-23517

WHEELSLIP DETECTION PANEL (WITH AXLE ALTERNATORS)

Wheelslip Trouble-Shooting

The following four subsections, dealing with the panel functional check, axle circuits balance adjustment and high and low-speed sensitivity checks, have been designed to be used in conjunction with the trouble-shooting procedures for the specific wheelslip/slide detection panel furnished on a particular locomotive. Refer to the overall maintenance manual for the applicable panel publication.

NOTE: *A wheelslip problem may be caused by loose or broken connections between the wheelslip panel and the axle alternators. Before checking the wheelslip panel, verify connections to the axle alternators are intact.*

To verify Type MM24 Axle Alternator connections:

1. Disconnect the axle alternator wires from the wheelslip detection panel.
2. Connect an ohmmeter to the alternator wires and measure the resistance of the alternator. Resistance should measure between 73 and 83 ohms.
   a. A resistance reading of infinity may indicate an open wire between the wheelslip panel and the axle alternator.
   b. A resistance outside of the 73 to 83-ohm range may indicate a defective axle alternator.

NOTE: *When using the TM14 Test Kit to calibrate wheelslip detection panel, it is recommended the following four checks be performed in the order they are given:*

1. Functional check of wheelslip detection panel
2. Balance adjustment of axle circuits
3. High-speed sensitivity check
4. Low-speed sensitivity check.

This sequence should provide the quickest solution to most problems that might exist in the panel. Do not deviate from this sequence.

Functional Check of Wheelslip Detection Panel

1. Disconnect the axle alternator wires from the wheelslip detection panel.
2. Connect the multiconductor cable to the Multiple Output plug on the test kit, Fig. II-60.
3. Connect one of the following pairs of wires of the multiconductor cable in place of each pair of alternator wires removed. (Polarity is unimportant.) The wire pairs are:

   3 Red – 3 Black
   4 Red – 4 Black
   5 Red – 5 Black
   6 Red – 6 Black
   7 Red – 7 Black
   8 Red – 8 Black.

   Each pair simulates one MM24 Axle Alternator output.

FIG. II-63, E-12350B

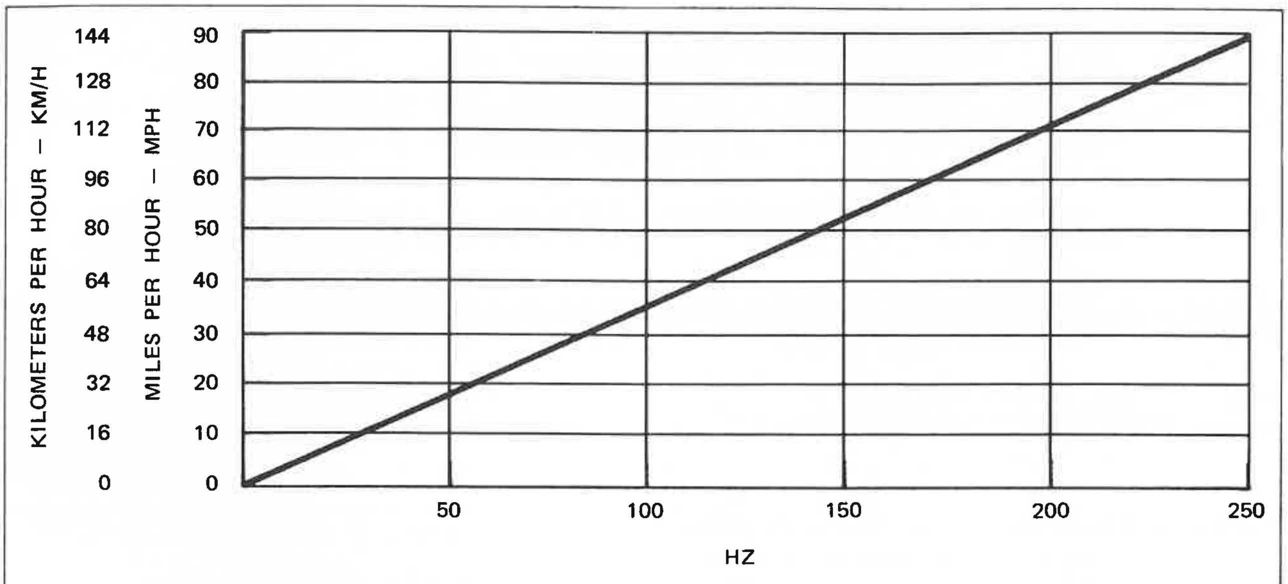


FIG. II-63. MPH VS. FREQUENCY FOR 17MM24 AXLE ALTERNATOR (40-IN. WHEELS).

NOTE: *Multiconductor cable clip leads 1 Black, 1 Red and 2 Red are not being used in this step of the test. Secure them out of the way where they will not be in contact with other terminals or parts of the locomotive. Do not short unused pairs together since possible internal damage may result.*

On a four-axle locomotive, in addition to clip leads 1 Black, 1 Red and 2 Red, two additional pairs will not be used. Also secure these leads out of the way. It does not matter which clip lead pairs are not used. For convenience, do not use 7 Red – 7 Black and 8 Red – 8 Black.

4. Be sure other wires are not shorted to each other or to locomotive.
5. Connect the d-c input cord on the test kit to a 24 to 74 vdc source. Observe polarity; red positive, black negative.
6. Place Range/Function switch in the desired range, Fig. II-63.

> **CAUTION:** *Do not exceed 400 Hz when testing wheelslip, transition or speedometer systems. Excessive output frequency may damage these systems. When operating the Range/Function switch, set the Freq. Adjust knob to the minimum (CCW) position and turn the test kit Power switch off.*

7. Place the test kit Power switch to ON.
8. Turn the Freq. Adjust rheostat to obtain Hz desired, Fig. II-63.

NOTE: *The wheelslip relay will operate and the light or buzzer will indicate a slip when Freq. Adjust rheostat is turned rapidly (if anticipation capacitor is used in the wheelslip panel). The slip indication should stop when the rheostat motion is stopped. This indicates the anticipation capacitor is working satisfactorily. If the signal does not stop, consult the trouble-shooting guide for the appropriate panel.*

If the wheelslip relay does not operate during a rapid twist of the frequency-control rheostat, the anticipation capacitor may be open, the transistor may be open, or the system wiring may be open.

9. Observe the panel operation at various simulated locomotive speeds. Set the test kit to simulate 10, 20, 30, 40, etc. mph, Fig. II-63. At each speed, the panel should not give any wheelslip indication.

NOTE: *Some panels contain overspeed circuitry that will give a wheelslip indication at 70 or 80 mph.*

If the panel does cause a wheelslip relay pick-up or other related operation, obtain a new set of panel cards and insert them, if spare cards are available. If these new cards correct the wheelslip situation, substitute the old cards one at a time, until the defective card is located.

If spare cards are not available, continue to Balance Adjustment of Axle Circuits section.

10. Observe that the wheelslip detection panel energizes the locomotive WSR Relay when one axle alternator signal is removed.
    a. Adjust the test kit frequency to simulate some reasonable locomotive speed. For example, select 40 mph. From Fig. II-63, it can be seen that 40 mph would produce a 115-Hz frequency.

b. Adjust the test kit Freq. Adjust knob to obtain 115 Hz on the display. The wheelslip detection panel should not be indicating a slip condition.

c. Disconnect one lead from a pair of test kit multiconductor cable wires that is simulating an axle alternator. A wheelslip indication should result the moment the wires are disconnected and stop when reconnected.

d. If a wheelslip indication is not produced with one wire pair disconnected, try changing panel cards. Also, try different locomotive speeds.

If spare cards are not available, continue on to Balance Adjustment of Axle Circuits section.

Balance Adjustment of Axle Circuits

1. With the test kit connected as described in Functional Check of Wheelslip Detection Panel section, Steps 1 through 5, perform a, b or c depending on the panel used.

   a. On the FM190 panel (four-axle system):

      Connect No. 1 Black lead to TB1H.
      Connect No. 2 Red lead to TB2J.
      Connect No. 1 Red lead to TB2K.

   b. On the FM190 panel (six-axle system):

      Connect No. 1 Black lead to TB1F.
      Connect No. 2 Red lead to TB1E.
      Connect No. 1 Red lead to TB1D.

   c. On the FL7 and FL8 panels (four-six axle systems), remove the card on which the balance is to be checked, insert the card extender, and plug the card into it:

      Connect No. 1 Black lead to card terminal Pin A.

      Connect No. 2 Red lead to card terminal Pin H.

      Connect No. 1 Red lead to card terminal Pin G.

2. Set the test kit Range/Function switch to 100-1 kHz. Adjust the Freq. Adjust rheostat to read at least 150 Hz on the test kit frequency display.

> **CAUTION:** *Do not exceed 400 Hz when checking wheelslip, transition or speedometer systems. Excessive output frequency may damage these systems. When operating the Range/Function switch, set the Freq. Adjust knob to the minimum (CCW) position and turn the test kit Power switch OFF.*

3. Using a multimeter (on the highest milliamp scale available), clip the positive lead of the meter to the test kit terminal marked Null Reference. Clip the negative lead to the center tap of the balance potentiometers one at a time, and record the readings. If the meter does not read, move progressively to the lowest microampere scale. (If the meter reads backwards, change the polarity of the leads and record the reading as a negative reading.)

4. If the meter reads more than ± 6 microamperes, adjust the potentiometer to which the meter is connected to zero microamperes. (Zero microamperes is a perfect balance.)

High-Speed Sensitivity Check

1. With the test kit connected as in Functional Check of Wheelslip Detection Panel section, Steps 1 through 5, proceed as follows:

2. Place the Range/Function switch in the 100 Hz-1 kHz range. Adjust the Freq. Adjust rheostat to obtain 150 Hz on the Frequency (Hz) display.

3. Perform a or b depending on panel used.

   a. On the FM190 panel: Using a multimeter, measure the voltage between the brush arms of P7 and P8 (the two rheostats at the top of the 426C921 and 41C650359 cards). Voltage should be 0.75 v. Adjust P7 rheostats (furthest from the terminal board) if necessary.

   b. On the FL7 and FL8 panels: Using a multimeter, measure the voltage from Pin E (+) to H (–) on the 182 card. Voltage should be 0.41 v. Adjust the R9 rheostat (rheostat has center tap shorted to one outside terminal) if necessary.

Low-Speed Sensitivity Check

1. Connect only one pair of wires from the multiconductor cable to wheelslip-detection panel terminals in place of any one pair of alternator wires. All other wires from the Multiple Output cable should be disconnected.

2. Proceed as in Functional Check of Wheelslip Detection Panel section, Steps 4 and 5.

3. Place the test kit Range/Function switch in the 10-100 Hz position.

4. Set the Freq. Adjust rheostat to its extreme counterclockwise position. The meter should indicate 10 Hz or less.

5. Turn the Freq. Adjust rheostat to increase the frequency output. The wheelslip relay should operate at 14 Hz. On the FM190 panel, adjust P8 rheostat (on the 426C921 and 41C650359 card, at top, closest to the terminal board strip) if necessary. If this adjustment is changed, the high-speed sensitivity must be checked. See High-Speed Sensitivity Check section. On the FL7 and FL8 panels, no adjustment is provided.

For a locomotive with 40-in. wheels, the following relationship exists:

11 Hz equals 4 mph.
14 Hz equals 5 mph.
17 Hz equals 6 mph.
20 Hz equals 7 mph.
22 Hz equals 8 mph.

The basic relationship is 2.8 Hz equals 1 mph. All values listed are rounded to the nearest whole number.

NOTE: *If all four of the previous checks do not show the cause of trouble, the trouble is most likely in the axle alternators.*

1. *Disconnect the alternator wires from the wheelslip detection panel. Connect an ohmmeter to alternator wires, and measure the resistance of the alternator. Resistance should measure between 73 and 83 ohms.*
2. *If resistance is within limits specified in Step 1, remove axle alternator cover and check for a loose rotor, broken or loose parts or other mechanical damage.*

SPEEDOMETER SETTING

1. Disconnect the one set of axle alternator wires (which controls speedometer readings) from the axle circuit on wheelslip detection panel, or if wheelslip detection is not used, from speedometer panel. See locomotive schematic for exact circuit.
2. Connect jack-type leads between the two plugs on test kit marked Freq. Output and terminals from which two wires, in Step 1, have been removed.
3. See Functional Check of Wheelslip Detection Panel section, and perform Steps 5, 6, 7 and 8.

CAUTION: *Do not exceed 400 Hz when checking wheelslip, transition or speedometer systems. Excessive output frequency may damage these systems. When operating the Range/Function switch, set the Freq. Adjust knob to the minimum (CCW) position and turn the test kit Power switch OFF.*

4. If readings on speedometer and test kit do not correspond with those shown in Fig. II-63, adjust the calibration potentiometer (on FM192 speedometer panel) to obtain desired proportion.

AUTOMATIC TRANSITION SETTING

1. With the engine shut down, the controls set for motoring, and sufficient control air pressure to operate the contactors, move the Throttle handle to the first notch.
2. Disconnect the one set of alternator wires which controls transition speeds. On some locomotives the alternator wires are connected to the wheelslip panel. On locomotives built since 1977, the alternator wires are connected directly to the transition panel. See locomotive schematic for details.
3. Connect the jack-type leads between the two plugs on the test kit marked Freq. Output and the terminals from which the two wires, in Step 2, have been removed.
4. See Functional Check of Wheelslip Detection Panel section, and perform Steps 5, 6, 7 and 8. See locomotive schematic diagram for specific transition settings.

NOTE: *Many locomotives use a transition time-delay circuit. This causes the traction motor power contactors to be energized at some preset amount of time (seconds) LATER than the transition panel is actuated. Refer to the locomotive schematic to determine exact transition time delay action.*

CHECK 17MM24 AXLE ALTERNATOR OUTPUT WITH LOCOMOTIVE MOVING

NOTE: *Remember to calibrate this test kit before using. See Calibration section.*

1. Connect test kit Signal Input terminals in parallel with the axle alternator output (jack-type leads provided).
2. Connect d-c input cord on test kit to a 24 to 74 vdc source. Observe polarity; red positive, black negative.
3. Place the test kit Power switch to ON.
4. Place Range/Function switch in the MONITOR position.
5. The test kit frequency display will indicate Hz when the alternator rotates. Hz are proportional to miles per hour, as shown in Fig. II-63.

TYPE MM54 SPEED SENSOR SIMULATION AND MONITOR

The TM14 Test Kit will simulate the output of one 17MM54 Speed Sensor. Refer to the overall maintenance manual and the locomotive schematic.

1. Connect the test kit as described in Functional Check of Wheelslip Detection Panel section, Steps 4 thru 6.

2. Disconnect the leads connecting the 17MM54 Speed Sensor to its control panel at the control panel. The control panel will usually be located in the control compartment of the locomotive.

3. Using jack-type leads provided, connect the TM14 Test Kit Aux. Output terminals (+15, Vo, Com) to corresponding terminals of the control panel from which the speed sensor leads were removed.

NOTE: *Early versions of the MM54 Speed Sensor had the speed sensor terminals labeled 1, 2 and 3. These terminals are as listed below:*

Terminal 1 – Common
Terminal 2 – Vo
Terminal 3 – +15 vdc.

Newer versions use color-coded terminals.

White Terminal – Common
Blue Terminal – Vo
Red Terminal – +15 vdc.

4. Set the test kit Range/Function switch to the frequency range desired. See Fig. II-64.

5. Adjust the Freq. Adjust knob to obtain frequency desired. See Fig. II-64. Read frequency on the Frequency (Hz) display.

NOTE: *The 17MM54 Speed Sensor generates a signal that gives 50 Hz/mph.*

To check the MM54 Speed Sensor with locomotive moving:

1. See Check 17MM24 Axle Alternator With Locomotive Moving section. Perform Steps 2 thru 4.

2. Connect test kit Signal Input terminals in parallel with the MM54 Speed Sensor output (Vo, Common).

3. The test kit Frequency (Hz) display will indicate Hz when the speed sensor rotates.

NOTE: *Hz are proportional to speed, as shown in Fig. II-64. The speed sensor generates a signal that gives 50 Hz/mph.*

TYPE MM102 SPEED SENSOR SIMULATION AND MONITOR

NOTE: *This TM14 Test Kit will simulate the output of the 17MM102 motor Speed Sensor. To simulate the 17MM102 output, use the Aux. Output (+15 v, Vo, Com) terminals on the test kit. The general procedure is similar to the 17MM54 Speed Sensor. For exact details and frequency settings, consult the maintenance instruction covering the system using the 17MM102 Motor Speed Sensor.*

The MM102 Motor Speed Sensor can be monitored by connecting the sensor output in parallel with the test kit signal input. Also perform Steps 2 thru 4 given in Check 17MM24 Axle Alternator Output with Locomotive Moving section.

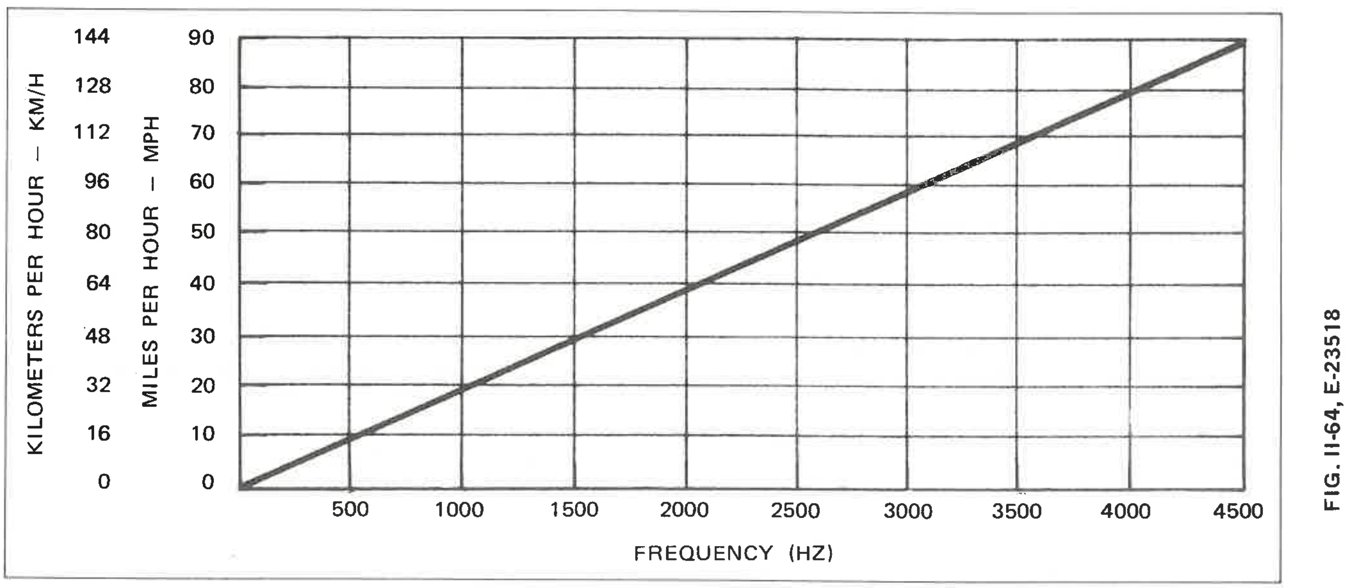


FIG. II-64. MPH VS. FREQUENCY FOR 17MM54 SPEED SENSOR (40-IN. WHEELS).

II

TURBO SPEED SENSOR MONITOR

Locomotives equipped with the CHEC excitation control system, monitor engine turbocharger speed with a turbo speed-sensor probe. The output of this probe can be monitored using the TM14 Test Kit. Refer to the overall maintenance manual for specific turbo probe output data.

To monitor output:

1. Connect TM14 Test Kit Signal Input terminals in parallel with the turbo speed sensor probe output. (See locomotive schematic for a convenient location to connect to turbo output circuit.)
2. Connect d-c Input cord on test kit to a 24 to 74 vdc source. Observe polarity; red positive, black negative.
3. Place the test kit Power switch to ON.
4. Place Range/Function switch in the MONITOR position.
5. The test kit Frequency (Hz) display will indicate Hz when the turbocharger rotates.

   Relationship between turbo rpm and Hz.

   $$\frac{\text{Turbo rpm} \times 2}{60.} = \text{Hz}$$

   or Turbo rpm = Hz x 30

NOTE: *Turbo probe output at idle speed may not be enough to trigger the TM14 Test Kit counter circuitry. This would tend to indicate no output, when in reality there is output. Try higher speeds to verify probe output.*

NOTES:

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GENERAL ELECTRIC

INSTRUCTIONS

CONTROL EQUIPMENT

III

FIG. III-1, E-18381

CONTENTS

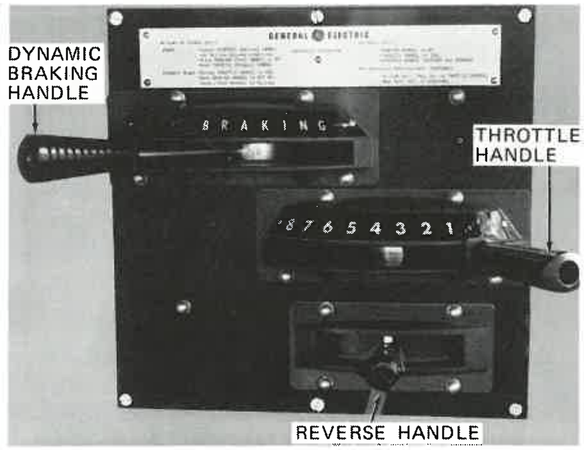

FIG. III-1. TYPICAL KC108 MASTER CONTROLLER, WITH BRAKING HANDLE.

CONTENTS (Cont'd.)

INTRODUCTION

This section includes information about control equipment for Series-7 Locomotives. Control equipment consists of devices and panels which provide the means of control of the locomotive.

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III

MASTER CONTROLLER

DESCRIPTION

The Type KC108 Master Controller is a three-handle, manually-operated, set-up switch with which the operator can control the direction, speed and (if equipped) the dynamic braking output of the locomotive, Fig. III-1.

The controller has the following handles:

1. REVERSE - bottom handle–Determines direction of locomotive movement: REVERSE, OFF, FORWARD. Handle removable with Throttle handle in IDLE and Braking handle in OFF.
2. THROTTLE - middle position–Controls speed of the diesel engine with SHUTDOWN, IDLE and eight power notches. Movement of handle into SHUTDOWN position to right of IDLE causes all engines in consist to shut down–for emergency use only.
3. BRAKING - upper position (if equipped)–For determining dynamic braking set-up and output with OFF, SET-UP positions and a BRAKING (B) sector.

Each handle opens and closes cam-operated contacts. Mechanical interlocking between the handles prevents improper operation of any handle.

MECHANICAL INTERLOCKING

Reverse Handle

With this handle removed, the controller is "locked-up." Neither the Brake handle nor the Throttle handle can then be moved. At lock-up, the Throttle handle is in IDLE position. Only when the Reverse handle is inserted can the Throttle handle be advanced thru the full engine speed range.

The Reverse handle cannot be moved from FORWARD or REVERSE when the Throttle handle is in Notch 1 or higher.

The Reverse handle cannot be moved from FORWARD or REVERSE when the Braking handle is advanced to SET-UP or BRAKING (only applies when Braking is included).

Throttle Handle

This handle cannot be moved to Notch 1 or higher if the Braking handle is advanced to SET-UP or any Braking position.

The Throttle handle can be placed in the emergency SHUTDOWN position under any operating condition except when the Reverse handle is removed.

The Throttle handle grip must be pulled outward (compress spring) to move from IDLE to SHUTDOWN position, and the Reverse handle must be inserted.

Braking Handle

This handle cannot be moved when the Reverse handle is in OFF (center) position; it must be in either FORWARD or REVERSE and the Throttle handle in IDLE or SHUTDOWN positions.

The Braking handle cannot be advanced for dynamic braking when the Throttle handle is in any notch between 1 and 8, or the Reverse handle is in OFF (center).

Data

Contact Finger: Throttle, Brake, Reverse

Overtravel (in.)	
Throttle	3/32-4/32
Brake	3/32-4/32
Reverse	3/32-4/32
Tip Brake (in.)	
Throttle	11/32-13/32
Brake	11/32-13/32
Reverse	11/32-13/32
Tip Pressure (lb.)	
Throttle	3/4-1.0
Brake	3/4-1.0
Reverse	3/4-1.0

INSPECTION AND MAINTENANCE

General

Periodically, the control stand cover over the back of the controller should be removed and the following inspections made:

1. Full contact must be obtained on all sets of contact fingers.
2. Examine contact surfaces for burning and wear. Replace badly worn, burned or pitted contacts. Contacts may be filed smooth with a fine file. DO NOT USE SANDPAPER OR EMERY CLOTH.
3. Contact tip pressure is the force the compression spring applies to keep the finger against the stationary contact. Compare the contact tip pressure with values given in "Data" section. Measure the pressure as follows:

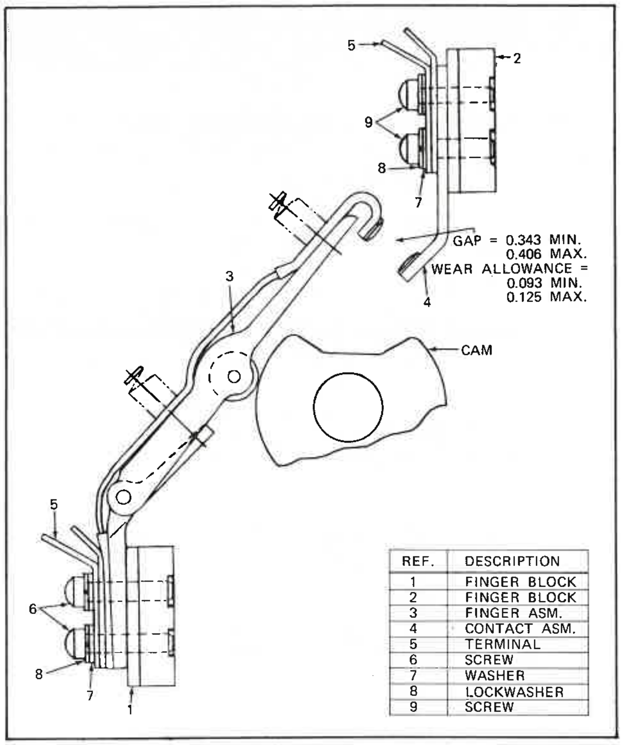
   a. Use a spring scale with a hook which can be inserted in the contact loop, Fig. III-2.

FIG. III-2, E-18384B

FIG. III-3, E-18382A

FIG. III-4, E-18383

III



REF.	DESCRIPTION
1	FINGER BLOCK
2	FINGER BLOCK
3	FINGER ASM.
4	CONTACT ASM.
5	TERMINAL
6	SCREW
7	WASHER
8	LOCKWASHER
9	SCREW

FIG. III-2. KC108 FINGER AND CONTACT ASSEMBLY.

b. Insert a strip of paper between the stationary contact and movable finger.

c. Pull on the spring scale until the finger separates sufficiently to allow the paper to be removed. Observe the scale value at this time. This should agree with the values given in the "Data" section. If it does not, the contact should be repaired or replaced.

4. Examine all wiring for loose connections and breaks in insulation. Replace damaged wiring.

5. Check handle movements for any binding or incorrect interlocking between handles.

6. Refer to Fig. III-3 for maintenance of the controller lighting circuit. The voltage should be from 6 to 8 v at the light socket. To replace the No. 44 pin-type pilot lamps, remove the two screws on the indicating strip involved. Slipping a short piece of suitable, small hose over lamp to remove it and to install new lamp is suggested.

CAUTION: *Remove and replace one indicating strip at a time to prevent possible interchange of strips.*

7. Check braking potentiometer (when equipped) for open or shorted condition. Resistance should measure from 45 to 55 ohms.

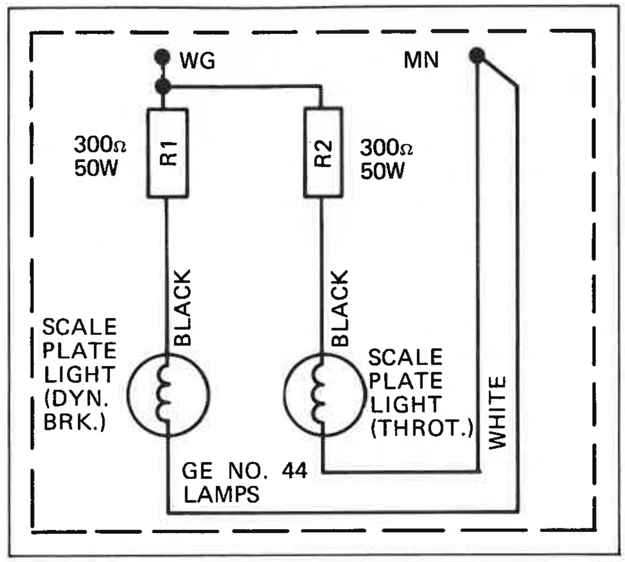


FIG. III-3. SCHEMATIC OF LIGHTING CIRCUIT.

Finger Contact and Replacement
(See Figs. III-2 and III-4)

To replace a Finger:

1. Remove back cover from operator's stand to get at back of controller.

2. Remove screws (6), lockwashers (8) and washer (7) from finger block (1) to be replaced.

3. Remove terminal (5) with lead attached, and place it to one side. (If terminal is to be replaced, remove wire.)

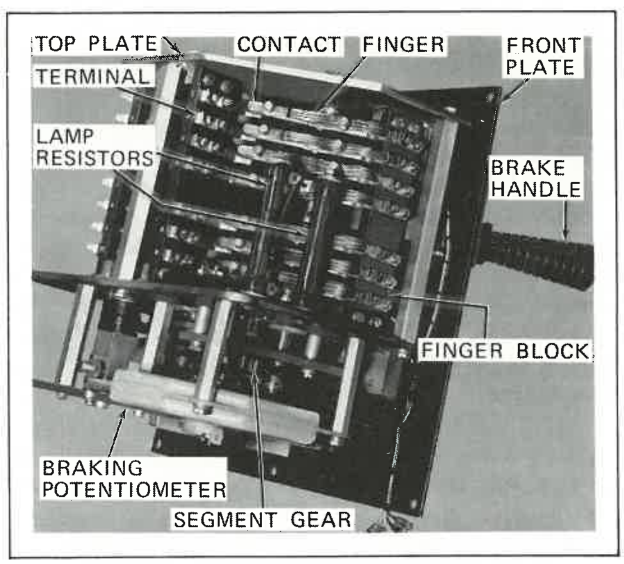


FIG. III-4. REAR VIEW OF CONTROLLER.

4. Remove finger assembly (3) from controller.

5. Place new finger assembly (3) in position on finger block (1).

6. Insert screws (6) with lockwashers (8) and washers (7) through terminal (5), and then through mounting holes of finger assembly (3). Secure the screws to finger block (1).

7. Repeat Steps 1 thru 6 for each finger assembly being replaced.

To replace a Contact:

1. Remove screws (9), lockwasher (8) and washer (7) from finger block (2).

2. Remove terminal (5) with lead attached, and place it to one side. (If terminal is to be replaced, remove wire.)

3. Remove contact (4) from controller.

4. Insert screws (9) with lockwashers (8) and washers (7) through terminal and new contact (4). Secure the assembly to finger block (2) with screws (9).

5. Repeat Steps 1 thru 4 for each contact to be replaced. It is suggested they be done one at a time, so circuits will not be altered.

Replace cover on back of operator's stand.

REVERSER

DESCRIPTION

The Type DP26 Reverser is an electrically-controlled pneumatic switch which connects traction motor fields for FORWARD or REVERSE motor (armature) rotation.

When the Reverse lever on the controller is moved to either the FORWARD or REVERSE position, the corresponding contact behind the Reverse lever closes to energize either the forward or reverse magnet valve. The magnet valves, in turn, activate the main contacts to switch traction motor fields to correspond with the position of the Reverse lever.

The reverser consists of the following main parts: main contacts, interlocks, magnet valves and air cylinders. These main parts, along with other components, are mounted on a metal frame. Frame legs have special mounting feet to bolt the reverser in position.

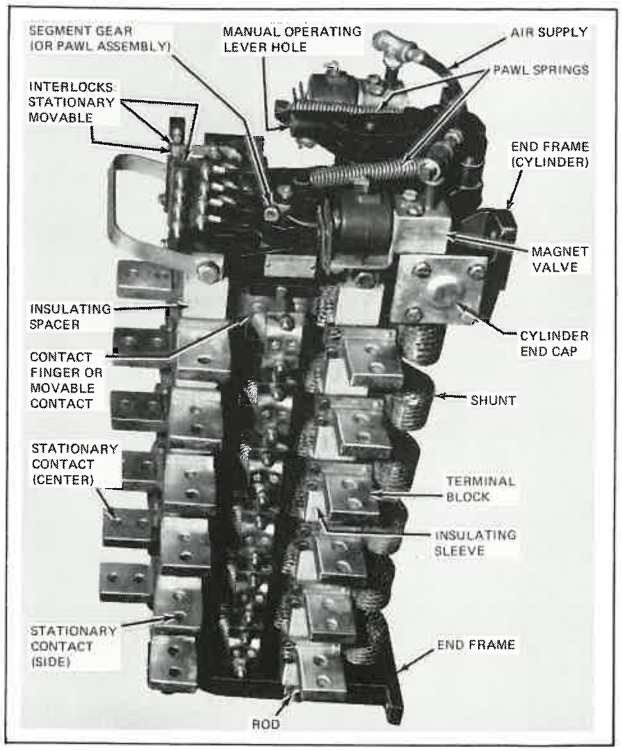


FIG. III-5. 17DP26A1 REVERSER.

FIG. III-5, E-18822

Refer to Fig. III-5 for location of principle parts and to Fig. III-6 for typical contact numbering of the interlock and main contact terminals.

LUBRICATION

Apply several drops of D50E5B oil to the surface of each bearing or bushing. Grease the surface of both pawl rollers and the segment gear with D6A2C5.

INSPECTION AND MAINTENANCE

Preliminary Inspection

Check all bolted connections for proper tightness. Torque 5/16-18 bolts to 12-14 lb.-ft.; 3/8-16 bolts to 21-24 lb.-ft.; and 1/2-13 bolts to 40-45 lb.-ft.

Check condition of insulated rods, insulated sleeves and support blocks. Mark for replacement any rods, sleeves or blocks that are cracked, burned or broken.

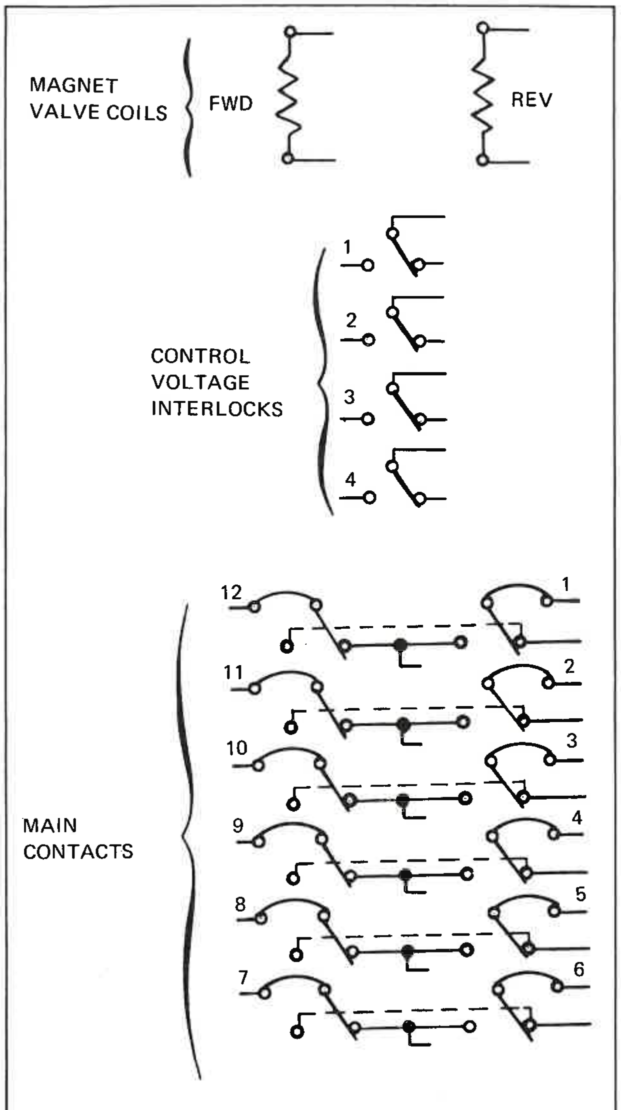
Main Contacts and Contact Fingers

Mark for replacement any tips that are excessively worn, burned or pitted. Tips pitted less than 1/32 in. may be dressed with a fine flat file. Observe that contacts make, break, overtravel and align properly.

FIG. III-6, E-18823

FIG. III-7, E-6511A

III



NOTE: NUMBERS USED FOR DESCRIBING CIRCUIT CONNECTIONS - NOT STAMPED ON DEVICE.

FIG. III-6. TYPICAL REVERSER CONTACT NUMBERING (FRONT VIEW, FORWARD POSITION).

Interlock Contacts

Mark for replacement any tips that are excessively worn, burned or pitted.

Drive Mechanism

Inspect the operation of the reverser, with control air supplied, by depressing the armatures of both magnet valves, one at a time. Sluggish operation may indicate:

1. Sticking or leaking magnet valves.
2. Leaking piston packing.

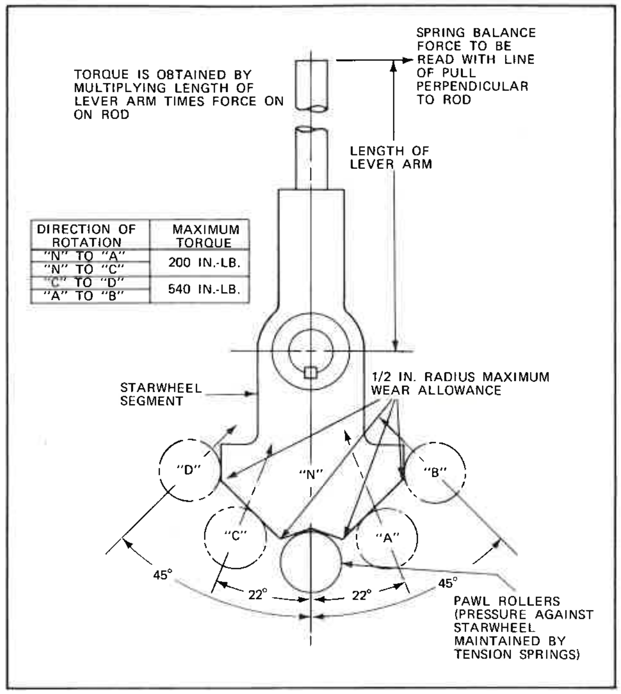


FIG. III-7. MEASUREMENT OF FORCE REQUIRED TO MANUALLY OPERATE REVERSER.

If the packing shows signs of wear, deterioration or if blowby exists, replace the packing. Check for air leaks at the hose and pipe connections, at the magnet valves and air engine cylinders with a soapy solution. Use normal locomotive control air pressure.

Reduce control air pressure to 45 psi and check for proper operation of reverser in both directions.

With control air shut off, check the torque required to operate the reverser manually by inserting a rod in the lever hole and pulling with a spring scale at a known distance. Measure torque from the NEUTRAL position over the starwheel notches in both directions, Fig. III-7. Check that the starwheel and pawl hold the contact fingers from completely unwiping with the air pressure shut off.

Main contacts should all close within 1/8 in. of each other at both positions. Also check that the main contacts close before, and open after the interlock contacts.

REPAIRS (ON LOCOMOTIVE)

It is anticipated that some busbars or cables must be disconnected to make reverser available for repair. Note, the right-hand door post of the main control compartment is removable for better access to the reverser area.

CAUTION: *All busbars, cables and contact mounting rods must be marked for proper replacement before removal from the reverser to prevent misapplication and subsequent electrical damage. Care must be exercised in handling and storing the busbars to prevent bending the copper.*

NOTE: *When aluminum cables or busbars are connected to copper terminal blocks, special instructions on application of joint compound must be followed. Refer to the overall maintenance manual.*

Interlock Contacts

Remove and replace any damaged parts.

Main Contacts

Stationary Contacts – Inside or Outside.

Cast Type

1. Remove the 1/2-in. bolts holding the insulated support rod (with damaged contact) to the end frames.
2. Remove the rod and stationary contacts.
3. Slide the insulator spacers and stationary contacts from the insulated rod; repair or replace the contacts.
4. Reassemble in reverse order.

Formed Type

1. Remove clamp bolt and metal spacer from damaged stationary contact.
2. Remove contact from insulated rod.
3. Repair or replace damaged contact.
4. Reassemble in reverse order.

Contact Fingers

1. Remove the two bolts holding the terminal block of the flexible shunt to the insulated support rod, Figs. III-8 and III-9.
2. Remove the nuts holding the retaining plate to the contact finger block support studs.
3. Remove and repair or replace the contact finger assembly.
4. Reassemble in reverse order.

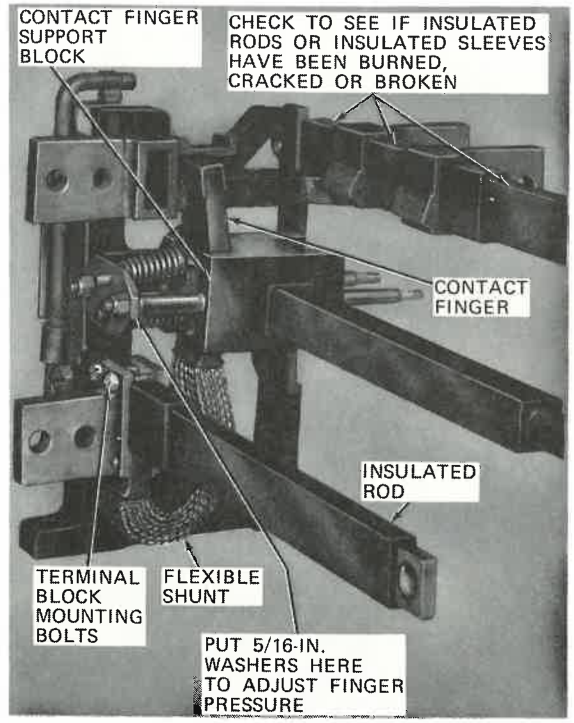


FIG. III-8. LOWER END FRAME AND PARTIAL ASSEMBLY OF CONTACT AND SUPPORT PARTS.

FIG. III-8, E-6504B

Drive Mechanism

Normally, a damaged segment gear-support assembly can be disassembled by removing the two pawl springs so the four 3/8-in. mounting bolts can be unbolted. Replace or repair any damaged parts and reassemble in reverse order, Fig. III-10.

CAUTION: *After reassembly, check all connection and retaining bolts for tightness. Check connections and insulated contacts for proper location as shown on the locomotive diagram, since rods are not keyed to prevent inverting them. Improper assembly can result in damage to electrical equipment.*

MAGNET VALVES

Description

The Type MV38 Magnet Valves are used on the DP26 reverser. These valves control the air flow to the air cylinders which, in turn, control the action of the reverser.

A magnet valve has the following main parts: frame, coil, armature, valve body, valve, valve stem and terminals. These main parts are assembled with others to make the complete valve assembly as shown in Figs. III-11 and III-12.

FIG. III-9, E-6501B

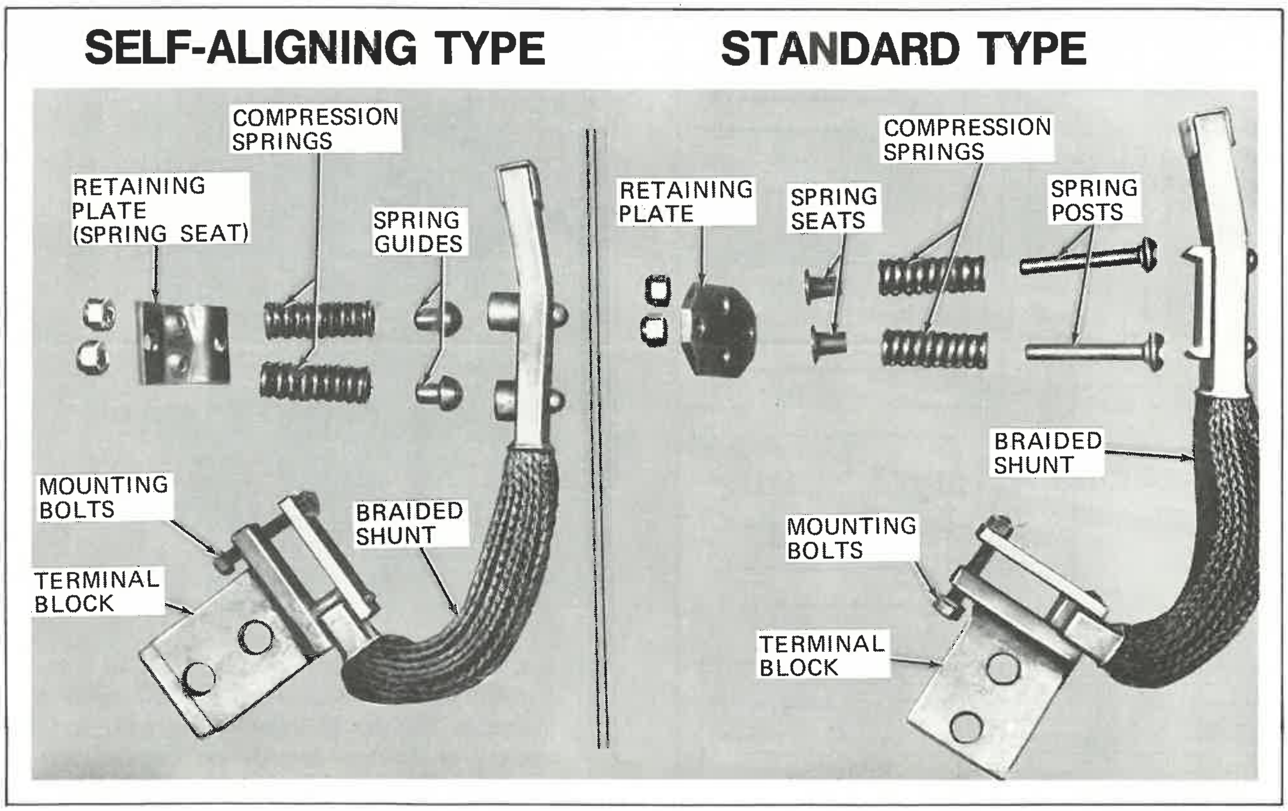


FIG. III-9. EXPLODED VIEW OF SELF-ALIGNING AND STANDARD FINGER ASSEMBLIES.

FIG. III-10, E-6502A

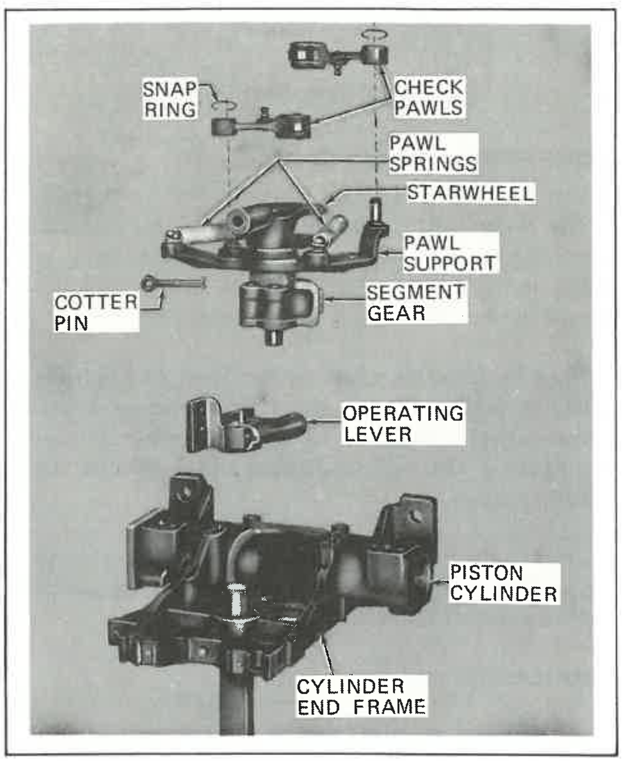


FIG. III-10. EXPLODED VIEW OF DRIVE MECHANISM PARTS.

Magnet Valve Data

Table III-I shows the coil resistance, volts continuous and amps required to operate the various forms of MV38 magnet valves.

FIG. III-11, E-10647

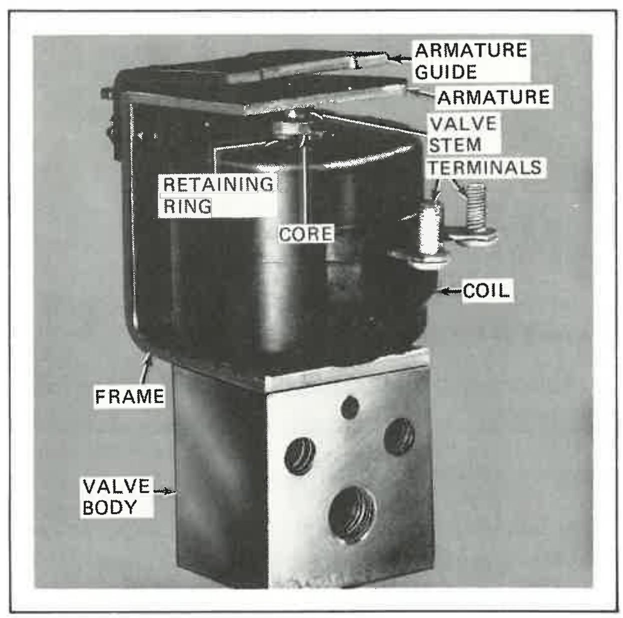
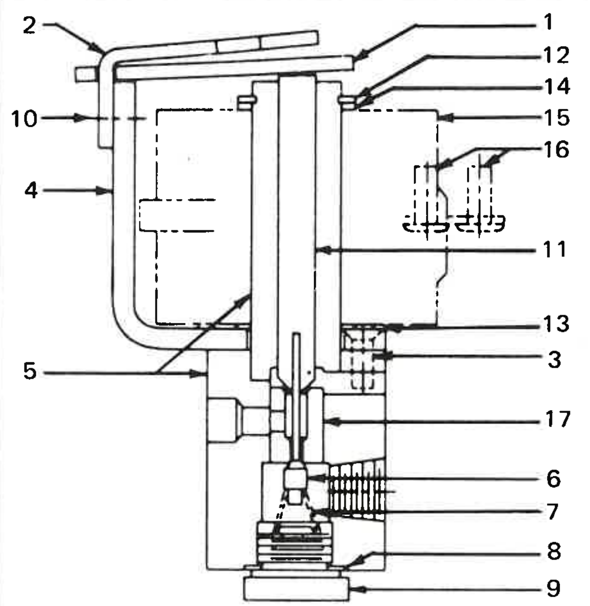


FIG. III-11. MV38 MAGNET VALVE.



REF.	DESCRIPTION	REF.	DESCRIPTION
1	ARMATURE	10	SCREW
2	ARMATURE GUIDE	11	EXHAUST VALVE STEM
3	SCREW	12	RETAINING RING
4	FRAME	13	FRICTION WASHER
5	VALVE BODY	14	WASHER
6	INLET VALVE	15	VALVE COIL
7	SPRING	16	TERMINALS
8	GASKET	17	VALVE SEAT
9	CAP PLUG		

FIG. III-12. SECTIONAL VIEW OF MAGNET VALVE.

TABLE III-I, TYPE MV38 MAGNET VALVES

Coil Form	Resistance at 25 C (ohms)	Volts Continuous	Amps To Operate at 90 psi
1	336	88	0.108
2	128	55	0.181
6	775	135	0.069
8	3080	270	0.036
12	84.9	44.6	0.206

Amps required to operate at 70 psi are 91 percent of amps required to operate at 90 psi.

Amps required to operate when mounted upside down increase 15 percent.

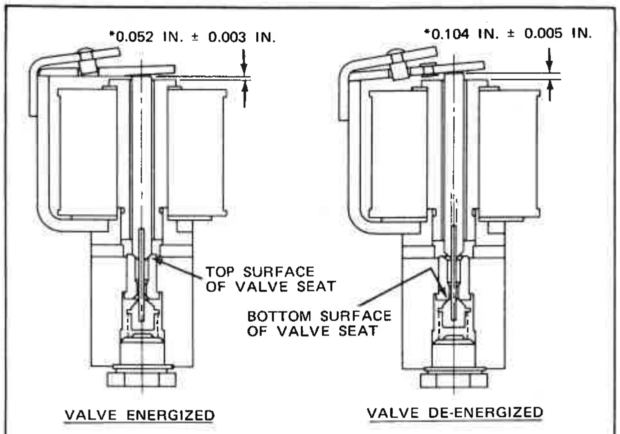
Application at more than 90 psi is practical only under special conditions.

Inspection and Maintenance

The following procedure will assist in the inspection and maintenance of the magnet valves, Figs. III-12 and III-13.

1. Test the magnet valve operation by depressing the armature on the top of the magnet valve. If the valve sticks, it must be cleaned. Refer to the applicable maintenance manual.

2. Test for leaks by applying soapy water to the pipe connections and exhaust port while air pressure is on the valve. Tighten all leaky connections. A small amount of leakage through the exhaust port is acceptable if the locomotive leak-down test can still remain in limits. If excessive leakage is found, disassemble the valve for cleaning. Refer to the applicable maintenance manual.



*NOTE: DIMENSIONS GIVEN ARE FOR NEW OR REBUILT VALVES.

FIG. III-13. VALVE TRAVEL.

BRAKING SWITCH

DESCRIPTION

The Type GP19 Braking Switch is an electrically-controlled power switch which connects braking grids across the traction motor armatures and sets up power circuits for dynamic braking on the locomotive.

When the Selector or Braking Handle on the Controller is moved to the BRAKING position, electric-actuated magnet valves supply control air to the positioning air engine, causing the contacts on the Braking switch to close in one of two positions.

Refer to Fig. III-14 for location of principle parts, and to Fig. III-15 for typical contact numbering of the interlock and main contact terminals.

LUBRICATION

Apply several drops of D50E5B oil to the surface of each bearing or bushing. Grease the surface of both pawl rollers and the segment gear with D6A2C5.

FIG. III-12, E-10645

FIG. III-13, E-10646B

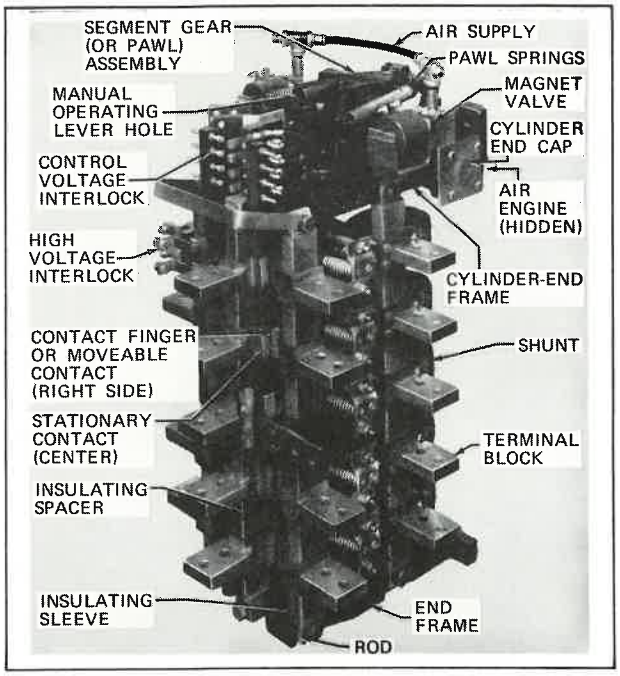


FIG. III-14. 17GP19L1 BRAKING SWITCH.

FIG. III-14, E-14000A

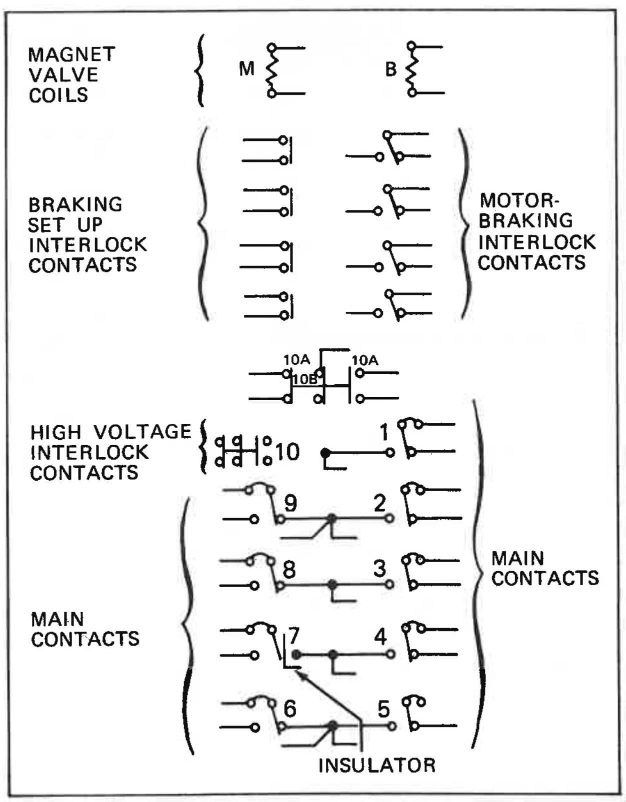


FIG. III-15. TYPICAL CONTACT NUMBERING ON A BRAKING SWITCH (VIEWED FROM FRONT).

FIG. III-15, E-17788A

INSPECTION AND MAINTENANCE

Preliminary Inspection

Check all bolted connections for proper tightness. Torque 5/16-18 bolts to 12-14 lb.-ft.; 3/8-16 bolts to 21-24 lb.-ft.; and 1/2-13 bolts to 40-45 lb.-ft.

Check condition of insulated rods, insulated sleeves and support blocks. Mark for replacement any rods, sleeves or blocks that are cracked, burned or broken.

III

Main Contacts and Contact Fingers

Mark for replacement any tips that are excessively worn, burned or pitted. Tips pitted less than 1/32 in. may be dressed with a fine flat file. Observe that contacts make, break, overtravel and align properly.

Interlock Contacts

Mark for replacement any tips that are excessively worn, burned or pitted.

Drive Mechanism

Inspect the operation of the switch, with control air supplied, by depressing the armatures of both magnet valves one at a time. Sluggish operation may indicate:

1. Sticking or leaking magnet valves.

2. Leaking piston packing. If the packing shows signs of wear or deterioration or if blowby exists, replace the packing. Check for air leaks at the hose and pipe connections, at the magnet valves and air engine cylinders with a soapy solution. Use normal locomotive control air pressure.

Reduce control air pressure to 45 psi and check for proper operation of the Braking switch in both directions.

With control air shut off, check the torque, Fig. III-16, required to operate the Braking switch manually by inserting a rod in the lever hole and pulling with a spring scale at a known distance. Measure torque from the NEUTRAL position over the starwheel notches in both directions. Check that the starwheel and pawl hold the contact fingers from completely unwiping with the air pressure shut off.

Main contacts should all close within 1/8 in. of each other at both positions. Also check that the main contacts close before, and open after the interlock contacts.

III

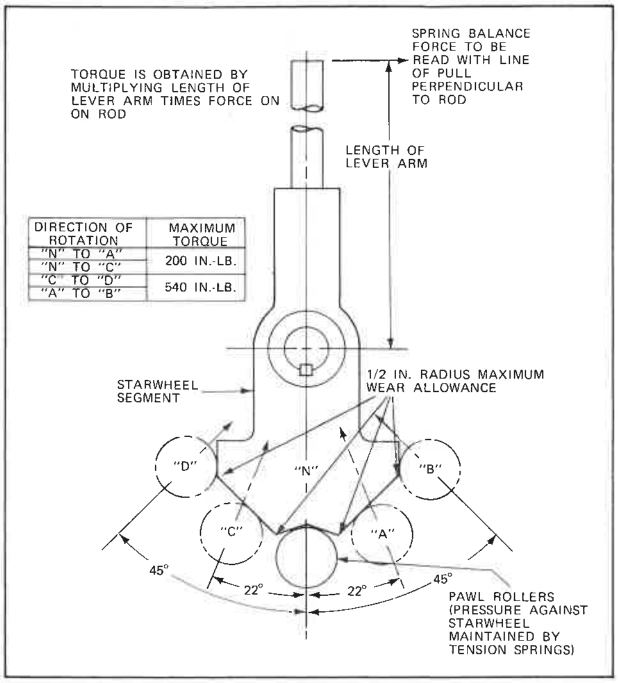


FIG. III-16. MEASUREMENT OF FORCE REQUIRED TO MANUALLY OPERATE BRAKING SWITCH.

FIG. III-16, E-6511A

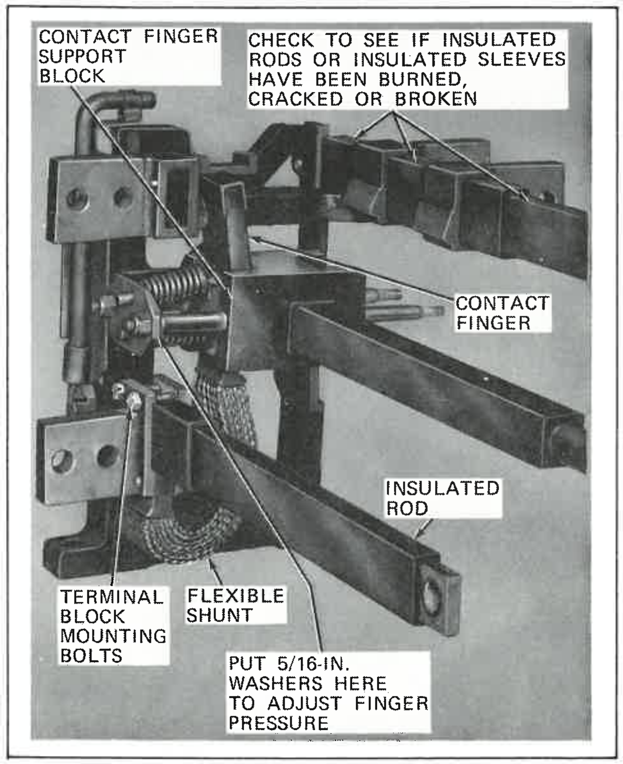


FIG. III-17. LOWER END FRAME AND PARTIAL ASSEMBLY OF CONTACT AND SUPPORT PARTS.

FIG. III-17, E-6504B

REPAIRS (ON LOCOMOTIVE)

It is anticipated that some busbars or cables must be disconnected to make Braking switch available for repair. Note, the right-hand door post of the main control compartment is removable for better access to the Braking switch area.

CAUTION: *All busbars, cables and contact mounting rods must be marked for proper replacement before removal from the Braking switch to prevent misapplication and subsequent electrical damage. Care must be exercised in handling and storing the busbars to prevent bending the copper.*

NOTE: *When aluminum cables or busbars are connected to copper terminal blocks, special instructions on application of joint compound must be followed. Refer to the overall maintenance manual.*

INTERLOCK CONTACTS

Remove and replace any damaged parts.

MAIN CONTACTS

Stationary Contacts – Inside or Outside

Cast Type:

1. Remove the 1/2 in. bolts holding the insulated support rod (with damaged contact) to the end frames.
2. Remove the rod and stationary contacts.
3. Slide the insulator spacers and stationary contacts from the insulated rod; repair or replace the contacts.
4. Reassemble in reverse order.

Formed Type:

1. Remove clamp bolt and metal spacer from damaged stationary contact.
2. Remove contact from insulated rod.
3. Repair or replace damaged contact.
4. Reassemble in reverse order.

CONTACT FINGERS

1. Remove the two bolts holding the terminal block of the flexible shunt to the insulated support rod. See Figs. III-17 and III-18.

FIG. III-18, E-6501B

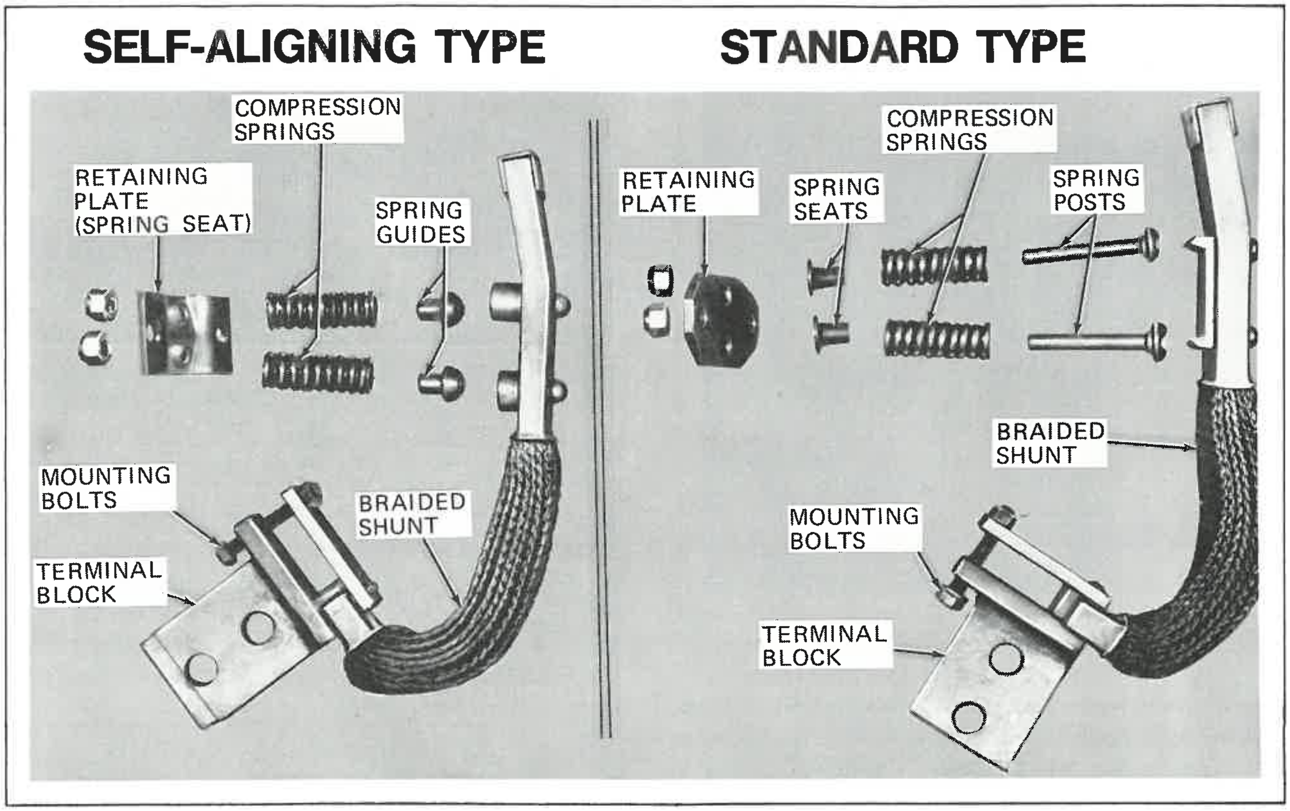


FIG. III-18. EXPLODED VIEWS OF STANDARD AND SELF-ALIGNING FINGER ASSEMBLIES.

2. Remove the nuts holding the retaining plate to the contact-finger block support studs.
3. Remove and repair or replace the contact finger assembly.
4. Reassemble in reverse order.

DRIVE MECHANISM

Normally, a damaged segment gear-support assembly can be disassembled by removing the two pawl springs so the four 3/8 in. mounting bolts can be unbolted. Replace or repair any damaged parts and reassemble in reverse order. See Fig. III-19.

> **CAUTION:** *After reassembly, check all connection and retaining bolts for tightness. Check connections and insulated contacts for proper location as shown on the locomotive diagram since rods are not keyed to prevent inverting them. Improper assembly can result in damage to electrical equipment.*

MAGNET VALVES

Description

The Type MV38 Magnet Valves are used on the GP19. These valves control the air flow to the air cylinders which, in turn, control the action of the Braking switch.

FIG. III-19, E-6502A

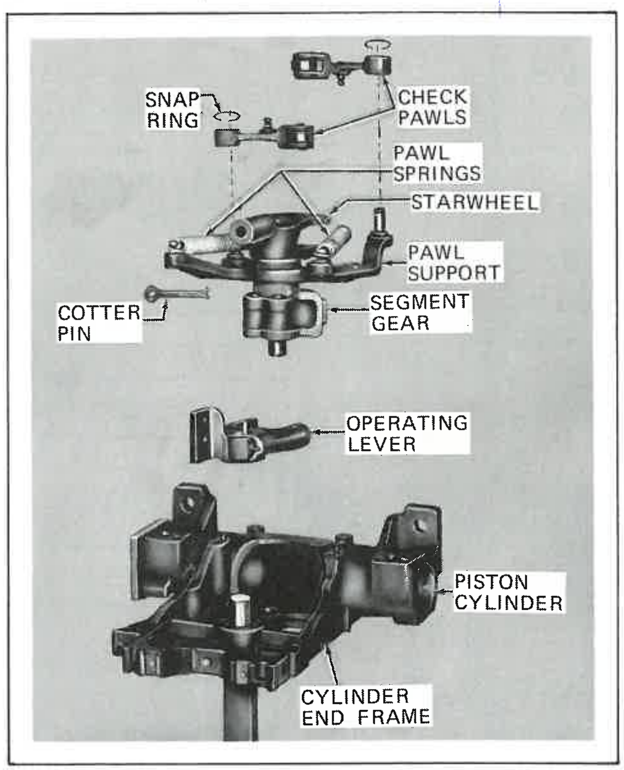


FIG. III-19. EXPLODED VIEW OF DRIVE MECHANISM PARTS.

III

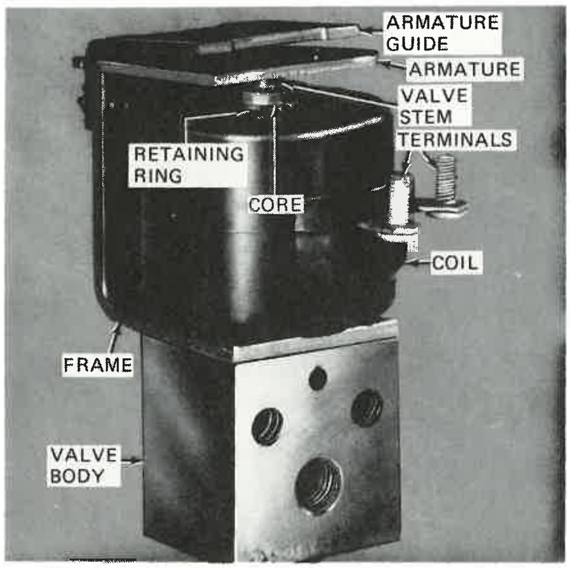
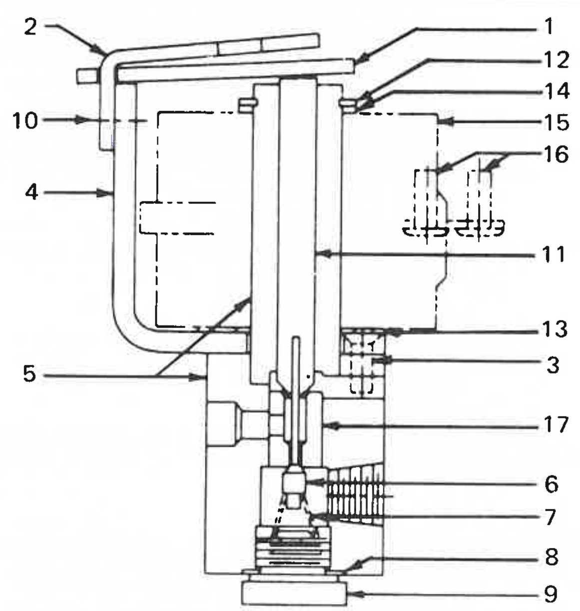


FIG. III-20. MV38 MAGNET VALVE.

A magnet valve has the following main parts: frame, coil, armature, valve body, valve, valve stem and terminals. These main parts are assembled with others to make the complete valve assembly as shown in Figs. III-20 and III-21.



REF.	DESCRIPTION	REF.	DESCRIPTION
1	ARMATURE	10	SCREW
2	ARMATURE GUIDE	11	EXHAUST VALVE STEM
3	SCREW	12	RETAINING RING
4	FRAME	13	FRICTION WASHER
5	VALVE BODY	14	WASHER
6	INLET VALVE	15	VALVE COIL
7	SPRING	16	TERMINALS
8	GASKET	17	VALVE SEAT
9	CAP PLUG		

FIG. III-21. SECTIONAL VIEW OF MAGNET VALVE.

Magnet Valve Data

Table III-II shows the coil resistance, volts continuous and amps required to operate the various forms of MV38 magnet valves.

TABLE III-II, TYPE MV38 MAGNET VALVES

Coil Form	Resistance at 25 C (ohms)	Volts Continuous	Amps To Operate at 90 psi
1	336	88	0.108
2	128	55	0.181
6	775	135	0.069
8	3080	270	0.036
12	84.9	44.6	0.206

Amps required to operate at 70 psi are 91 percent of amps required to operate at 90 psi.

Amps required to operate when mounted upside down increase 15 percent.

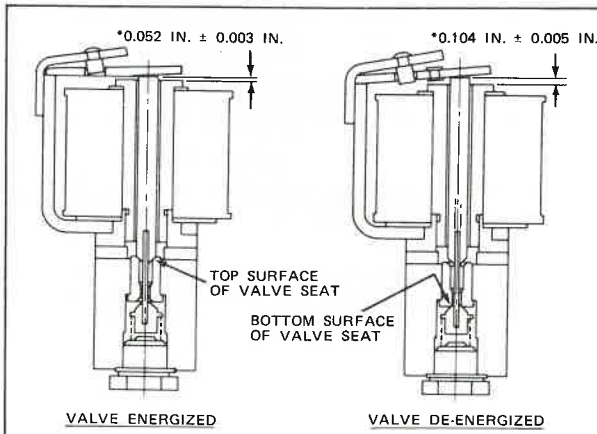
Application at more than 90 psi is practical only under special conditions.

Inspection and Maintenance

The following procedure will assist in the inspection and maintenance of the magnet valves, Figs. III-21 and III-22.

1. Test the magnet valve operation by depressing the armature on the top of the magnet valve. If the valve sticks, it must be cleaned. Refer to applicable maintenance manual.

2. Test for leaks by applying soapy water to the pipe connections and exhaust port while air pressure is on



*NOTE: DIMENSIONS GIVEN ARE FOR NEW OR REBUILT VALVES.

FIG. III-22. VALVE TRAVEL.

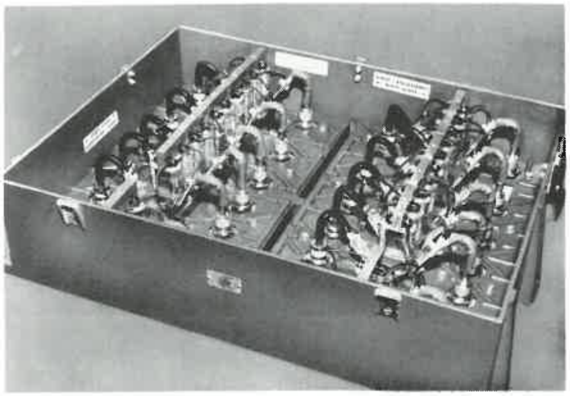


FIG. III-23. 17FM307B1 POWER RECTIFIER PANEL.

the valve. Tighten all leaky connections. A small amount of leakage through the exhaust port is acceptable if the locomotive leak-down test can still remain in limits. If excessive leakage is found, disassemble the valve for cleaning. Refer to applicable maintenance manual.

POWER RECTIFIER PANEL

DESCRIPTION

The principle parts of the Type FM307 Power Rectifier Panel include high-current silicon rectifier diodes, heatsinks, resistors, capacitors and associated hardware, Figs. III-23 and III-24.

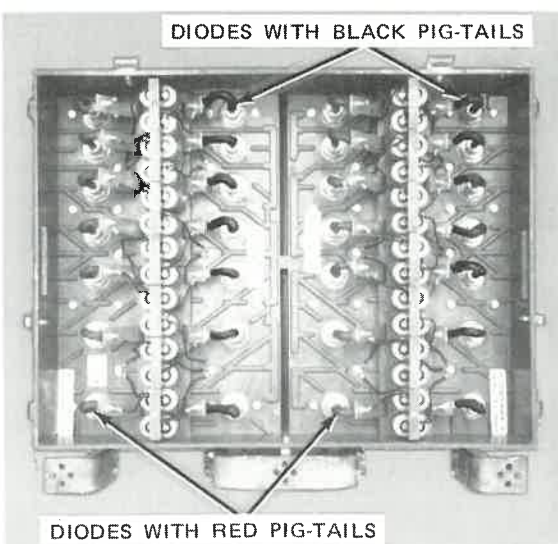


FIG. III-24. FORM A1 RECTIFIER PANEL (DIODES IN ALL POSITIONS).

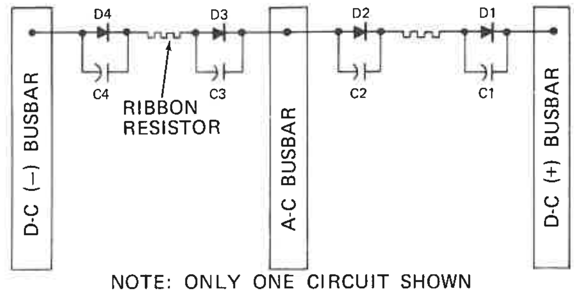


FIG. III-25. TYPICAL SINGLE CIRCUIT SCHEMATIC.

Electrically, the FM307 Panel has a number of parallel circuits from a d-c negative to the a-c, and from the a-c to the d-c positive busbars as shown in Figs. III-25 and III-26. Table III-III gives various model differences.

TABLE III-III, MODEL DIFFERENCES

FM307 Models	No. Parallel Circuits	Provision For Temperature Sensor	Negative Diode 41A281049-P	Positive Diode 41A281206-P
A1	7	X	11	1
A2	7	X	11	1
B1	6	X	11	1
B2	6	X	11	1
C1	5	X	11	1
C2	5	X	11	1

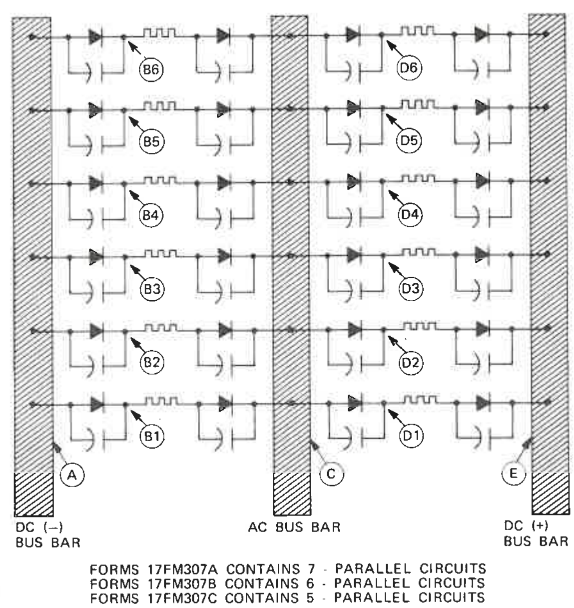


FIG. III-26. TYPICAL SCHEMATIC OF PANEL.

FIG. III-23, E-19658
FIG. III-24, E-18357
FIG. III-25, E-18365
FIG. III-26, E-18355B

III

FIG. III-27. COMPARISON OF NEGATIVE AND POSITIVE BASE DIODES.

This panel uses two different types of diodes to simplify the circuits. These are positive (red 4-1/2 in. pigtail) and negative (black 5-1/2 in. pigtail) types. See Fig. III-27 for comparison of the two types.

The Form A Power Rectifier Panels contain seven parallel circuits having 28 high-current, 1200-volt silicon rectifiers, with a 0.5 mfd capacitor connected in parallel across each rectifier Fig. III-24. The panel contains four separate heatsink strips and 14 load-sharing ribbon resistors.

The left heatsink strip on all panels is prepared for a sensing element to monitor the panel temperature. The Form 1 panels have a cover plate over the sensor location, while Forms 2 and 3 have sensing elements installed. A terminal strip is also provided near the sensing element in the lower left corner of Forms 2 and 3 panels, Fig. III-28, for external wiring. The Form 4 panel has "tell-tale" resistors to give a visual indication of component failure, Figs. III-29 and III-30.

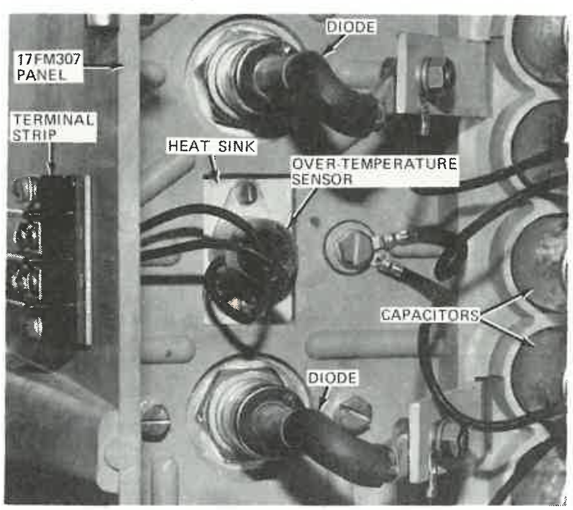


FIG. III-28. OVERTEMPERATURE SENSOR AND TERMINAL STRIP.

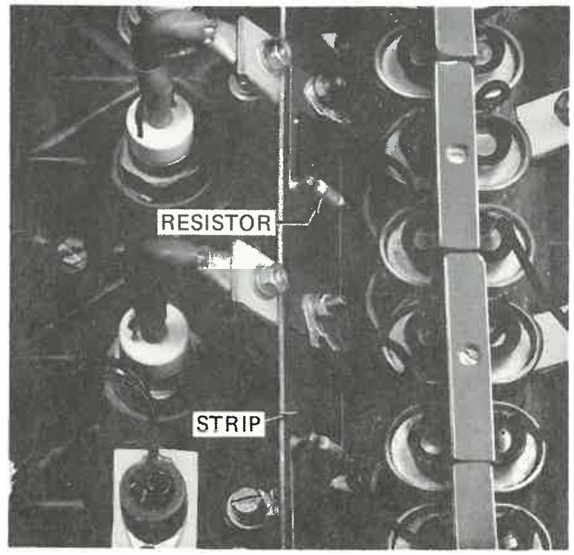


FIG. III-29. RECTIFIER PANEL SHOWING EARLY "TELL-TALE" RESISTORS SOLDERED TO MOUNTING STRIP.

Form B panels contain six parallel circuits having 24 high-current, 1200-volt silicon rectifiers, with a capacitor connected in parallel across each rectifier. These panels contain four separate heatsink strips and 12 load-sharing ribbon resistors. Schematically, the Form B has one less string of components than the Form A panels.

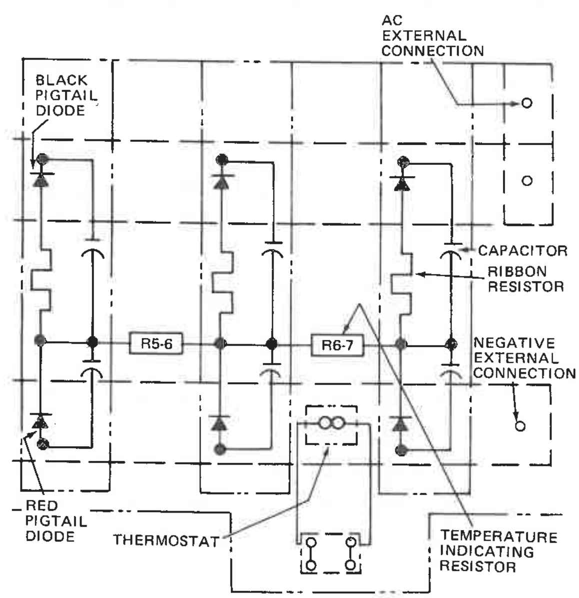


FIG. III-30. PARTIAL SCHEMATIC DIAGRAM SHOWING CONNECTION OF "TELL-TALE" RESISTORS BETWEEN ADJACENT CIRCUITS.

FIG. III-27, E-19659
FIG. III-28, E-21363
FIG. III-29, E-23389
FIG. III-30, E-23390

Form C panels contain five parallel circuits having 20 high-current, 1200-volt silicon rectifiers, with a capacitor connected in parallel across each rectifier. These panels contain four separate heatsink strips and ten load-sharing ribbon resistors. Schematically, the Form C has two less strings of components than the Form A panels.

Diodes must be checked periodically per an established schedule. Failed diodes must be detected and replaced to prevent overloading the remaining diodes in parallel circuits. Each interruption of a circuit forces the remaining circuits to share the same load. This causes higher average currents and an associated increase in operating temperature. The ultimate is the burn-up of a panel and possible single phasing of the alternator.

Special Tools and Equipment

1. Diode Wrench (Part 2X2823)
2. Torque Wrench (Part 147X1592)
3. Sealer (Part 1X7071)
4. Simpson 260 Analyser or equivalent
5. DeVilbiss Type DGD520 Cleaning Gun, or HM521 Spray Gun
6. Cleaning Solvent, Chlorothene N.U.
7. Diode Test Unit.

CLEANING

Blow out any dirt accumulation with dry, compressed, shop air. If this fails to remove the dirt, continue with the following cleaning method.

> **WARNING:** *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

1. Use a spray gun such as DeVilbiss Type DGD520 cleaning gun or HM521 oil spray gun. The two guns differ in that the DGD520 gun has a syphon hose to be inserted in a separate container of solvent while the HM521 gun has an attached quart container; not quite enough to clean one panel. If the DGD520 spray gun is used, the solvent can be syphoned directly from the container if an opening just large enough to permit inserting the syphon hose is provided.
2. Be sure to locate equipment to be cleaned in a well-ventilated area. The cleaning solvent Chlorothene N.U. is highly volatile and a degreasing agent.

> **WARNING:** *Solvent should be used in a well-ventilated area, with a face mask to protect against breathing too much of the vapor. Also, avoid skin contact as it is a degreaser and will dry up natural skin oils.*

3. With power plant shut down, remove covers from the rectifier panels.
4. Spray diodes with solvent, making sure to soak the ceramic sleeve portion. Repeat the spray operation several times as surface appears dry after each application period. Remove the dirt with a clean cloth, but if still dirty, repeat spraying and wiping process.

III

TROUBLE-SHOOTING

The early detection and replacement of bad rectifying diodes (OPEN or SHORTED) will prevent catastrophic damage caused by a major rectifier panel failure.

Periodically remove covers and inspect panel components, wiring and cables for damage or overheating. Inspect the panel for dirt accumulation.

View panel for failed components and loose or broken connections. Check color of each "tell-tale" resistor. If one or more are darkened, check for failed power diodes or capacitors.

Panel Replacement

With power plant shut down, remove busbar or cable connections to the damaged panel. If hatch is provided over rectifier panels, use a crane to lift out damaged unit. Panels weigh about 126 pounds each.

Reverse the procedure to install new panel. Be sure to check the cable connectors on <u>both</u> ends of any a-c cables for possible damage or signs of overheating. Trouble here could result in single phasing the alternator even if the rectifier panels were working and cause loss of power and initiate heavy torsional vibration of the engine, the alternator and all the equipment mechanically connected to the alternator rotor. This includes the blower, air compressor and radiator fan.

Bolting Busbars Or Cables to Busbars

Since there is always a slight gap between mating surfaces, it is important to apply a thin coat of joint compound (T&B M-53, GE Part 41A204944P1) to both surfaces before bolting them together. This will prevent dampness or moisture from accumulating in the joint and prevent subsequent corrosive action, high resistance, oxidation or loose connections at the junction. Also, the compound contains fine particles of a high-conductivity metal which "bite" into the contact surfaces, making a low-resistance joint.

Bolt Torquing

Proper torquing of the bolts is very important. See Table III-IV for torque values. An over-torqued joint is in trouble just as an under-torqued joint. The proper reassembly of plate washers or flat washers on the bolts is very important to properly distribute the pressure.

TABLE III-IV, TORQUE VALUES

Bolt Size	Torque (Lb.-Ft.)
5/16-18	12-14
3/8 -16	21-24
1/2 -13	40-45

Rectifier Diode

WARNING: *Electric shock can cause serious or fatal injury. To avoid such injury, personnel should take and observe proper precautions.*

1. A quick check of the rectifying diodes may be accomplished without disconnecting them, using the Test Unit; the schematic of which is shown in Fig. III-31. Complete instructions for building and using this unit can be obtained from your General Electric locomotive representative.
2. An alternate method of checking the individual rectifiers can be done with the setup shown in Fig. III-32. The braided terminal must be disconnected to make this test.

CAUTION: *Make the following resistance checks with power removed from panel to prevent damage to analyzer.*

Panel diodes can be checked for open or shorted condition by measuring forward and reverse resistance with an analyzer. It is not necessary to disconnect rectifier, rectifier diodes, resistor or capacitor leads from panel circuits for these checks.

Forward-Resistance Check

NOTE: *The Forward Direction for diodes with black pigtails is from the pigtail to the base, while red pigtail diodes conduct in the Forward Direction from the base to the pigtail.*

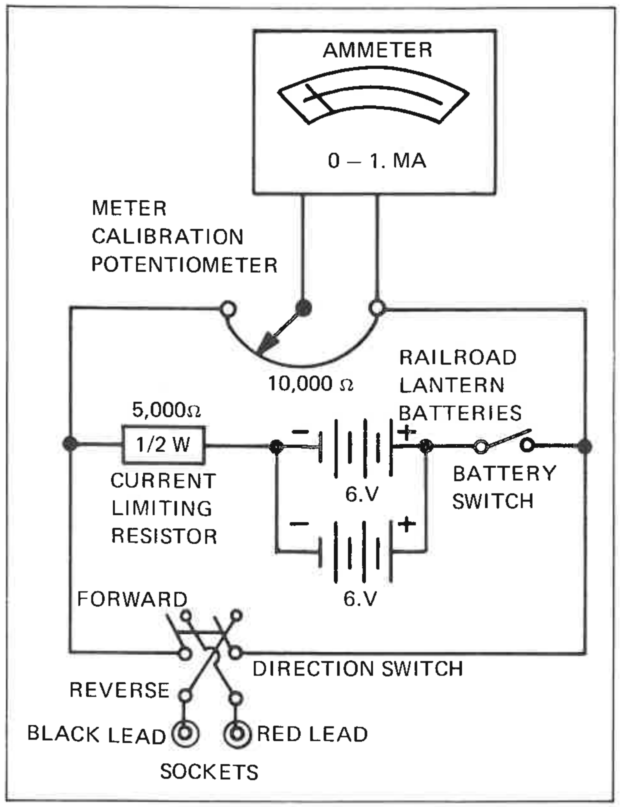


FIG. III-31, E-18354A

FIG. III-31. DIODE TEST UNIT SCHEMATIC.

1. Set analyzer on R x 100 scale.
2. Check forward resistance of each rectifier by placing (+) and (–) leads of analyzer on points indicated in Fig. III-26 with the following polarity:

Step	Analyzer (+)	Analyzer (–)	Test Limits
1	A	B	280 to 440Ω
2	B	C	280 to 440Ω
3	C	D	280 to 440Ω
4	D	E	280 to 440Ω

NOTE: *Braided lead of rectifier with black pigtail is (+); with red pigtail is (–).*

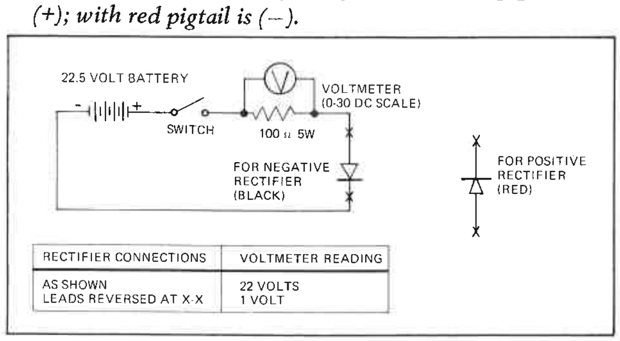


FIG. III-32, E-18398A

FIG. III-32. SILICON RECTIFIER DIODE VOLTAGE CHECK SCHEMATIC.

FIG. III-33, E-18367A

3. Check forward resistance across the four rectifiers in the lower string, as shown in Fig. III-26. Using the same polarity, transfer analyzer leads to comparable points in the other strings, thereby checking each rectifier in the panel. Forward resistance should be 280 to 440 ohms across each rectifier.

NOTE: *If the forward-resistance value of a rectifier is not within the limits given, disconnect rectifier from circuit and make a forward and reverse voltage check, as shown in Fig. III-29.*

Reverse-Resistance Check

1. Set analyzer on R x 10,000 scale.

2. Check reverse resistance of each rectifier by connecting analyzer leads in reverse of polarity indicated in Step 2 under Forward-Resistance Check. For example, A (–) to B (+). Reverse resistance should be 15,000 to 21,000 ohms.

Step	Analyzer (+)	Analyzer (–)	Test Limits
1	B	A	15,000 to 21,000Ω
2	C	B	15,000 to 21,000Ω
3	D	C	15,000 to 21,000Ω
4	E	D	15,000 to 21,000Ω

3. Check resistance of each rectifier in same manner in which forward resistance was checked.

NOTE: *If the reverse-resistance value of a rectifier is not within the limits given, disconnect the rectifier from the circuit and make a forward and reverse voltage check, as shown in Fig. III-29.*

Alternate Diode Check

A special test unit can be built locally to check the rectifier panel diodes without disconnecting them from the circuit. This unit measures voltage drops with diode energized with lantern batteries Instructions for using the unit are given in the same publication. Request copies from your service engineer.

FIG. III-34, E-12989B

Removal

1. Remove power to panel.
2. Disconnect rectifier braid terminal.
3. Remove rectifier using special socket wrench (Part 2X1337). See Fig. III-33.
4. Remove rectifying diode from panel.

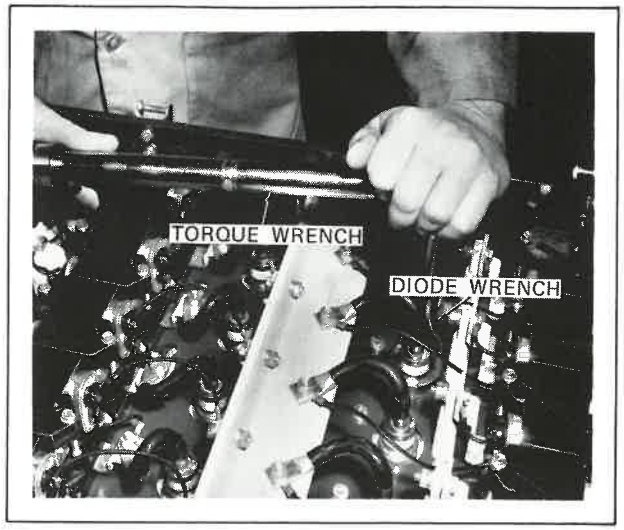


FIG. III-33. TORQUING DIODES ON TYPICAL PANEL.

III

Replacement

1. Apply a light film of Dow Corning 340* (Part 41A271707-P1) to the diode mounting face only, as shown in Fig. III-34.

CAUTION: *Do not apply Dow Corning 340 to diode threads. This may prevent obtaining required torque values.*

2. Replace the diode in reverse order. Make certain the capacitor connections are tight.

CAUTION: *When replacing diode, locate braid so it does not touch or short against an adjacent component. Keep as far away from all other components as possible.*

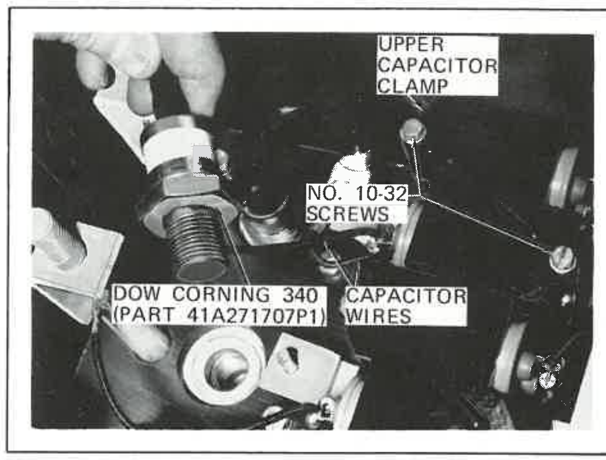


FIG. III-34. TYPICAL APPLICATION OF DOW CORNING 340.

*Product of Dow Corning Chemical Co.

III

3. Assemble the diode at a torque of 25 lb.-ft. Back off one half turn, and reapply torque of 25 lb.-ft. to obtain proper electrical contact and heat transfer.

Capacitor

Check

Check all soldered connections on capacitor terminals for broken connections. Check for open or shorted capacitors of the electrolytic type. Use an analyzer with an ohms scale of 0 to 10,000 or greater.

1. Adjust the analyzer to the highest resistance range.

> **CAUTION:** *Discharge capacitors before disconnecting leads or testing with analyzers.*

2. Discharge capacitors through a 1000-ohm resistor connected between the terminals, then obtain full discharge by shorting the capacitors with an insulated jumper.

Replacement

1. Remove power from panel and discharge capacitor to be replaced.

2. Unsolder wires connected to capacitor.

3. Unsolder any resistor connected across capacitor terminals.

4. Loosen upper restraining clamp by removing the 10-32 nuts, washers and lockwashers holding it in place.

5. Remove the capacitor.

6. Replace the capacitor in reverse order.

Resistor

Check

Check ribbon resistor for looseness or shorted condition. Tighten or replace defective units.

Replacement of Tell-Tale Resistors

Resistors installed in FM307 panels after early 1977 plug into spring-clutch sockets on the terminal strips. The resistors can be replaced simply by pulling out the blackened one and inserting a new one.

On early panels, the resistors were soldered to connections on the terminal strip. Care must be taken when replacing one of these resistors to use a low-wattage soldering iron and heatsinks to prevent premature discoloration of the heat-sensitive tape on the new resistors. Tape turns black when temperature of resistors exceeds 120 C (248 F).

Replacement of Ribbon

1. Remove power from panel.

2. Remove the panel.

3. Remove clamp-block assembly containing capacitor.

4. Remove end of ribbon resistor connected to heatsink.

5. Remove other end of ribbon resistor connected to braided rectifier lead.

6. Replace ribbon resistor in reverse order.

Over-Temperature Sensor

The sensor, Figs. III-28 and III-29, should be checked annually for proper operation. Recommend removal of sensor and testing in an oven to prove circuit opens when temperature exceeds 99-104 C (210-220 F).

VOLTAGE REGULATOR PANEL

DESCRIPTION

All forms of the Type FH23 Voltage Regulator Panel have a voltage-regulator module as a basic component to keep the locomotive battery properly charged. It controls the output of a self-excited auxiliary d-c generator. The regulator senses the auxiliary generator output and adjusts the field current to maintain +74 vdc under various conditions of load and of engine rpm, Fig. III-35.

Component parts for the voltage regulator are assembled on a printed-circuit module (not a removable card), which is bracket-mounted to an insulated base along with resistors, diodes, transistors and a capacitor.

Test points, a monitor light, the fine-voltage adjustment potentiometer, a circuit breaker and the seven-pin connector, thru which all external connections are made, are all mounted on the front of the panel. The A1 model uses a 5-amp circuit breaker.

This section covers the basic 17FH23A1 panel, the voltage-regulator function and the additional protection

FIG. III-35, E-22258

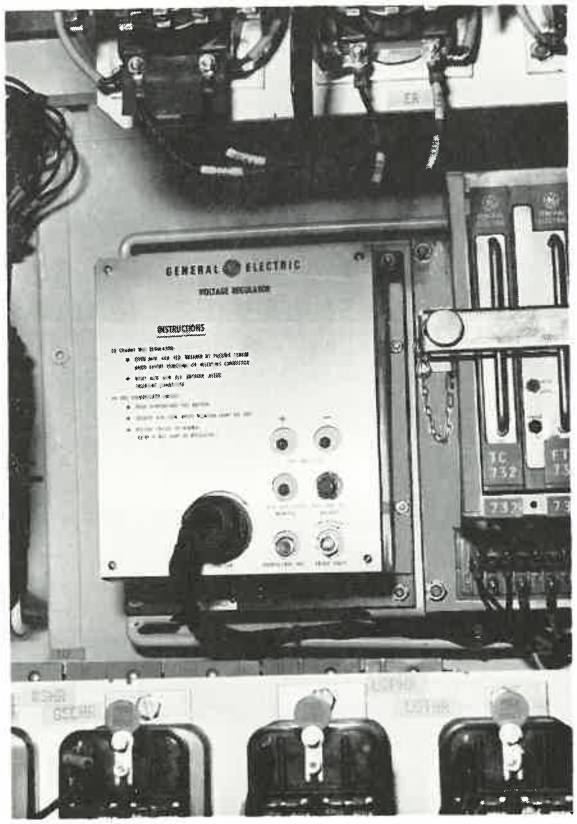


FIG. III-35. TYPICAL FH23 PANEL INSTALLATION.

module: Overvoltage Limit Protection. Other forms of the panel include one or both additional functions:

1. Negative Current Limit Protection
2. Positive Current Limit Protection

Each of these functions is assembled on an individual module, and several modules are mounted on a panel providing various forms of the FH23 voltage regulator. See Table III-V.

TABLE III-V, PANEL FORMS AND PROTECTIVE FUNCTIONS

Protective Function Modules	Position Of Mod.	Panel Form					
		A1	B1	C1	D1 D2	E1	F1 F2
Voltage Regulator	1	X	X	X	X	X	X
Negative Current Limit	2		X				X
Positive Current Limit	2			X		X	
Overvoltage	3				X	X	X

A voltage regulator with the additional protection module will protect the control circuits and the locomotive battery against any excessive voltage due to a runaway failure of the regulator.

The schematic diagram for this model FH23 voltage regulator is shown in Fig. III-36.

The 17FH23D1 model differs from the 17FH23D2 model by having a circuit breaker, 23CB1, in the auxiliary generator field circuit which rates 5.0 amps; while the D2 model rates 7.5 amps.

III

OPERATION

The battery voltage is monitored from Terminals B to D on the module. The voltage is applied across the resistance network R2, R3, P1 and R4.

When the battery voltage reaches a preset overvoltage threshold, normally set at 85 vdc, transistor Q1 begins to conduct, allowing relay RL1 to pick-up. This supplies battery voltage to Terminal E thru two pairs of relay contacts in series (to increase the arc gap of the relay contacts). An external relay of LV66 type can then be used to interrupt the auxiliary generator shunt-field circuit.

The circuit can be tested by pressing the push-button switch on the face of the panel, since the circuit is brought out thru Terminals C and F.

MAINTENANCE

Periodically examine the panel and perform the following operations:

1. Inspect the panel for damaged or discolored components. Replace all faulty parts.

> **WARNING:** *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

2. Blow out dust and dirt with clean, dry compressed air.
3. Check for loose terminal connections and broken or damaged wiring. Tighten and replace if necessary.
4. Assure the modules are securely fastened in place.

CMR WHEELSLIP PANEL

DESCRIPTION

The Type FL80 CMR Wheelslip Panel, Fig. III-37, is part of the wheelslip detection system on six-axle diesel electric locomotives with rectified a-c propulsion systems. This

III

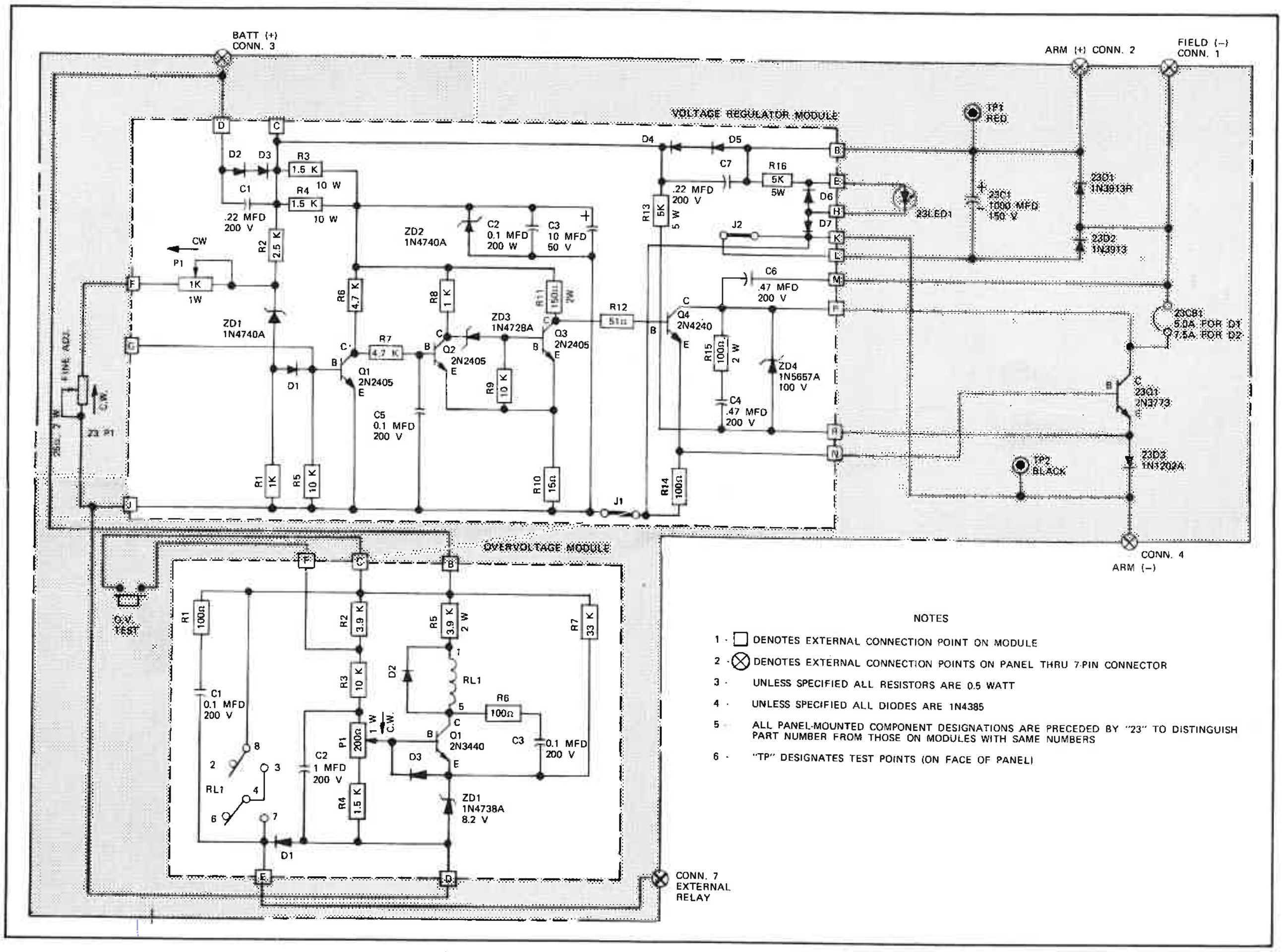


FIG. III-36. SCHEMATIC DIAGRAM OF 17FH23D1, D2 PANEL.

FIG. III-36, E-22269

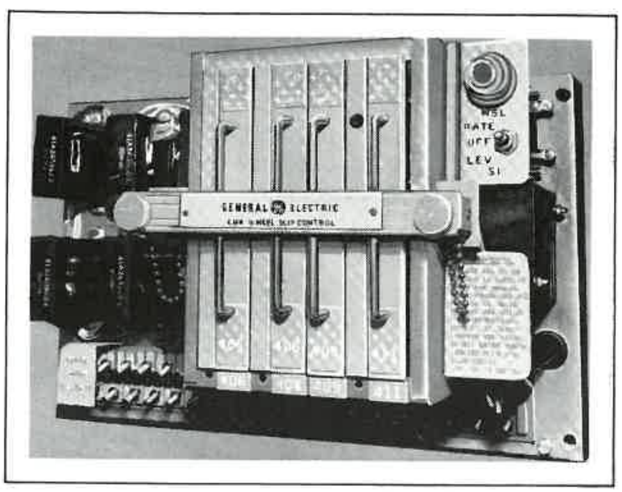


FIG. III-37. TYPICAL CMR WHEELSLIP PANEL (FL80).

FIG. III-37, E-16600

wheelslip detection system is called the Current Measuring Reactor, or CMR type. It provides wheelslip/slide detection and correction by sensing current unbalance in the traction motor circuits, and reduces the applied power by adjusting the Excitation System, Fig. III-38. Fig. III-39 shows the schematic of the panel.

A test button is provided on the EC panel, in the operator's cab, to check RATE operation of the CMR wheelslip system.

A Toggle switch is provided on the panel to check RATE and LEVEL operation of the CMR system.

OPERATION

Monitoring currents are supplied from current measuring reactors in each traction motor circuit as the primary sensing elements. One axle alternator is used in this system to provide the locomotive speed signal for transition, overspeed and speedometer functions.

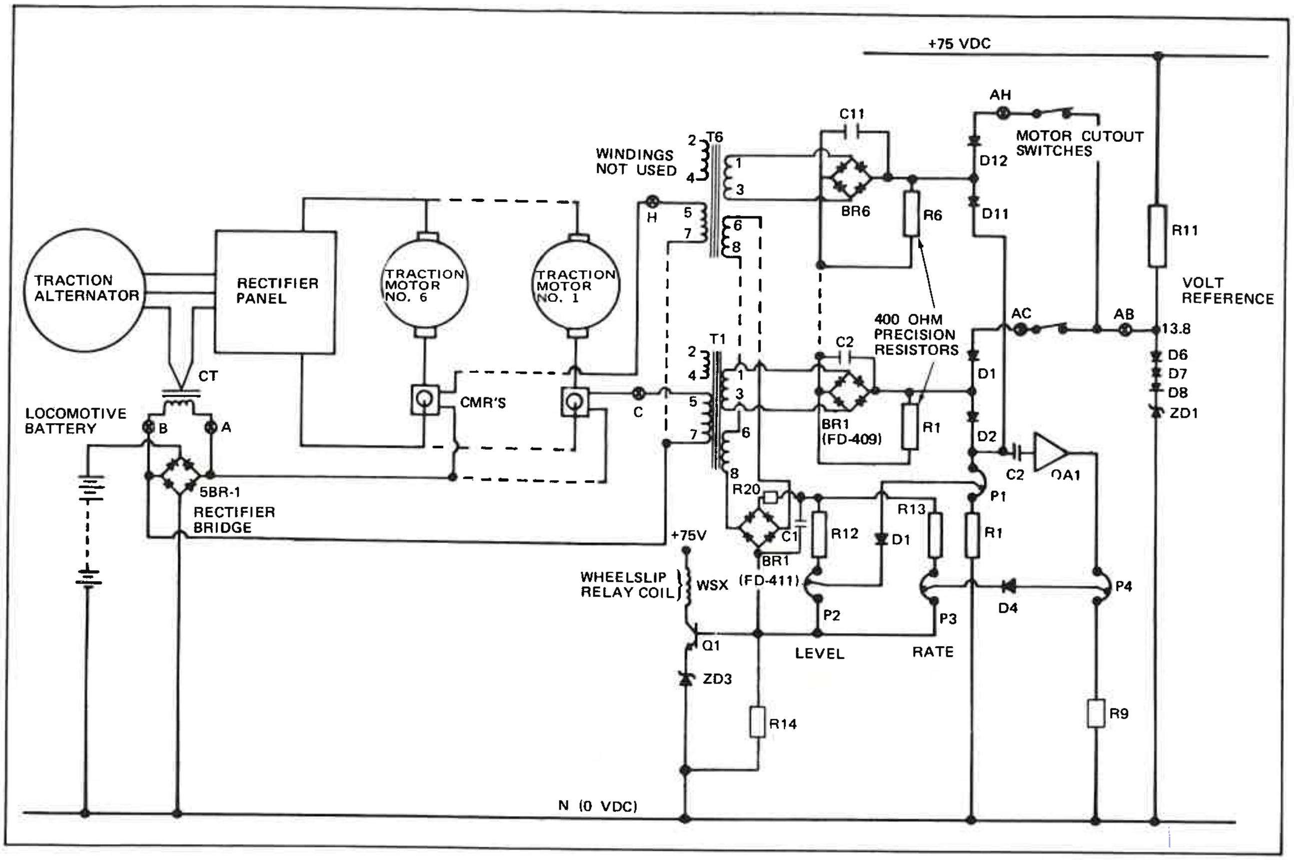


FIG. III-38. TYPICAL CMR WHEELSLIP SYSTEM FOR "C" LOCOMOTIVE.

A current transformer (CT) is connected in one phase of the traction alternator circuit. Its secondary winding furnishes square wave power for the CMR's at a frequency determined by engine speed. The output of this current transformer is regulated at 74 volts by a bridge rectifier, which diverts the excess current peaks into the locomotive battery.

WARNING: *A current transformer MUST NEVER be permitted to operate in an open circuit condition, i.e., with the traction alternator under load and the current transformer to battery circuit open. Dangerous voltages develop during this condition, and personal injury could result.*

Also furnished is a test circuit which provides a quick manual check of the system. This includes a lamp (WSL) and Toggle switch (S1) mounted on the panel frame adjacent to the instruction plate. Operation of the Toggle switch introduces simulated wheelslip signals (LEVEL or RATE) to the panel. This action should cause the panel to function and initiate corrective action on the locomotive.

MAINTENANCE NOTES

1. If Automatic Sanding does not function, check for a missing jumper bar between Terminals AL and AM, especially if panel has been replaced.

2. Cold solder joints can be a major source of trouble on printed circuit cards which have been repaired due to failure or change of parts.

3. The wheelslip relay (WSX), located on the left end of the card rack, is an 11-pin plug-in device containing three sets of double-throw bridging contacts. Periodically tighten wing nut to keep relay in place.

4. Terminal connections of all CMR reactors should be clamped between two metallic surfaces to prevent loosening of the connections due to possible cold flow of the potting compound.

5. Check for loose current transformer coil, with locomotive shut down and open battery switch. If loose, secure at terminal board end with a nylon Ty-Wrap*.

*Product of Thomas Betts Co.

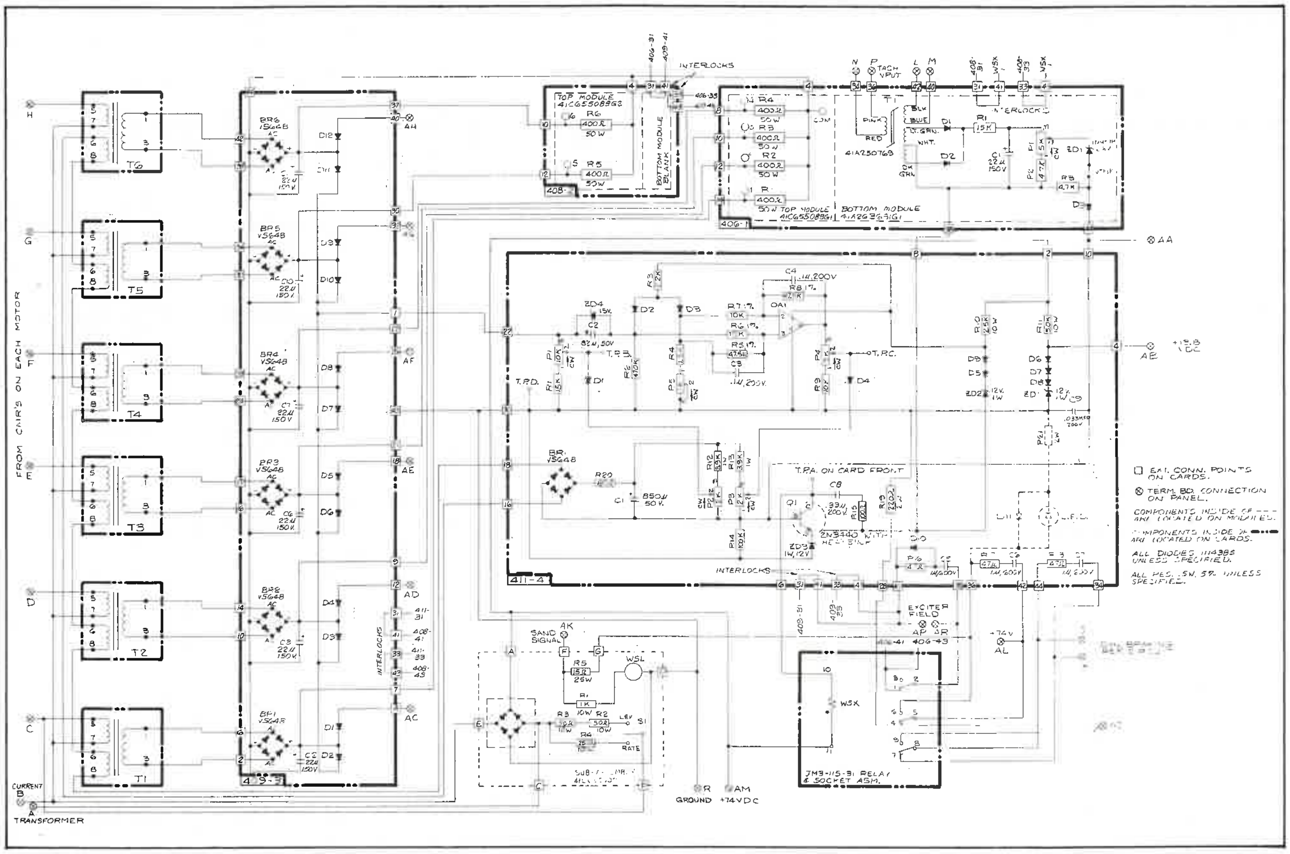


FIG. III-39, E-18347A

FIG. III-39. FL80 SCHEMATIC DIAGRAM.

6. Black CMR coils have been superseded by red and white coils. On a locomotive with black coils, if the system does not function properly when a red or white coil is applied, suggest:

   a. Replace failed black coil with reusable black coil (saved from previous fix).

   b. Try substituting a couple different red or white coils for the failed black one.

   c. Replace locomotive set with all red and/or white coils, and save the good black ones for future changeouts on other locomotives with black CMR's.

7. Five of the six CMR reactor coils are presently located on the underside of the deck, Fig. III-40. The remaining coil for the No. 2 traction motor (A-2 cable) is behind the side channel and under the control compartment.

   Boxes are provided to protect and isolate the coils. They are equipped with hinged covers, for access to the coil terminals. Conduit is included to protect and carry the control wires to the wireway along the left side of the deck, or to the control compartment directly, for the No. 1 and No. 3 motor cables.

CHEC EXCITATION PANEL

DESCRIPTION

CHEC is a new excitation system for GE diesel-electric locomotives of which the FL138 Excitation Panel is the major component. The panel contains ten blue-face 44-pin cards. It has other electrical components in its high-voltage section. Fig. III-41. The first nine cards from the left are

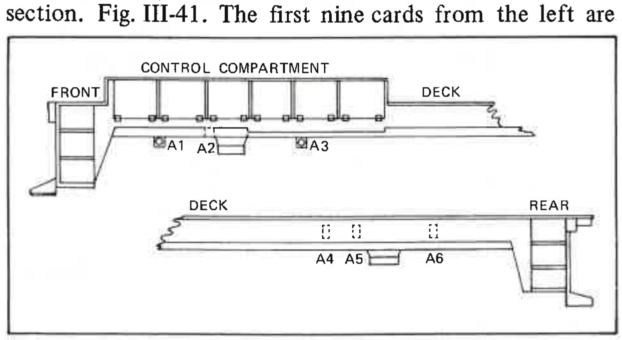


FIG. III-40, E-22208

FIG. III-40. LOCATION OF CMR COILS ON A SIX-MOTOR LOCOMOTIVE.

TABLE III-VI, CARD DATA AND FUNCTION

Position (Left to Right)	Symbol	Card Title	Card No.	Function
1	TC	Test	FD732	Card reserves the left contact strip in panel for replacement by CHECKIT plug during system tests or checks. No components are mounted on it; however, it has interlock wiring, and must be in place unless CHECKIT is plugged in.
2	FT	Field Control	FD733	Provides a variable current to the shunt field of the exciter (GY27).
3	MD	Modulator	FD734	Controls the variation in the shunt field current.
4	MP	Multiplier	FD735	Generates the power signal by multiplying the voltage and current signals supplied to it.
5	TS	Turbo Speed	FD736	Generates a signal proportional to turbo-rotor speed.
6	CP	Comparator	FD737	Determines which of the various signals will control the locomotive power output or the amount of dynamic braking effort developed.
7	FL	Filter	FD738	Smooths signals from ACCR, BCCR and VCR reactors and furnishes two signals to comparator card.
8	OS	Oscillator	FD739	Generates a 400 Hz signal to excite the three reactors (ACCR, VCR, BCCR) and supplies power to the RG card.
9	RG	Regulator	FD740	Supplies regulated positive and negative 15-volt power for certain cards and contains four relays which repeat the Throttle command on MU trainline wires.
10	RF	Reference	FD——	Presets the power, current and voltage limits for each throttle notch, furnishes a power match signal when specified and modifies turbo speed signal.

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the same in all panels for the different models of GE locomotives, Table III-VI. The tenth, or Reference Card, is different for each model of locomotive.

PRINCIPLE OF SYSTEM OPERATION

The control of the power supply on a diesel-electric locomotive is dependent on the proper operation of the excitation system and the engine governor. The excitation system, after considering all the circumstances it can sense,

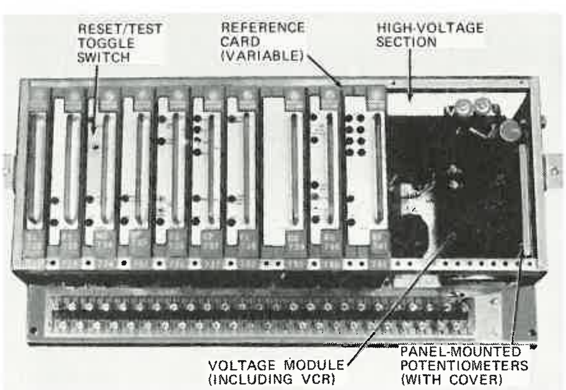


FIG. III-41, E-20343

FIG. III-41. FL138 EXCITATION PANEL WITH HIGH-VOLTAGE SECTION EXPOSED.

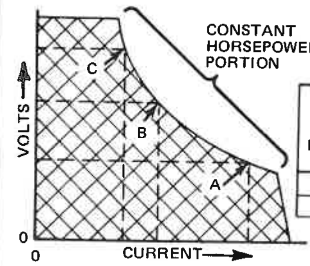
adjusts the amount of current supplied to the shunt field of the GY27 exciter. This determines where on the constant horsepower portion of the output curve the locomotive power plant will operate – whether at a high, medium or low current point – which corresponds to a low, medium or high voltage (points A, B and C on Fig. III-42). Thus, the electrical transmission system must be regulated to get maximum efficiency in applying the engine output to drive the locomotive's traction motors.

Several external signals are required for proper operation of the FL138 panel. This includes signals from the turbo-rotor, engine governor, ACCR, BCCR and VCR reactors. Then, the following signals are generated within the panel: a 400 Hz oscillator output, current and voltage limit voltages, power limit reference and an indication of the Throttle handle notch position from the lead locomotive.

MOTORING

Three reference voltages are developed during motoring for the eight Throttle handle positions:

1. Power Limit
2. Voltage Limit
3. Current Limit.



POINT	CURRENT (TRACTIVE EFFORT)	VOLTAGE (SPEED)
A	HIGH	LOW
C	LOW	HIGH

FIG. III-42. CHARACTERISTIC POWER SUPPLY OUTPUT CURVE.

FIG. III-42, E-20345

DYNAMIC BRAKING

Three feedback signals are used during dynamic braking:

1. ACCR – represents current in the traction motor fields.
2. BCCR – represents current in the traction motor armature and braking grid.
3. VCR – protects the system by overriding BCCR signal if alternator voltage should rise above normal value.

MAINTENANCE

This panel should require very little maintenance. However, it must be kept free of dirt and other foreign material. The cards on this panel mount static electronic components under a protective coating. Thus, vibration is minimized and cleaning can be accomplished by blowing with low pressure, dry air.

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

Periodically inspect the cards and the panel wiring for damaged components or insulation and be sure all wire connections are tight.

QUALIFICATION FOR SERVICE

Refer to Table III-VII for qualification for service.

WARNING: *Electrical shock can cause serious or fatal injury. Proper precautions should be observed by personnel performing the trouble-shooting and adjustments.*

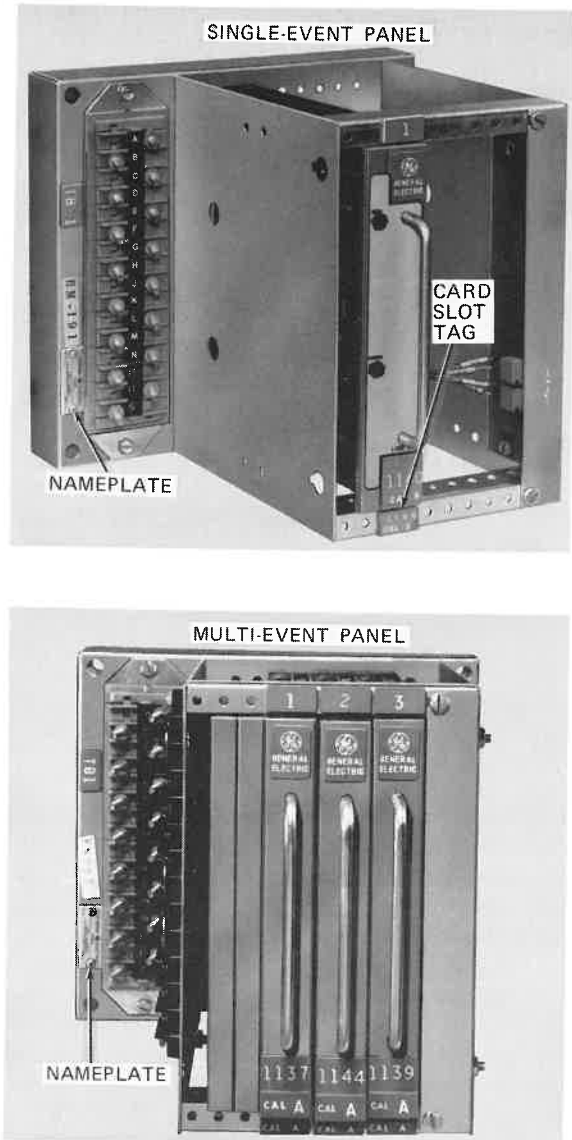


FIG. III-43. TYPICAL SINGLE AND MULTI-EVENT FL182 PANELS.

FIG. III-43, E-24599

SPEED EVENT PANEL

DESCRIPTION

The Type FL182 Speed Event Panel provides one, two, four, six or eight speed-event signals. A speed event is a predetermined vehicle speed where some change in control circuitry is desired. The suffix letters in the panel designation indicate the number of events generated by each particular panel. The panel designation is the nameplate number, Fig. III-43. For example, in nameplate 17FL182B1, the B is the suffix letter indicating panel form.

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TABLE III-VII, PROCEDURE FOR QUALIFYING LOCOMOTIVE FOR SERVICE

Procedure	Engine Shutdown	Engine Running
1. Check locomotive EC panel for a lit REDUCED EXCIT indicating light. a. If ON, the locomotive is in the reduced excitation mode. Open the Forward Control Compartment door and press the Toggle switch on the MD card to RESET. b. Indicating light will go OUT with operation of Reset Switch on MD card. c. To verify whether fault remains or has cleared, locomotive must be set for Motoring, air brakes set, reverser thrown, GF in ON position, EC switch in RUN position and isolate all other units. d. Move Throttle handle to Notch 1, until unit starts to load. e. When indication of loading is observed on loadmeter of faulty locomotive, return Throttle handle to IDLE and note whether indicating light is now ON or OFF on faulty locomotive. f. If indicator relights, go to the Control compartment and check all cards for proper location and assure they are securely plugged in.		X (Run)
2. The two red LED lights on the RG card (FD740) should be ON when the +15 vdc and −15 vdc power supplies are functioning. If not, change out this and/or the OS card (FD739).	X	X (Start or Run)
3. Move the Toggle switch on MD card (FD734) to TEST position to simulate a fault, causing the panel to go to the reduced excitation mode. The red LED on this card (Field Switch Light) should come on and stay lit until Toggle switch is moved to the RESET position. As the switch is moved, you should hear the EF relay operate.	X	X (Start or Run)
4. Check terminals for loose connections, and wires for charred or discolored insulation. Replace any damaged wires or hardware and tighten any loose connections. **CAUTION:** *The eight panel mounted potentiometers are factory sealed and should not be tampered with, otherwise equipment may be damaged.*	X	X (Start)
5. Check that cards are in their assigned locations and that card numbers agree with panel numbers.	X	X (Start or Run)
6. Check that the RF (10th) card is the proper one for the model of locomotive on which installed.	X	X (Start or Run)

Each form of the card has separate, selected resistor and capacitor values to determine operating range for each speed event.

A series of two to eight potentiometers is located on the panel end-sheet to set the speed-event points. On the single-event panel (17FL182B, etc.), potentiometer P7 will adjust the drop-out (DO) and P8 will adjust pick-up (PU).

On most multi-event panels the other speed events are provided with only one adjustment. Usually, the pick-up value is the one to be calibrated. The drop-out will then be predetermined by the value of a fixed resistor on the FD-event cards. Conversely, if it is desired to set the drop-out speed, the pick-up will be predetermined.

In special cases where no speed adjustments are permitted, potentiometers are replaced with fixed resistors on the speed-event cards.

The a-c speed sensor signal is converted to d-c on the FD1140 card for single-event panels, and on the FD1137 card for all other forms of the panel. A fixed resistor, RS1, is preselected by test for the proper scaling of a particular combination of speed sensor and speedometer scaleplate.

A wheel-wear panel (FM379) for locomotive applications is used in conjunction with, and sometimes attached to, the FL182 panel when speed indication is provided.

NOTE: *When replacing an FL182 panel with wheel-wear panel attached, be sure new panel is complete with same attachment.*

The panel contains one, two or three cards which plug into a metal frame that also mounts terminal boards, potentiometers and plug-in receptacles. See Fig. III-44 for interconnection diagram for single-event panel, and Fig. III-45 for a multi-event panel.

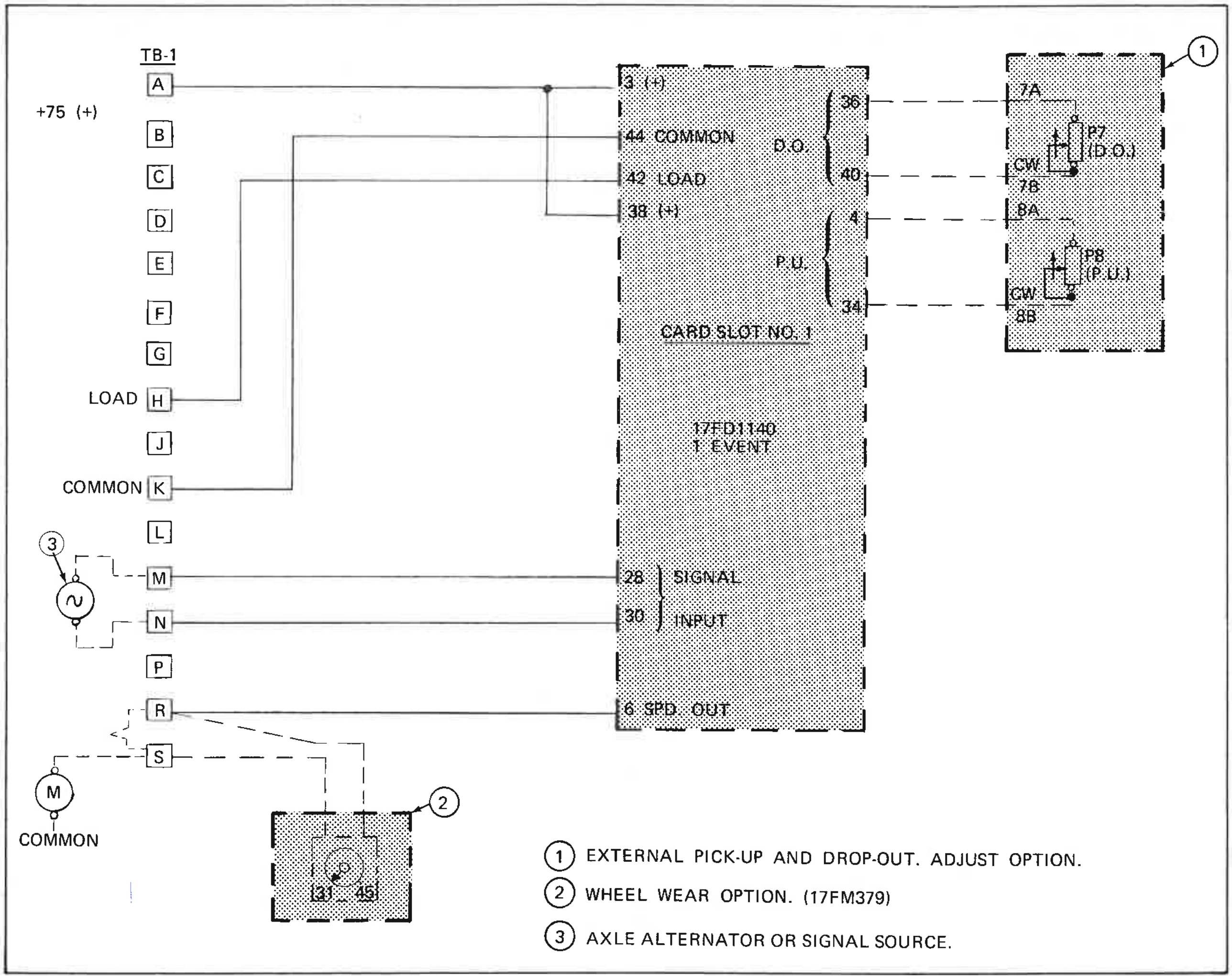


FIG. III-44. BLOCK DIAGRAM FOR FL182 SINGLE-EVENT PANEL.

FIG. III-44, E-22657A

CARD DESCRIPTION

The cards used in the panel are as follows:

FD1137 Tach Receiver Card – contains two separate tachometer channels, a voltage regulator, a frequency-to-voltage converter for use by speedometers, a +12 to 18 vdc source for excitation of external active sensors and a test oscillator for use in self-test, when desired.

FD1138 Four-Channel Speed-Event Card – contains four speed-event channels, each of which will energize loads up to one amp.

FD1139 Two-Channel Speed-Event Card – contains two speed-event channels, each of which will energize loads up to one amp.

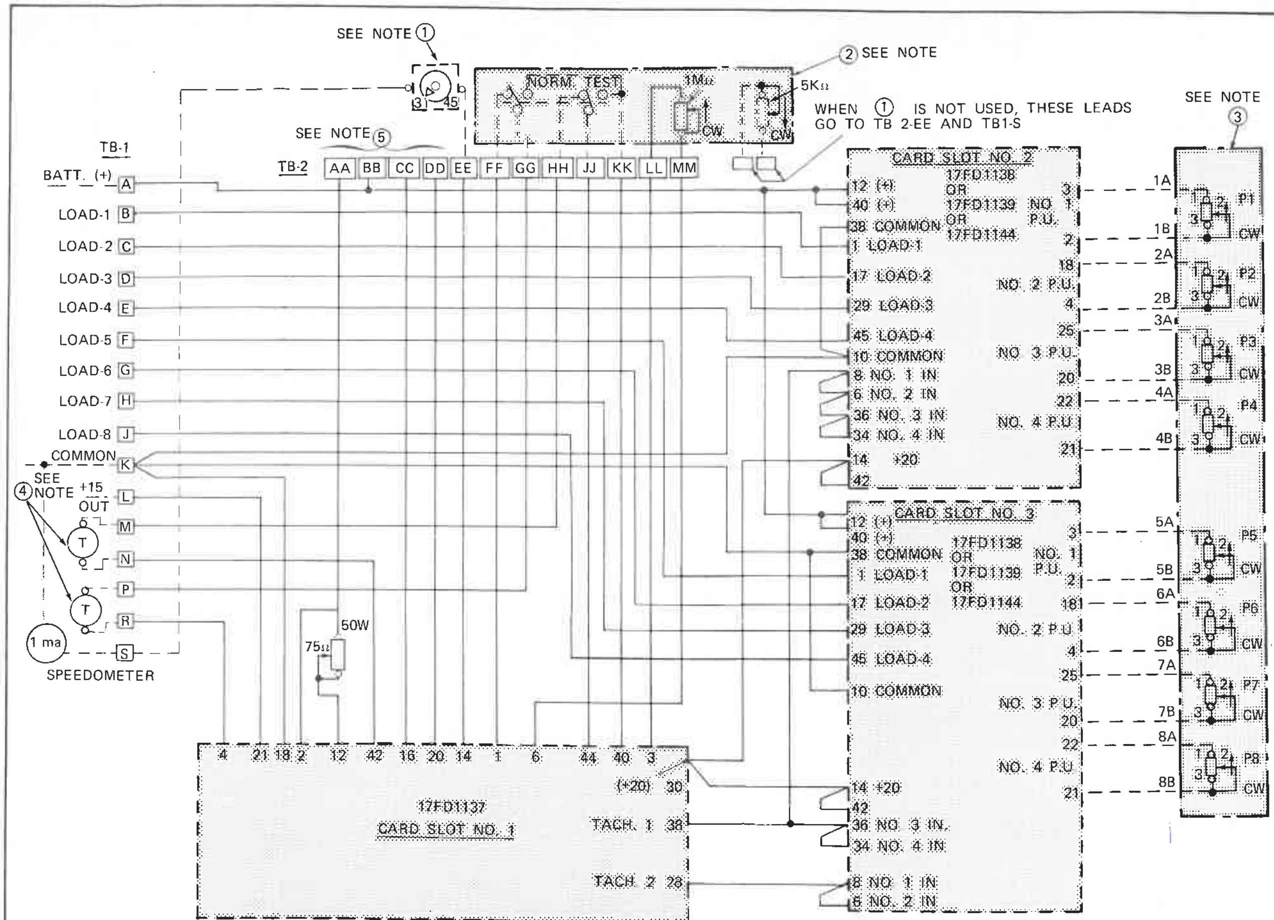
FD1140 Voltage Regulator and Speed-Event Card – contains a voltage regulator, a tachometer channel, one speed event and a test oscillator circuit. Maximum speed-event load current is one amp.

FD1144 Four-Channel Speed-Event Card – contains four speed-event channels. All output loads are *energized* up to a set frequency and *de-energized* at frequencies above that point. Maximum load current is one amp.

MAINTENANCE

The panel requires very little maintenance; however, it must be kept free of dirt and other foreign material.

Cleaning can be accomplished by blowing dry, compressed air into and around the panel.



① WHEEL DIAMETER COMPENSATOR (17FM379)

② SELF TEST OPTION (JUMPER FF-GG & HH-JJ IF NOT USED) (17FM380)

③ EXTERNAL "PICK-UP" ADJUST OPTION (4-TYPES 2-POT, 4-POT, 6-POT AND 8-POT)

④ AXLE ALTERNATOR OR SIGNAL GENERATING DEVICE. IF SINGLE DEVICE USED PARALLEL INPUTS (M TO P AND N TO R)

⑤ FOR 75 VDC OPERATION JUMPER AA-BB
FOR 37.5 OR 28 VDC OPERATION JUMPER BB-CC-DD

FIG. III-45, E-22658A

FIG. III-45. BLOCK DIAGRAM FOR FL182 MULTI-EVENT PANEL.

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

The cards in this panel have static components mounted on them under a protective coating, thus minimizing vibration of components.

CAUTION: *Power should be removed when pulling or replacing electronic cards to prevent electrical damage to the cards.*

Periodically inspect the cards and the panel wiring for damaged components or insulation, and assure all wire connections on panel are tight.

OPERATION, TROUBLE-SHOOTING AND TESTING

The following operation, trouble-shooting and testing section describes two specific FL182 panel applications. Both applications are for a diesel-electric road locomotive. Since many forms of the FL182 panel exist, only the single-event B form (17FL182B), Fig. III-46, and the six-event CA form (17FL182CA), Fig. III-47, will be described.

NOTE: *The panel form is indicated by the last letters on the panel identification nameplate. See Figs. III-43, III-46 or III-47 for nameplate location.*

The B form of the panel, Fig. III-46, provides one speed event and is used when a single-speed indication is required, like for transition. Pick-up and drop-out adjustments are provided.

III

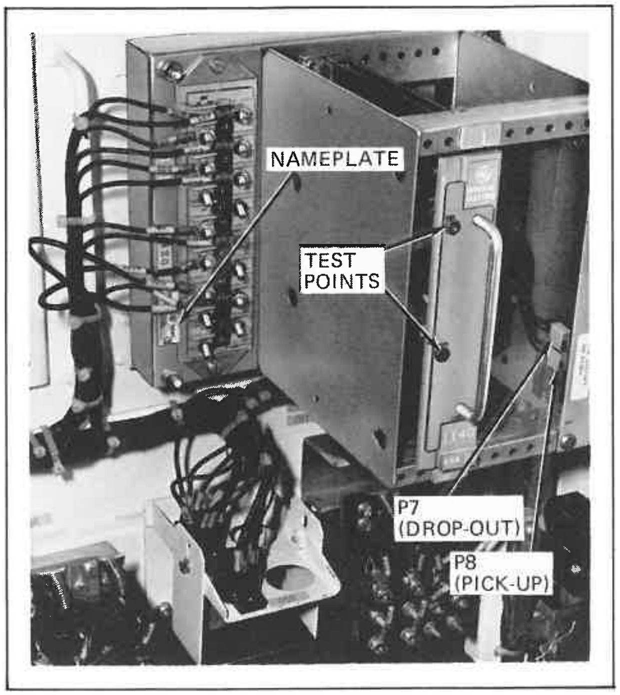


FIG. III-46. TYPICAL SINGLE-EVENT FL182 PANEL MOUNTED ON LOCOMOTIVE.

The CA form, Fig. III-47, is used where six-speed indications are required like four events for extended-range dynamic braking, and one event for transition and one event for locomotive overspeed. Only one adjustment is provided for each of the six events.

When working with a panel other than the B or CA form, determine which form the panel most closely resembles; the B or the CA form. Basic operation of other panel forms may be the same as the B or the CA form, differing only in cards, numbers or speed settings. If this is so, the method used for the B or CA form may be applied to the other form. Speed settings for the other form would then be substituted for the settings given for the B or the CA form in the procedure outlined in text.

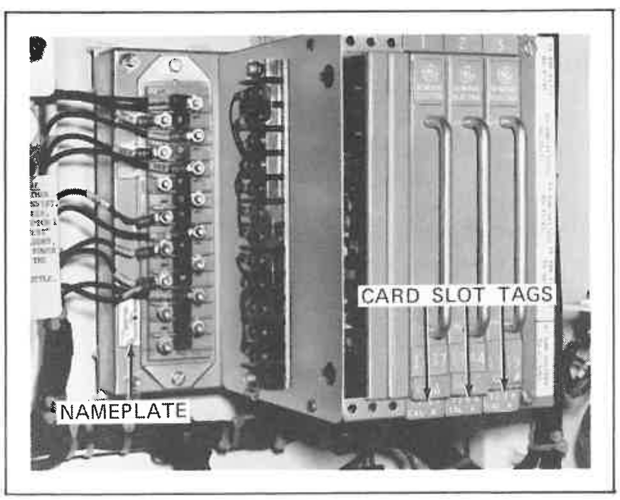


FIG. III-47. TYPICAL MULTI-EVENT FL182 PANEL MOUNTED ON LOCOMOTIVE.

The following section includes description, operation, trouble-shooting and testing of the B form of the panel. If information is desired on the CA form, proceed to the "CA Form, Six-Event Panel (17FL182CA)" section.

B Form, Single-Event Panel (17FL182B)

Description

This panel provides a single speed-event, using one FD1140 card, Fig. III-46. The pick-up speed can be adjusted using P8; P7 adjusts the drop-out speed, Fig. III-48.

NOTE: *These potentiometers are mounted on the panel frame and are preset by the factory. Any card can be replaced without making adjustments to the panel. Only reason to readjust potentiometers would be interchange of panel to locomotive with different gear ratio or transition speed settings.*

Operation

The single-event panel is normally used to initiate transition. Forward and reverse transitions occur at specific locomotive speeds predetermined by the design of the locomotive. The locomotive schematic usually lists the required transition speeds; pick-up (forward transition) being set higher than drop-out (reverse transition).

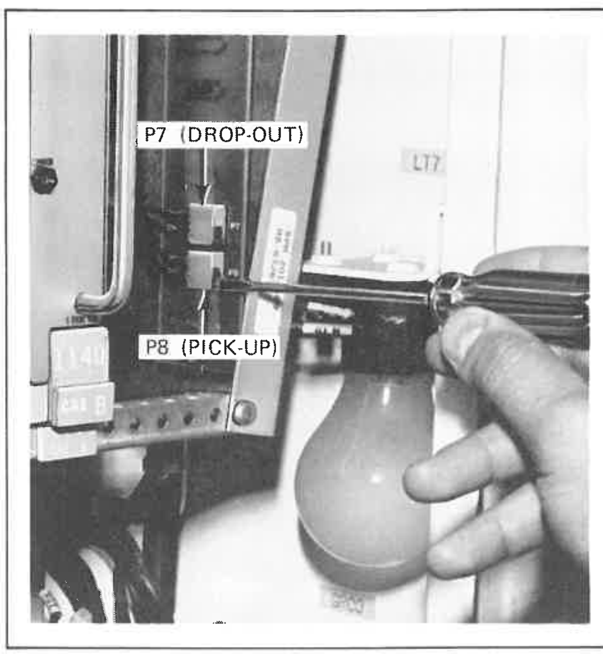


FIG. III-48. ADJUSTMENT OF TYPICAL SINGLE-EVENT FL182 PANEL.

FIG. III-46, E-24600

FIG. III-47, E-24601

FIG. III-48, E-24602

FIG. III-49, E-24605

III

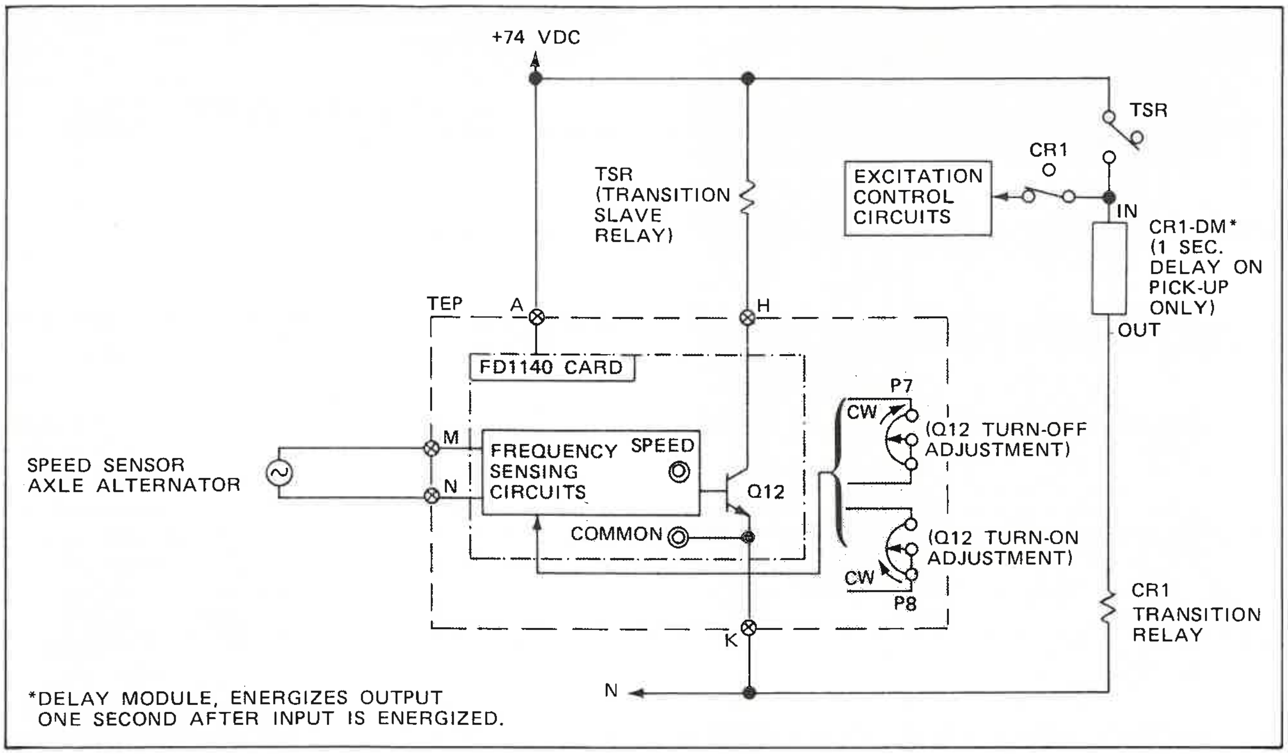


FIG. III-49. 17FL182B TRANSITION EVENT PANEL (SINGLE-EVENT TYPE) FOR A TYPICAL LOCOMOTIVE APPLICATION.

Trouble-Shooting and Testing

> **CAUTION:** *Always refer to the locomotive schematic for the exact speed settings. The speeds given in this section are examples only and are not correct for all applications.*

The following describes a method for trouble-shooting, testing and adjusting the B form single-event panel. Refer to Fig. III-49 during the following description. The locomotive schematic for the specific locomotive being repaired should also be referred to since Fig. III-49 cannot represent all applications.

NOTE: *The following steps will apply to the panel only. It is assumed the axle alternator circuit and other locomotive wiring to the panel is operating properly.*

1. Connect Test Set

Remove one axle-alternator wire from the transition panel (TEP), Terminal M or N. Connect an a-c signal producing device to Terminals M and N. The TM14, MM37 or MM26 test set can provide this signal, Fig. III-50.

FIG. III-50, E-24603

FIG. III-50. CHECKING FL182 PANEL USING TM14 TEST SET.

TABLE III-VIII, TYPICAL FACTORY TEST SETTINGS FOR SINGLE-EVENT PANEL
(Must be Reset For Specific Locomotive Application)

FL182 Panel Form	Load on TB1-H		Signal Generating Device Output Frequency to Get 9.75 to 10.25 vdc (on TB1-R or Speed Test Point)
	Pick-Up (Hz)*	Drop-Out (Hz)*	
A	875 to 925**	805 to 855**	1000 Hz
B	66 to 68 (P8)	62 to 64 (P7)	358
C	66 to 68 (P8)	62 to 64 (P7)	267
D	66 to 68 (P8)	62 to 64 (P7)	323
E	66 to 68 (P8)	62 to 64 (P7)	290
F	66 to 68 (P8)	62 to 64 (P7)	255
H	26.2 to 27.8 (P8)	19.4 to 20.6 (P7)	358
J	223 to 237 (P8)	204 to 216 (P7)	358

*Adjust to Accuracy shown using potentiometer indicated.
**No adjustment provided on this panel.

NOTE: *Any signal-generating device can be used as long as a 2-vp–p (minimum) signal is provided at the proper frequencies.*

2. Card Test Points

   Test points have been provided on the front of the FD1140 card, Fig. III-46. The test points are labeled SPEED and COMMON. The information provided by these test points is not essential for checking the operation of the FL182 panel. These test points are provided for special applications. If the test-point values are observed, the following information will apply:

   a. The SPEED (+) to COMMON (–) test points will produce a 0-10 vdc reading depending on the frequency of the axle alternator or test-set signal input to the FL182 panel.

   b. The voltage to frequency relationship differs for each panel form and the FD1140 card calibration.

   c. Table III-VIII lists the axle alternator or test-set frequency that produces a 10-vdc test-point reading.

   d. The relationship between test-point voltage and axle-alternator frequency is linear.

3. Check Panel Operation (Pick-Up)

   Set the test-set or signal-source frequency at the FL182 panel pick-up value. Normally this pick-up value will be the locomotive transition speed which is listed on the locomotive schematic. The schematic usually lists the values in speed, frequency and axle rpm. With the test-set signal at the pick-up frequency, the normally OFF Transistor Q12 will turn ON and conduct, Fig. III-49. This allows current to flow thru TSR coil energizing TSR relay. If the TSR energizes, the panel has operated correctly; proceed to Step 4. If the panel did not operate correctly, proceed to Step 5.

4. Check Panel Operation (Drop-Out)

   With the FL182 pick-up operating properly, check the drop-out speed setting. Reduce the test-set or signal-source frequency to the drop-out value. Below this drop-out value the panel should de-energize the coil (Q12 turn-off). If the drop-out sequence does not operate, proceed to Step 5. If the drop-out sequence operates properly, the panel is operating properly. Remove test equipment and restore circuits to normal.

5. Change FD1140 Card

   If the FL182 panel does not operate at the proper pick-up or drop-out frequency (speed), try other frequencies to determine if the panel operates at all, then change the FD1140 card. Cards should be changed before panel adjustment is attempted.

NOTE: *When changing the FD1140 card, make sure the CAL (calibration) letter on the card front matches the CAL letter on the panel slot tag, Fig. III-43. For example, the FD1140 CAL B card must be replaced by an FD1140 CAL B card. The CAL B indicates that factory selected resistors and capacitors are built into the card for a specific frequency range.*

When the card is changed or repaired, return to Step 3 for retesting.

FIG. III-51, E-24606

FIG. III-52, E-24608

III

CA Form, Six-Event Panel (17FL182CA)

Description

The CA Form, Fig. III-47, is used when six speed indications are required like four events for extended-range dynamic braking; one event for transition and one event for locomotive overspeed. This panel contains three cards: FD1137, FD1144 and FD1138. The four events of extended-range braking are controlled by the FD1144 card. Transition and overspeed are controlled by the FD1139 card. The FD1137 card contains frequency sensing circuits. Only the pick-up portion of each event is adjustable.

NOTE: *These potentiometers, Fig. III-51, are mounted on the panel frame and are preset by the factory. Any card can be replaced without making adjustments to the panel. Only reason to readjust potentiometers would be interchange of panel to locomotive with different gear ratio or transition speed settings.*

Operation

The multi-event panel is used to initiate transition, detect locomotive overspeed and control the extended-range dynamic-braking contactor sequence, Fig. III-52.

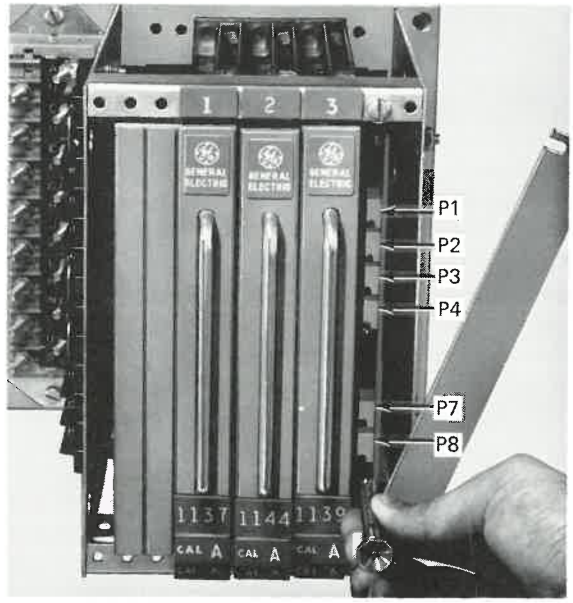


FIG. III-51. ADJUSTMENT OF TYPICAL MULTI-EVENT FL182 PANEL.

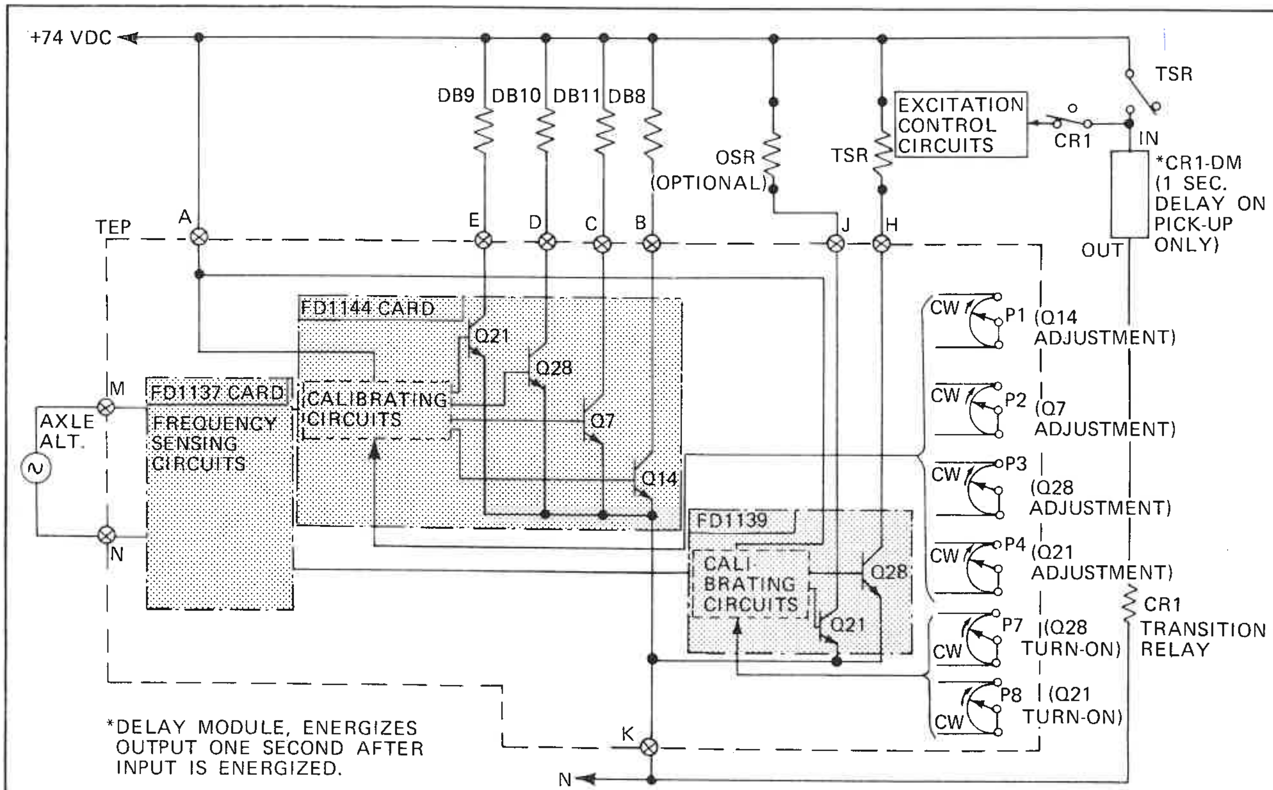


FIG. III-52. 17FL182CA TRANSITION EVENT PANEL (MULTI-EVENT TYPE) FOR A TYPICAL LOCOMOTIVE APPLICATION.

1. Transition

Forward and reverse transitions occur at specific locomotive speeds predetermined by the design of the locomotive. The locomotive schematic usually lists the required design transition speeds, pick-up (forward transition) being set higher than drop-out (reverse transition).

CAUTION: *Always refer to the locomotive schematic for the exact speed settings. The speeds given in this section are examples only and are not correct for all applications.*

2. Extended-Range Dynamic Braking

The purpose of extended range is to improve the effectiveness of dynamic braking at low locomotive speeds. This is done by altering the braking grid resistance as locomotive speed reduces. The contactors that alter the braking grid resistance are initially controlled by the FD1144 card, Fig. III-52. Transistors Q21, Q28, Q7 and Q14 are the switches that control the contactor sequencing.

Extended-range contactor sequencing occurs at specific locomotive speeds determined by the design of the locomotive. The locomotive schematic should always be referred to for the correct speeds.

3. Overspeed

The overspeed system detects excessive locomotive speed.

Trouble-Shooting and Testing

The following describes a method for trouble-shooting and testing for Form CA six-event panel. Since transition, overspeed and extended-range braking are controlled by this panel, the following steps will apply to all operations.

Refer to Fig. III-52 during the following description. The locomotive schematic for the specific locomotive being repaired should also be referred to since Fig. III-52 cannot represent all applications.

NOTE: *The following instructions will apply to the panel only. It is assumed the axle-alternator circuit and other locomotive wiring to the panel is operating properly.*

1. Connect Test Set

Remove at least one axle-alternator wire from the transition panel (TEP) Terminal M or N. Connect an a-c signal producing device to Terminals M and N. The TM14, MM37 or MM26 test set can provide this signal, Fig. III-50. Any signal-generating device can be used as long as a 2-vp–p (minimum) signal is provided at the proper frequencies.

2. Zero Signal Input to Panel

With the test-set frequency set at zero Hz (zero input to panel), Q21, Q28, Q7 and Q14 on the FD1144 card will be turned on energizing DB9, DB10, DB11 and DB8, Fig. III-52. Q28 and 21 on the FD1139 card will be turned off. If Q21, Q28, Q7 and Q14 are not turned on, replace FD1137 CAL A and/or the FD1144 CAL A card if spares are available.

To check further – if 15 v is available between L (+) and K (–) on TB-1, Fig. III-45; expect FD1137 card probably is not the one at fault.

NOTE: *When changing cards, make sure the CAL (calibration) letter on the card front matches the CAL letter on the panel slot tag, Fig. III-47. For example, the FD1137 CAL A card must be replaced by an FD1137 CAL A card. The CAL A (calibration A) indicates that factory selected resistors and capacitors are built into the card for a specific frequency range.*

NOTE: *Since adjustment potentiometers are mounted on the panel frame, Fig. III-51, and factory set, cards can be replaced without making adjustments to the card or to the panel. For this reason, the first attempt in trouble-shooting the panel should be to replace cards. If spare cards are not available, continue to Step 3.*

3. Checking Operation with Increasing Speed (Frequency)

Assume values given in Table III-IX. Increase the test-set frequency from zero to 27 Hz. This corresponds to increasing locomotive speed from zero to 9.7 mph. At 27 Hz transistor Q14 on the FD1144 card should turn off de-energizing DB8.

- Increase frequency to 39 Hz; Q7 should turn off.
- Increase frequency to 47 Hz; Q28 should turn off.
- Increase frequency to 58 Hz; Q21 should turn off.
- Increase frequency to 67 Hz; Q28 on the FD1139 card should turn on energizing TSR. If overspeed is provided, increase frequency to 208 Hz. Q21 on the FD1139 card should turn on energizing OSR. If none of the events work, expect FD1137 card is faulty; otherwise, replace the FD1144 card.

TABLE III-IX, SIX TYPICAL EVENT SETTINGS
(For a Diesel-Electric Road Locomotive Equipped with Extended-Range Dynamic Braking, Transition and Overspeed. (40-In. Wheels, 74/18 Gearing, 3000 Hp))

Event		MPH, Increase/Decrease	RPM, Increase/Decrease	CPS (Hz), Increase/Decrease
Extended range, dynamic braking contactor sequence	DB8	9.7/8.5	82/72	27/24
	DB11	13.9/12.5	117/105	39/35
	DB10	16.7/15.0	141/126	47/42
	DB9	20.6/18.9	173/159	58/53
Transition		24.0/22.5	202/189	67/63
Overspeed		74.0/70.5	623/593	208/197

If Q28 or Q21 on the FD1139 card did not operate, replace the card. Repeat Step 3 to verify new cards, if changed.

4. Checking Operation with Decreasing Speed (Frequency)

Set the test-set frequency as 208 Hz or higher. Reduce the frequency to 197 Hz. Q21 on the FD1139 card should turn off. Reduce the frequency to 63 Hz. Q28 on the FD1139 card should turn off. Reduce the frequency to 63 Hz. Q28 on the FD1139 card should turn off.

– Reduce frequency to 53 Hz; Q14 on the FD1144 card should turn on.

– Reduce frequency to 42 Hz; Q7 on the FD1144 card should turn on.

– Reduce frequency to 35 Hz; Q28 on the FD1144 card should turn on.

– Reduce frequency to 24 Hz; Q21 on the FD1144 card should turn on.

If the panel did not operate as described, replace cards. If no cards are available, continue to Step 5. If all events operated as described, the panel is operating properly, proceed to Step 6.

5. Additional Trouble-Shooting

Refer to Figs. III-45 and III-52 for further trouble-shooting information; like checking panel for broken wires. Potentiometer circuits on panel can be checked for continuity using card extender in Slots 2 and/or 3. Fig. III-45 shows pin connections for each potentiometer. These values could approach 200k ohms.

6. Remove Test Equipment

Restore circuits to normal. Panel testing completed.

ADJUSTMENTS

1. Three potentiometer arrangements are used on various models of the 17FL182 panels.

   a. On single-event panels (i.e. – 17FL182B, C), Fig. III-46:

      1) P8 adjusts event settings
      2) P7 adjusts differential range.

   b. On most two, four, six and eight-event panels (i.e. – 17FL182AA-DD), Fig. III-51:

      P1 thru P8 adjust event settings only. The differential range is not adjustable since fixed resistors on the card determine the differential range for each event setting involved.

   c. On a few four and six-event panels (i.e. – 17FL182BC, BD, BJ and CD) intended ONLY to replace other FL panels, both the event setting and differential range adjustments are provided.

      1) P1 thru P4 adjust event settings
      2) P11 thru P14 adjust differential ranges.

2. The event setting is the frequency at which switching takes place on rising frequency.

   This was called PICK-UP frequency on former products which turned-on a relay at that frequency.

   The 17FD1138, 1139 and 1140 cards act in this manner. When these cards are involved, the event setting corresponds to relay pick-up (energizing).

   The 17FD1144 card, however, does not operate in the same manner. It has an "inverted output" so the connected relay is energized until the event-setting frequency is reached and then drops-out. It picks-up again on decreasing frequency at a value of Event Setting (–) Differential.

3. Procedure – Refer to Fig. III-53, Upper Portion.

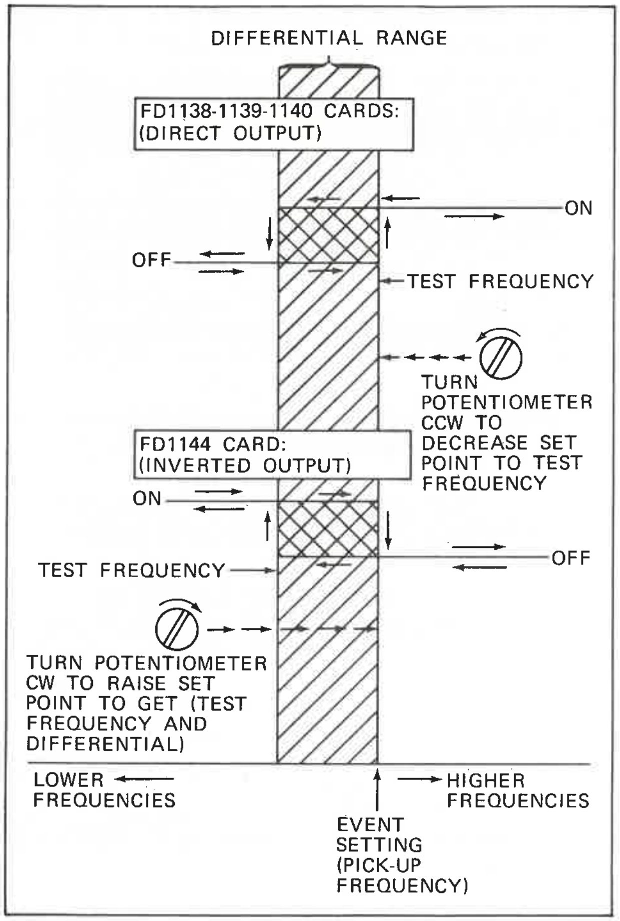


FIG. III-53. SETTING DIRECT AND INVERTED SPEED EVENTS.

a. Single-event panels, Step 1a1, and replacement panels, Step 1c1:

1) Adjust oscillator input frequency to desired operating point or pick-up frequency as listed on locomotive schematic (test frequency for event being checked).

2) If output is ON, turn appropriate potentiometer CW until output goes OFF (relay drops-out). The potentiometers are 20 turns from minimum to maximum resistance.

3) With output OFF, slowly turn potentiometer CCW. Stop when event goes ON (relay picks-up).

You have lowered the event setting to match the test frequency.

4) Decrease the test frequency to the desired drop-out value.

5) If output goes OFF, turn P7 range (P11-P14 on FD1144 card with inverted output) CW several turns to decrease differential. Increase test frequency until output goes ON then decrease it to desired drop-out value. Repeat as needed until event remains ON at drop-out setting of test frequency.

6) Turn P7 (or P11-P14) CCW slowly to increase differential range. Stop when event goes OFF.

b. Multi-event panels with FD1138, 1139 or 1140 event card. Refer to the upper portion of Fig. III-53.

1) Adjust test frequency to desired event setting.

2) If output is ON, turn appropriate potentiometer CW until it goes OFF (relay drops-out).

3) Turn potentiometer slowly CCW. Stop when output goes ON (relay picks-up).

c. Multi-event panels with FD1144 card. This is referred to as an inverted event card, and is used for extended range dynamic brake and some overspeed functions. Refer to Fig. III-53, lower portion.

1) Adjust test frequency to the value desired for turn-on during decreasing frequency (test frequency).

2) If output is ON, turn potentiometer CCW to lower setting until output goes OFF.

3) Turn potentiometer slowly CW. Stop when output goes ON. You have raised Set Point above test frequency by an amount equal to the differential range.

ANNUNCIATOR PANEL

DESCRIPTION

The 17FM369A2 Annunciator Panel is used to indicate malfunctions of equipment or systems on a locomotive. The panel is provided so a maintainer can better service a locomotive by knowing the cause of a locomotive malfunction and properly correcting it before resetting the panel and releasing the locomotive for service.

FIG. III-53, E-24682

FIG. III-54, E-24785

Twelve separate but identical circuits provide memory by lighting individual LED's that remain lit, as long as the d-c power is not interrupted or the Toggle switch thrown to reset the panel. Normally the panel is wired directly to the battery, not thru the battery switch, thus it receives continuous power. The spring-returned Toggle switch for resetting or clearing the panel lights has provision for a seal wire which must be broken to reset the circuits and turn off the lights.

A maximum of 12 different indications are provided and any or all may be used by changing the decal on the face of the panel to properly identify each light. A panel with nine indications is shown in Fig. III-54. A push-to-test switch is provided to simultaneously check the illumination of all the LED's.

The panel operates on voltages from 55 to 80 vdc and will maintain its memory down to 37.5 vdc. Provision is also made for one remote indicator that will illuminate simultaneously with a preselected panel indicator. The maximum load current for the remote indicator is 0.25 amps.

MAINTENANCE

This panel should require very little maintenance. However, at normal established inspection periods, perform the following:

> **WARNING:** *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

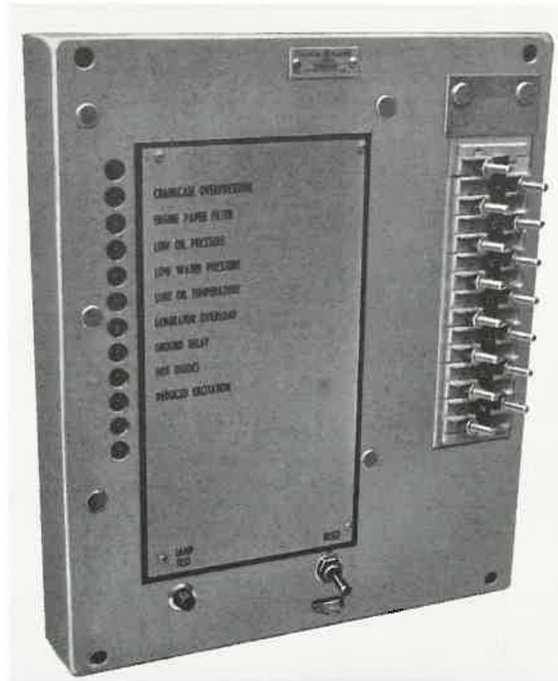


FIG. III-54. 17FM369A2 ANNUNCIATOR PANEL (TYPICAL)

1. Blow off excessive dirt build-up with dry, compressed air.
2. Inspect the panel for broken wires or damaged insulation.
3. Check to be sure all electrical components are secure and mounting hardware is tight.
4. When checking wiring, refer to schematic, Fig. III-55.

III

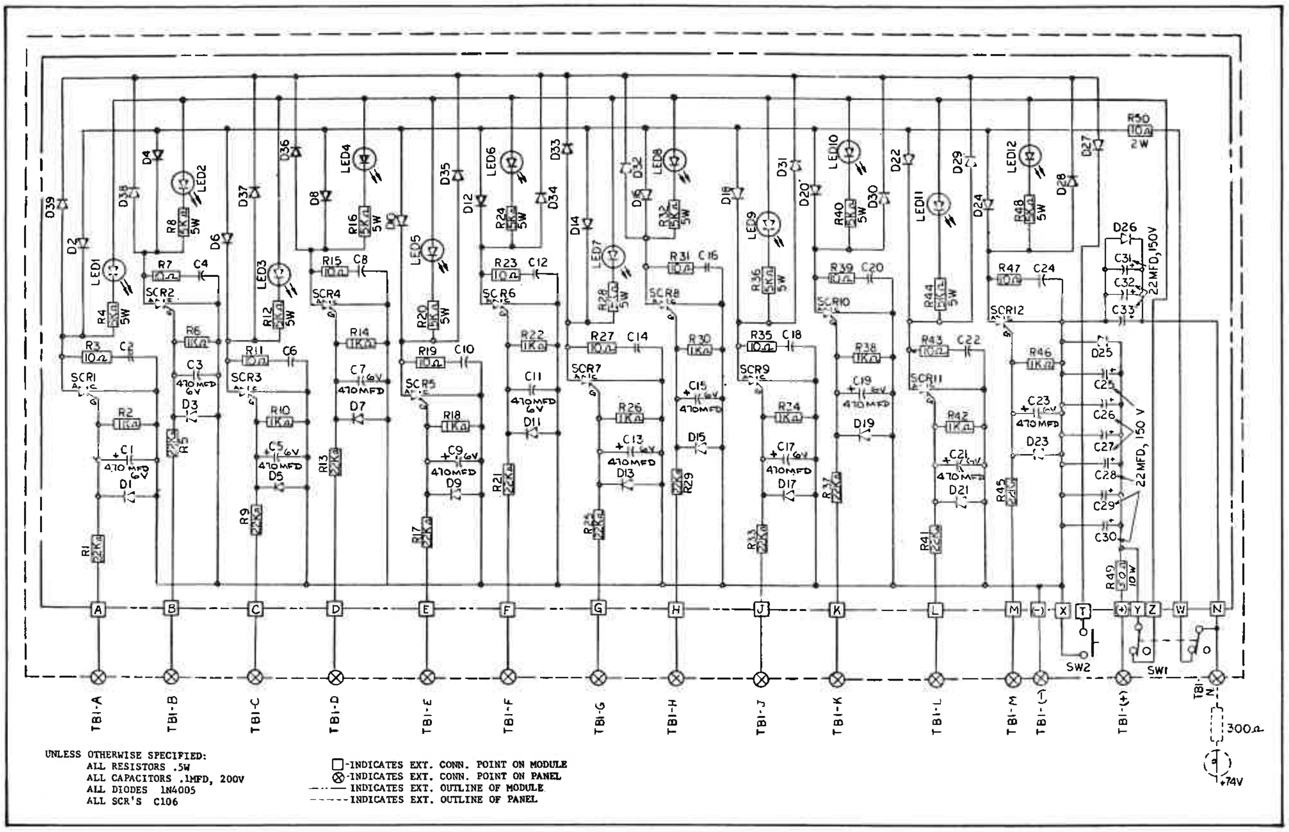


FIG. III-55. SCHEMATIC FOR 17FM369A2 PANEL.

FIG. III-55, E-24786

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TRANSPORTATION SYSTEMS BUSINESS DIVISION

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GENERAL ELECTRIC

INSTRUCTIONS

ROTATING EQUIPMENT

IV

FIG. IV-1, E-25151

CONTENTS

INTRODUCTION

This section is a brief description of electrical rotating apparatus on a locomotive such as the traction alternator, the auxiliary generator/exciter and the traction motor. For a detailed analysis, refer to the applicable maintenance manual furnished with the locomotive.

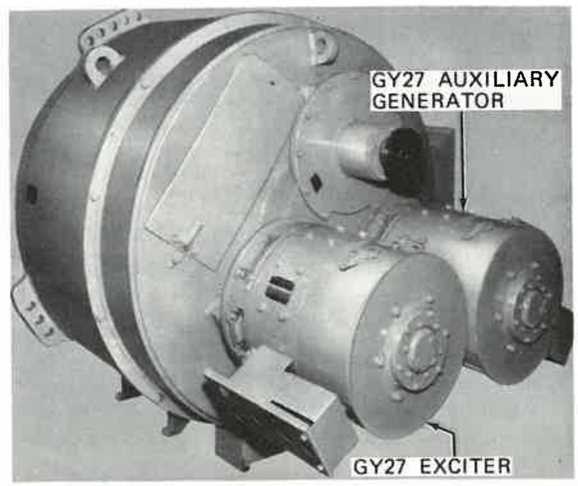

FIG. IV-1. TRACTION ALTERNATOR WITH AUXILIARIES.

TRACTION ALTERNATOR

DESCRIPTION

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

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

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GENERAL ELECTRIC

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Excitation is supplied by an exciter, Fig. IV-1, mounted on and driven by the alternator through the auxiliary-drive gear system. Also shown in Fig. IV-1 is the auxiliary generator which supplies power for the control system.

A simplified schematic diagram of the GTA11 alternator is shown in Fig. IV-2.

DATA

Type GTA11
Classification . . . . 10-pole, three-phase, Y-connected a-c generator
Rotation (facing collector-ring end) . . . . CCW

Brushes
Quantity per machine 6
Type . . . . Speer 524
Minimum Length (length at which brush becomes inoperative) (in.) 1-3/16
Brush-Arm Pressure (new brush) (lb.) . . . . . 4-1/4 to 4-3/4

Brushholder
Clearance to Collector Ring (in.) . . . . 3/32 to 1/8

Lubrication
Auxiliary-Drive Gear Case Capacity (initial filling, approximately) (pt.) 5
Lubricant (low-foam type) . . . . . SAE-40 Engine Lube Oil GE-D6B-18D

LUBRICATION

The alternator roller bearing is splash-lubricated from the auxiliary-drive gear unit. No other lubrication is required.

Check the oil level in the auxiliary-drive gear unit by means of the dipstick located on the lower right-hand side of the gear case (facing collector end) between the exciter and the alternator framehead.

If the engine is shut down, read the oil level on the side of the dipstick marked Generator Stopped. If the engine is idling, read the oil level on the side of the dipstick marked Generator Running. Maintain the oil level between the FULL and ADD marks on the dipstick.

> **CAUTION:** *Do not overfill gear case. Overfilling may result in oil being drawn through the alternator bearing onto the collector rings and windings, and cause serious operating difficulty.*

Drain the gear case once a year or after 180,000 miles of operation, whichever occurs first, and refill with SAE-40 engine lube oil, GE Specification D6B-18B.

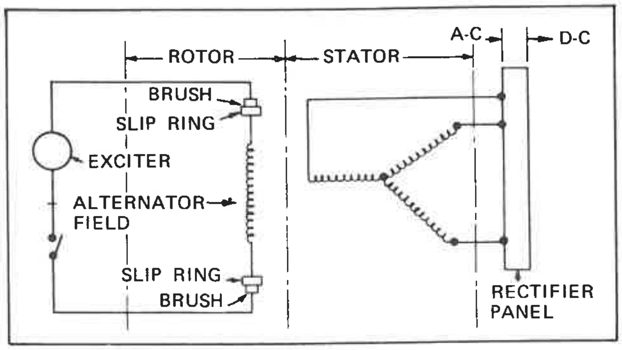


FIG. IV-2. SCHEMATIC DIAGRAM FOR GTA11 ALTERNATOR.

FIG. IV-2, E-12762

INSPECTION

In general, the inspection schedule of the alternator should conform to the inspection schedule established for the overall locomotive, but may be modified as required by actual operating experience.

The following information is offered as a general inspection guide which calls attention to what should be inspected and what to look for when making the inspection. If the inspection results call for corrective maintenance to be performed, the procedures for carrying out such maintenance are covered in the Maintenance Procedures section.

General

Make a visual inspection for evidence of loose or missing auxiliary and auxiliary gear-case mounting bolts, bolts which hold the electrical connection box cover in place, loose, damaged or missing latches in inspection covers. Also check for oil leakage from the auxiliary-drive gear unit and around the auxiliary mounting flanges. Make sure the gear unit oil-drain plug is tight.

Brushes

1. Inspect for wear, and replace brushes which have reached their minimum permissible length of 1-3/16 in., or which may be too short to run until the next inspection. When checking brush length, measure from the top of the brush clip to the center of the curved surface that is in contact with the collector ring.

2. Look for chipped or broken brushes, brushes with loose or frayed pigtails, and replace such brushes as necessary.

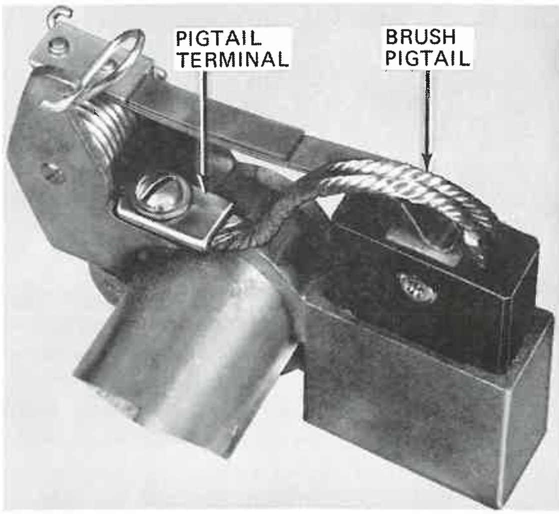


FIG. IV-3. CORRECT POSITION OF BRUSH PIGTAIL AND TERMINAL.

3. Make sure the pigtail terminals are positioned as shown in Fig. IV-3 and that pigtail terminal screws are tight.

4. Move brushes up and down several times in the brushholders to release carbon dust or foreign matter from the carbonways, which may prevent free movement of the brushes.

Brushholders

1. Check for loose, broken, bent or overheated pressure arms. Overheating will cause arms to become discolored and result in improper brush-arm pressure.

2. Make sure the thumb loop on the coiled brush pressure spring is in the position shown in Fig. IV-4.

3. Inspect brushholder mounting and make sure the studs are tight.

4. Check brushholder-to-collector ring clearance (3/32 to 1/8 in.) and adjust as necessary.

Collector Rings

1. Wipe off insulation between rings with a clean, dry cloth and inspect for evidence of physical damage.

2. Check the surface of the collector rings for evidence of discoloration, etching, grooving, threading or other signs of distress that may require corrective action. To help determine the need for such action, the following information is offered as an inspection guide. Ideally the collector ring surface should have a uniform, chocolate-brown color and be free of etching, threading or grooving. Conditions encountered in service, however, including oil vapors, adverse humidity conditions and air contaminants of various kinds add to the difficulty of maintaining an ideal collector ring surface.

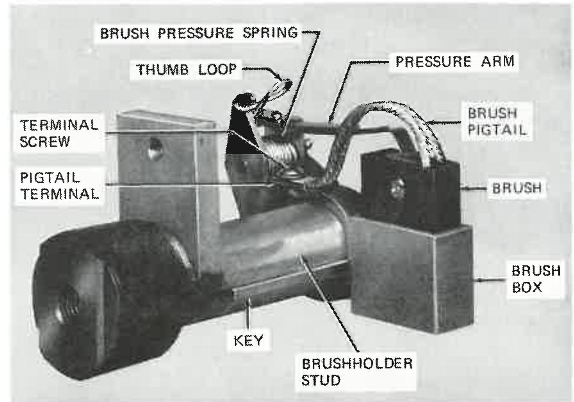


FIG. IV-4. BRUSHHOLDER ASSEMBLY.

If dark spots appear on the ring surface, they will likely be at uniform brush spacing. These spots later turn to a grayish color accompanied by etching of the collector ring surface. If appropriate action is taken at this point, that is, as soon as the dark spots appear or no later than the first evidence of the grayish, etched condition, more serious problems can be avoided later by removing the distressed areas with a brush seater stone as described under Maintenance Procedures section.

Without corrective action, severe arcing and grooving of the collector ring with resultant rapid brush wear, follow quickly until the grooving extends over 180 degrees or more of the ring surface. This requires the rings to be ground in order to remove the burned spots and grooving, and to restore the ring surface to a true circle.

Bus Rings and Field Leads

Check for cracked, frayed or damaged insulation.

Field Coil Connection Straps

Inspect insulation for evidence of cracks or physical damage that may require corrective action.

IV

FIG. IV-3, E-13698
FIG. IV-4, E-13699

IV

MAINTENANCE PROCEDURES

Resurfacing Collector Rings

When inspection reveals that corrective maintenance is required, resurface the collector rings by one of the following two methods depending on the severity of the burned spots or grooving:

Brush Seater Stone

1. With engine shut down, remove all collector ring brushes.

2. Tape seater stone to the end of a stick for use as shown in Fig. IV-5.

WARNING: *Projections from the end of the rotating field leave insufficient clearance above the rear (inboard) collector ring for use of a hand-held stone. To avoid serious injury, resurface rings only with a stone taped to the end of a stick.*

3. Start the engine and run it at idle speed.

4. Apply enough pressure to the seater stone to produce the cutting action required to remove the dark or burned spots.

5. Shut down the engine to inspect the ring surface. If further stoning is required, repeat Steps 2 and 3 and continue doing this until ring surfaces are clean.

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

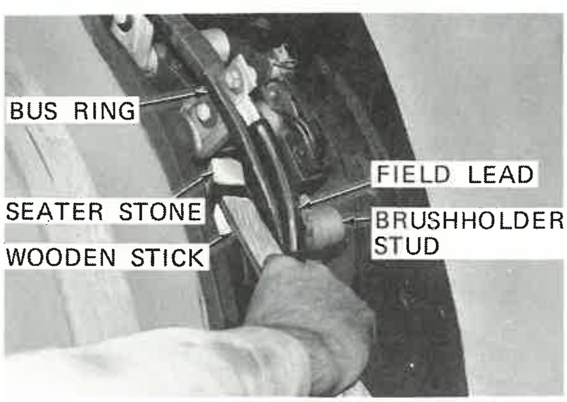


FIG. IV-5. RESURFACING COLLECTOR RINGS WITH BRUSH SEATER STONE.

6. With engine running at idle speed, clean collector ring surfaces by use of clean, dry compressed air.

7. Shut down engine and reinstall brushes.

8. Sand brushes to remove metal which may have transferred from collector ring to the brush contact surface. Use a strip of 2-in. wide by 24-in. long fine-grit sandpaper for this operation.

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

9. Blow out carbon dust with clean, dry compressed air.

Collector Ring Grinder

See Fig. IV-6 for collector ring grinder drawing.

1. With engine shut down, remove all brushes from brushholder.

2. Remove the two collector bus rings (with field leads attached) so they will not interfere with the grinder installation or the grinding operation.

3. Remove the two brushholders (Nos. 5 and 6) from the brushholder yoke located on the right-hand side of the alternator facing the collector end. Mark or label the studs to reduce the possibility of reassembling them in the incorrect position.

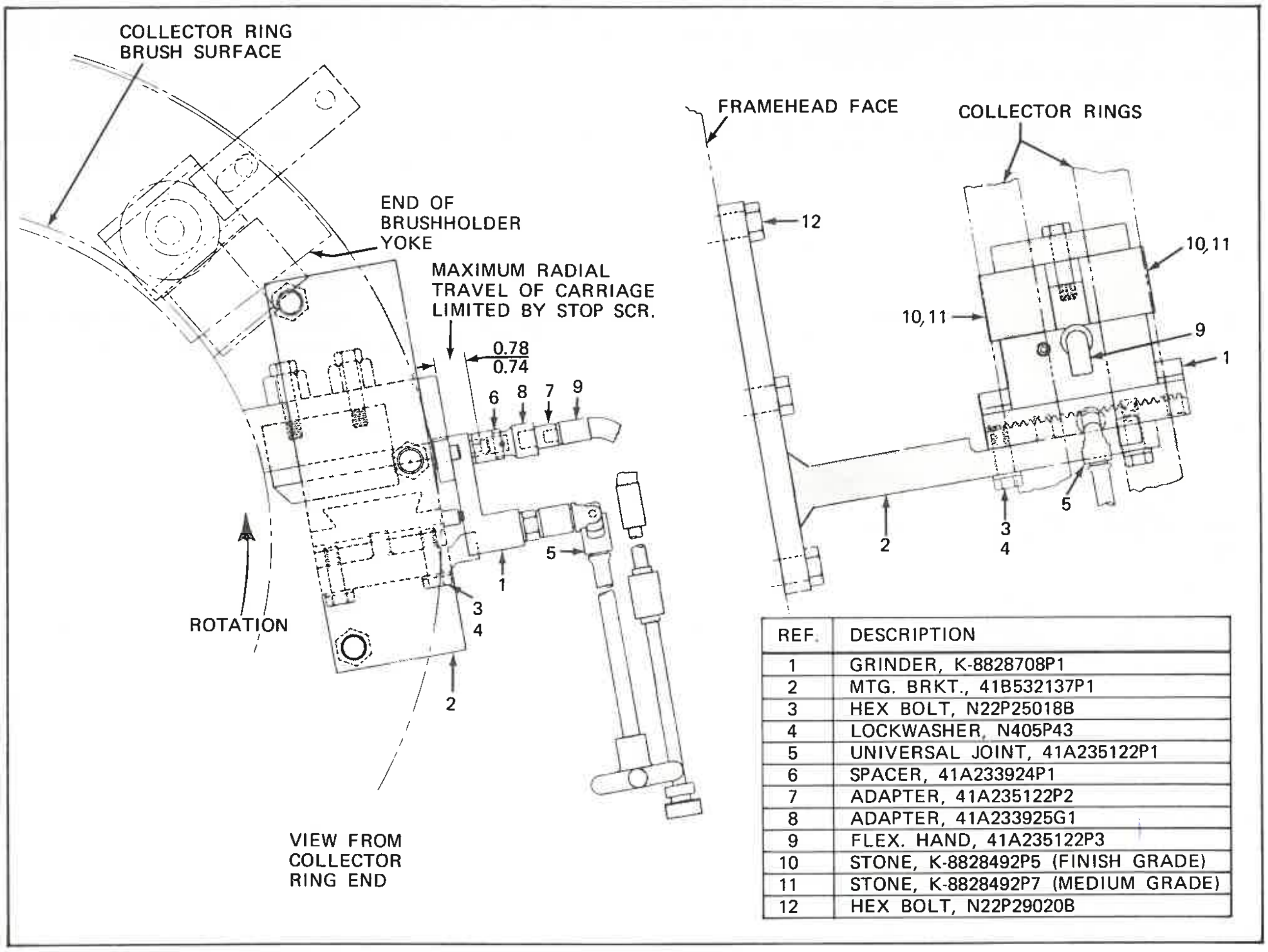
4. Attach the grinder (without stones installed) to the brushholder yoke in the No. 6 brushholder position by means of the No. 6 brushholder stud capscrew as shown in Fig. IV-7. The grinder mounting bracket is designed so that once it is attached to the yoke, no further alignment is required.

5. Adjust the radial-feed stop to prevent the grinder way from damaging the collector ring if the stone wears too short.

6. Install stone in right-hand (inboard) support and a dummy stone in left-hand (outboard) support. Clamp stone at the proper angle to permit full travel of the stone across the ring surface. If burning or grooving is severe, start with a medium-grade stone and change to a fine-grade stone for the finishing operation.

NOTE: *Grind only one ring at a time. Final ring diameters need not be the same.*

FIG. IV-5, E-13700



REF.	DESCRIPTION
1	GRINDER, K-8828708P1
2	MTG. BRKT., 41B532137P1
3	HEX BOLT, N22P25018B
4	LOCKWASHER, N405P43
5	UNIVERSAL JOINT, 41A235122P1
6	SPACER, 41A233924P1
7	ADAPTER, 41A235122P2
8	ADAPTER, 41A233925G1
9	FLEX. HAND, 41A235122P3
10	STONE, K-8828492P5 (FINISH GRADE)
11	STONE, K-8828492P7 (MEDIUM GRADE)
12	HEX BOLT, N22P29020B

FIG. IV-6. COLLECTOR RING GRINDER.

FIG. IV-6, E-14107

7. Start engine and run it at idle speed.

8. Feed the stone radially inward by means of the feed screw until the stone makes contact with the collector ring surface.

9. Traverse the stone back and forth across the ring surface by means of traverse knob. Alternately continue feeding the stone inward slowly as it wears, and traversing the ring.

10. Periodically shut down the engine to check progress of the grinding operation. Repeat Steps 7, 8 and 9 as many times as necessary to remove burned spots or grooving. Change to fine-grade stone for the finishing operation.

11. With the grinding operation completed and the engine shut down, remove the grinding fixture. Be careful not to nick or scratch the rings.

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

12. Restart the engine and, with alternator running at engine idle speed, blow out the alternator with dry compressed air. Direct the air so as to remove grinding dust from the stator windings and field coils.

13. Shut down the engine and reinstall brushholder studs in their original position.

CAUTION: *Failure to install brushholder studs in their correct position will result in short circuiting the collector rings when excitation is applied.*

14. Reinstall the bus rings and field leads.

IV

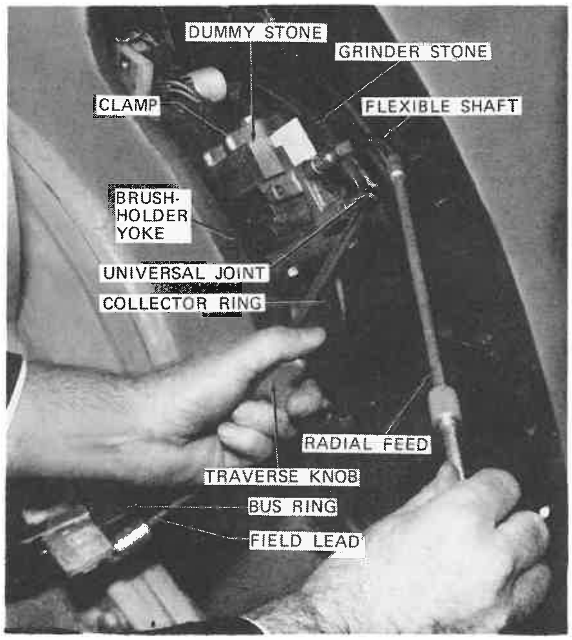


FIG. IV-7. SET-UP FOR GRINDING COLLECTOR RINGS.

15. Reinstall brushes removed for the resurfacing operation, or install new ones if necessary.

16. If brushes removed for the resurfacing operation are reused, sand them to remove metal which may have transferred from the collector ring to the brush contact surface. Use a strip of fine-grit sandpaper 2-in. wide by 24-in. long for this operation.

Installing New Brushes

CAUTION: *When installing new brushes use the GE recommended grade. Do not mix brush grades. Mixing brush grades in the same alternator or changing to another grade can seriously affect the collector-ring surface film and result in short brush life.*

Install new brushes as follows, see Fig. IV-4:

1. Insert brushes in the holder with the pigtail connection on the side farthest away from the pigtail terminal screws.

2. Position the pigtail terminal under the terminal screw so that the terminal is parallel to the brush pressure arm.

3. Tighten terminal screw and latch the brush pressure spring.

Seating New Brushes

Because new brushes are already contoured to the collector ring it is not necessary to seat them when they are first installed. Simply install them as described previously, and they are ready for operation.

Adjusting Brushholder Clearance

Maintain clearance between the brushholders and the collector rings at 3/32 to 1/8 in. If the clearance is not within this range, readjust the brushholders as follows:

1. Remove brush from the holder.

2. Loosen the capscrew located on the brushholder yoke.

3. Place a fiberboard shim of the proper thickness between the bottom of the brushholder and the collector ring.

4. Move the brushholder down against the fiberboard shim and tighten the brush stud capscrew.

5. Remove the fiberboard shim and replace brush in the holder. Make sure the pigtail terminal screw is tight and the pigtail is in the correct position shown in Fig. IV-3.

Reversing Brush Polarity

To increase life expectancy of the collector rings and brushes, periodically reverse the polarity of the brushes by interchanging the two exciter leads inside the alternator connection box or at the brushholder.

Because conditions which adversely affect collector ring and brush life vary so widely, brush polarity reversals should be made every six months until operating experience indicates that satisfactory wear rates can be obtained by reversing the polarity less frequently.

High-Potential Testing

It is customary to apply an annual ICC high-potential test to the complete locomotive power circuit which includes all traction motors, the traction alternator, auxiliaries, locomotive wiring and associated switching apparatus. For the procedure to be followed in making this test and the precautions to be taken to protect equipment and personnel, refer to the appropriate section in the overall locomotive maintenance manual.

FIG. IV-7, E-13701

AUXILIARY GENERATOR/EXCITER

DESCRIPTION

The Type GY27 Auxiliary Generator/Exciters are force-ventilated, shunt-wound, d-c machines. The GY27 located at the four o'clock position on the traction alternator, Fig. IV-8, is used as an auxiliary generator to supply regulated 75-vdc power to the control equipment, lights and to charge the battery. The GY27 at the eight o'clock position, is used as an exciter to control the field current of the traction alternator.

Both have cranking windings, and the two are used to start the diesel engine. The two models are the same except for the arrangement of the commutator covers for external ventilation connections.

Principal parts of the auxiliary generator/exciters are the armature assembly, commutator and pinion end bearings, brushholders, field coils, and magnet frame.

The auxiliary generator/exciters are mounted on the traction alternator gear box. A drive gear, mounted on the traction alternator shaft extension, meshes with a pinion gear on the auxiliary generator/exciter shaft to drive each auxiliary generator/exciter machine.

DATA

Type GY27
Rotation . . . . CW
Max. Speed (rpm) 2900
Full Speed (rpm) 2400

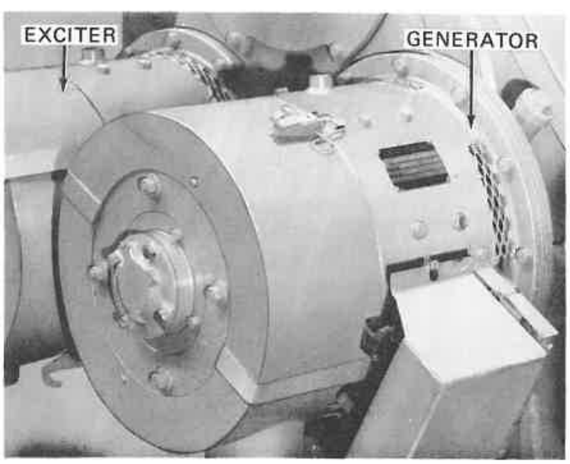


FIG. IV-8, E-25152

FIG. IV-8. TYPE GY27 MOUNTED ON TRACTION ALTERNATOR, TYPICAL.

Classification . . . . four-pole, commutating pole, force-ventilated, shunt-wound, d-c generator
Nominal Rating . . . . 12 kw, 75 v at 850 rpm
51 kw, 250 v at 2400 rpm

Resistances at 25 C (Ohms)
Armature 0.0229
Shunt Field 11.05
Commutating Field 0.00872
Starting Field 0.00665

Brush Data
Grade GE-T-583
Type . . . . Duplex with Rubber Pad
Pressure (oz.) . . . . 43 to 53
Size (in.) . . . . 0.50 x 1 x 2
Minimum Length (length at which brush becomes inoperative) (in.) 1
Brushholder Clearance to Commutator (in.) . . . . 0.06 to 0.10

Pole Bores (Average)
Exciting Poles (in.) 9.844
Commutating Poles (in.) 10.098

Commutator Data
Type . . . . Arch-Bound
Side Mica – Thickness (Nominal) (in.) 0.022
– Grooving Depth (in.) 0.047
Saw Width (in.) 0.024
Diameter – New (in.) 8.00
– Minimum Permissible (in.) 7.50

Grease Capacity of Bearing
Commutator End (oz.) 3-1/8
Type Lubricant GE-D6A2C4
Pinion End . . . . . . No grease required (splash lubricated)
Weight (lb.) 695

WARNING: *Electric shock can cause serious or fatal injury. To avoid such injury, personnel should take and observe proper precautions during high-potential testing.*

SPECIAL TOOLS AND EQUIPMENT

The following items are required to maintain, repair and overhaul the auxiliary generator/exciter.

	GE Part No.
Commutator Grinder	8843613G3
Resurfacing Stones	8828492P4

LUBRICATION

The pinion-end bearing is lubricated by oil splashed in the traction-alternator gear box. Maintain the oil level in the gear box between the HIGH and ADD marks on the dipstick.

IV

Periodically repack the CE bearing as follows:

1. Remove the bearing cap and examine the old grease for evidence of steel chips. This would indicate bearing damage.

2. Repack the bearing cap with approximately 2 oz. of D6A2C4 grease.

3. Replace the bearing cap.

INSPECTION

IV

1. Inspect brushes to be sure they are not worn near the minimum length, chipped or broken. Replace worn or damaged brushes. Also replace others in same brushholders since longer brushes are probably defective (did not share load equally).

CAUTION: *When replacing brushes, use the GE recommended grade. Mixing of brush grades in the same machine or changing brushes to another grade is not recommended as this will seriously affect commutation, surface film, commutator and brush life.*

2. Inspect brushholders for damage from burning or arcing. Check for damaged pressure springs or levers; replace parts as necessary.

3. Inspect the condition of the commutator. Be sure it has a smooth, polished surface. Clean and resurface when necessary. See section on Commutator Resurfacing.

4. Inspect all leads and connections. Be sure the connections are tight.

5. Measure the insulation resistance of the armature and field coils with a megohmmeter.

COMMUTATOR RESURFACING

When the commutator becomes worn, grooved, or burned, it may be resurfaced with a commutator grinder without removing the machine from the locomotive or the armature from the machine. Rotate the armature in its own bearings.

Resurfacing of a commutator is done with commutator grinder assembly, Part 8843613G3 and stones listed in Special Tools and Equipment section.

Resurfacing On Locomotive

WARNING: *An environment potentially hazardous to personnel in the immediate area is created when resurfacing. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

1. Remove any oil and dirt from the exposed insulation surfaces around the commutator, using an approved method.

2. Remove the four o'clock brushholder assembly and the A1 connection strap on the generator, Fig. IV-8, or the two o'clock brushholder assembly on the exciter. Lift all the other brushes on the machine being resurfaced.

3. Install the commutator grinder in the auxiliary generator/exciter as follows, Fig. IV-9:

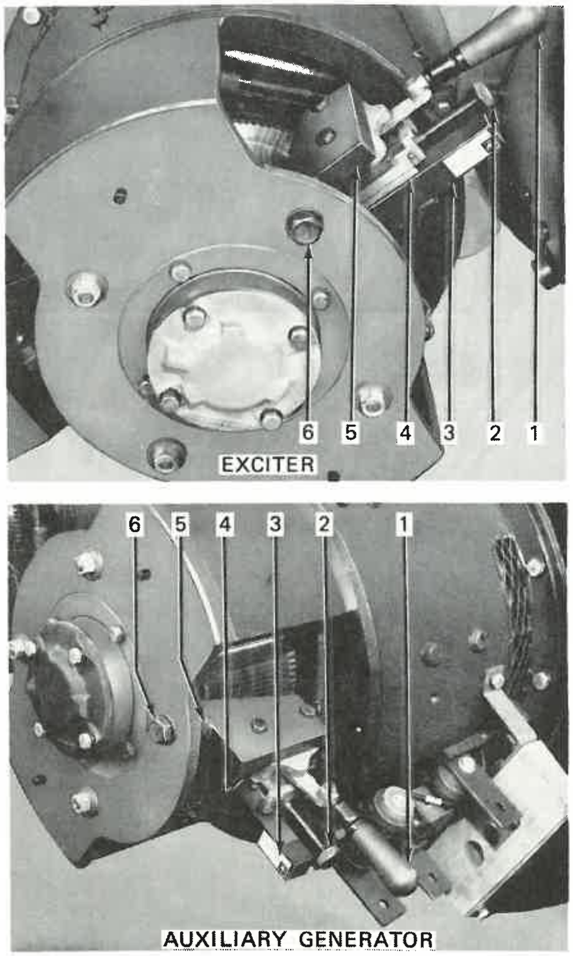
   a. Assemble the grinder to the mounting bracket with two 3/8-16 by 1-3/8 in. hex bolts and lockwashers.

   b. Bolt this assembly in the machine where the brushholder was removed. The key on the end of the bracket fits into the keyway on the end of the frame. Then insert the 5/8-11 by 1-1/2 in. hex bolt through the frame (with the flat washer under the head), screw the hex bolt into the hole in the bracket and tighten.

   c. Install two resurfacing stones on the grinder. Space them far enough apart to cover the entire width of the commutator surface when the carriage is moved from side to side. For small commutators, use only finish-grade stones.

   d. Adjust the holder on the bracket so each stone travels parallel to the surface of the commutator. To adjust, slightly loosen the two 3/8-16 hex bolts. Check by inserting a feeler gage between the surface of the commutator and each stone at each end of their travel along the commutator. This check should be made at unworn sections of the commutator and at both ends or between the brush paths. After adjustment, back the stones away from the commutator and tighten the two mounting bolts.

4. Place the locomotive Reverse handle in the OFF position. Have the Generator Field Breaker in the OPEN position so no current will pass through the machine being resurfaced. The engine can be started by cranking with one machine only.



REF.	DESCRIPTION
1	TRAVERSING HANDLE
2	FEED HANDLE
3	RESURFACING STONES
4	GRINDER
5	BRACKET
6	5/8-11 CAPSCREW WITH WASHER

FIG. IV-9. COMMUTATOR GRINDER INSTALLED IN GY27 MACHINES.

FIG. IV-9, E-25153

5. Start the engine and let it run at IDLE until it runs smoothly. This operation may be performed immediately after a locomotive returns from a run, while the engine is still warm.

6. Advance the stones to take a light cut across the commutator surface and to check alignment before proceeding with the operation. Stones should cut approximately the same amount at the front and the riser ends of the commutator where the brush paths are not worn in the surface. If the amount of the cut is not the same, readjust the grinder until the cut is approximately even at both ends of the commutator.

7. Traverse the grinder and advance the stones until the commutator is clean. Begin with light pressure and increase it no more than necessary. Do not take too deep a cut, for this will result in an excessive amount of copper being dragged over the edges of the commutator bars. If possible, use a vacuum-cleaning device to collect the copper and abrasive dust during the grinding operation.

8. Make a light finishing cut. Then, without changing the feed, traverse the commutator several times to obtain a good, smooth finish.

9. Shut down the engine and remove the grinder from the auxiliary machine.

10. Using an engraving tool, remove any ragged edges from the commutator bars and fins of copper which have dragged over the slots.

11. If necessary, undercut the slot mica between the segments with a 0.024 in. thick saw.

12. Clean the commutator slots to remove mica and grinding dust with a stiff nylon bristle brush. A new paint brush or stencil brush with bristles cut short for added stiffness is satisfactory.

> **WARNING:** *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

13. Start the engine and run it at IDLE. Thoroughly blow the commutator and interior of the machine with dry, compressed air to remove all copper filings and dust. Polish the commutator with fine sandpaper.

14. Shut down the engine and measure the commutator runout with a dial indicator mounted on the frame. The indicator should have a sensitivity of 50 divisions, 0.001 in. or smaller, for one revolution of the pointer. Maximum allowable runout after stoning is 0.001 in.

15. Replace the brushholder assembly that was removed and the A1 connection strap, if it was removed. Replace brushes, as necessary, with the GE recommended grade.

TRACTION MOTOR

DESCRIPTION

The Type GE752 Traction Motor, Fig. IV-10, is a four-pole, commutating-pole, series-wound d-c motor designed for locomotive propulsion. Its normal function is to convert the electrical energy supplied by the traction generator into mechanical power for driving the locomotive wheels.

The traction motor is coupled to the locomotive axle through a reduction gear system housed in a gear case. The gear case is attached to the traction motor and surrounds a pinion and gear. The gear case excludes dirt and moisture and holds the necessary gear lubricant.

Locomotives equipped with dynamic braking use the traction motors as generators to retard the rate of travel when descending grades or slowing down the train.

DATA

Type GE752
Maximum Permissible Speed 2445
Resistances at 25 C (Average) (Ohms)
Armature 0.01002
Exciting Field 0.00555
Commutating Field 0.00592
Brush Data
Pressure (lb.) 10-12
Size (Duplex) (in.) . . . . 3/4 by 2-1/4 by 2 long
Minimum Lenght (length at which brush
  becomes inoperative) (in.) 1-3/32
Brushholder Clearance to Commutator 1/16-3/32
Commutator
Side Mica – Thickness (in.) 0.060
  – Grooving Depth (in.) 3/64-5/64
Diameter – New Commutator (in.) 16-5/8
  – Minimum Permissible (in.) 15-3/8
Riser – Width Minimum Permissible (in.) 5/8
Pole Bores (Nominal – measured at center of poles)
Exciting Poles (in.) 19.640
Commutating Poles (in.) 19.970
Bearings (Assembled)
Diametrical Clearance
  Armature Bearings
    Commutator End (in.) 0.0017-0.0057
    Pinion End (in.) 0.0025-0.008
  Axle Bearings
    Minimum New (in.) 0.014
    Maximum Worn (in.) 0.060

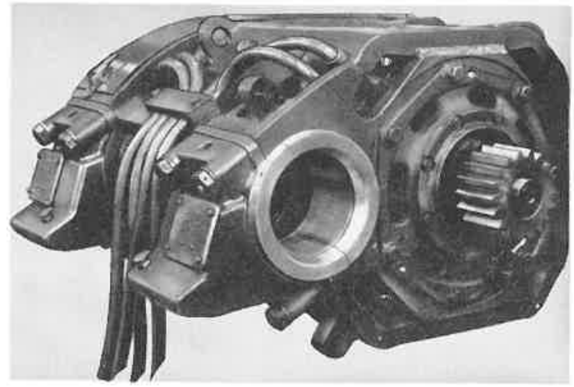


FIG. IV-10, E-9288

FIG. IV-10. TRACTION MOTOR.

End-Play
  Armature Bearings – New (in.) 0.005-0.014
  Axle Bearings
    New Linings (in.) 1/16
    Worn Linings (1/8 in. max. wear
      per lining flange) (in.) 5/16

Impedance of Field Circuits

	Amps	Volts Max.	Volts Min.
Measure before assembly of armature: 60 cycles a-c to hot field coils only			
Exciting Field	24	14.8	13.7
Commutating Field	24	9.6	8.3
Measure with brushes lifted and armature assembled: 60 cycles a-c			
Exciting Field	24	17.6	15.6
Commutating Field	24	12.7	11.0

Weights
Motor with Pinion (lb.) 7000
Armature (lb.) 2170

INSPECTION

1. Inspect the commutator and wipe off the string band. The commutator surface must be free of copper beads and have a smooth, polished surface. Clean and resurface the commutator when necessary.

2. The brushholder mechanisms must operate properly. Shunts and terminals must be tight and insulators clean.

3. Inspect the brushes for physical appearance and amount of wear. Replace any which are chipped, broken or worn near the minimum length of 1-3/32 in.

   Brushes must move freely in their holders and be free of dirt, carbon dust or other foreign material.

CAUTION: *When replacing brushes, use the GE recommended grade. Mixing of brush grades in the same machine, or changing brushes to another grade, could seriously affect commutation, surface film and brush life.*

4. Check and adjust the spring pressure. Inspect the clearance between the bottom of the brushholder and the commutator support. See Data section.

5. Examine the armature and field coils for cracked, charred or broken insulation. See that field coil connections are tight.

6. Examine the flash ring for damage. Keep the flash ring clean and free of paint or insulation.

7. Measure the insulation resistance with a megohmmeter. If a reading of less than one megohm is indicated, a further inspection to determine insulation failure or excessive moisture should be made. Correct the cause of low megohmmeter readings before placing a motor back in service.

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

8. Blow out the motor thoroughly, in both directions, with dry compressed air.

9. Clean the string band and paint it with insulating varnish A15B17A if needed.

CAUTION: *Do not apply insulating varnish over dirt. Dirt or other contaminants will provide a current leakage path under, as well as over, varnish.*

10. Measure end-play of the motor on the axle and diametrical clearance of the axle linings. See Data section for permissible limits of wear. Measure as follows:

a. To measure the end-play, move the motor toward the gear by barring between the nose suspension and truck bolster. Measure the end-play (lateral clearance) through the drain hole in the axle-flange dust guard located at the commutator end. Use feeler or go-no-go gage as shown in Fig. IV-11. If gear lubricant has frozen the pinion to the gear so the motor cannot be barred sidewise, add clearance at each end of the motor to get the total lateral clearance. Clearance at the pinion end can be measured between the gear hub and the axle-lining flange by inserting a feeler through the drain hole in the gear-case seal.

b. Another method of measuring end-play is to clamp an indicator to the commutator end of the axle cap so that the pointer rests against the wheel, Fig. IV-12. Force the motor as far as it will go one way along the axle. Set the indicator at zero. Force the motor in the other direction as far as it will go and read the lateral clearance or end-play. When this clearance equals or exceeds the permissible amount, install new linings. See Fig. IV-13 for a method of measuring diametrical clearance of axle linings.

IV

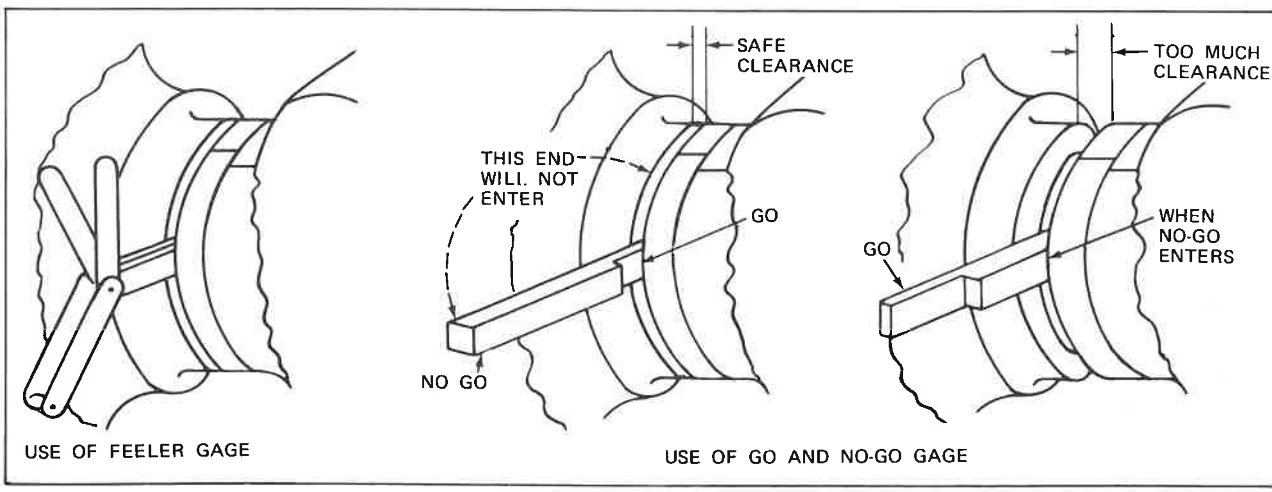


FIG. IV-11. MEASURING END-PLAY.

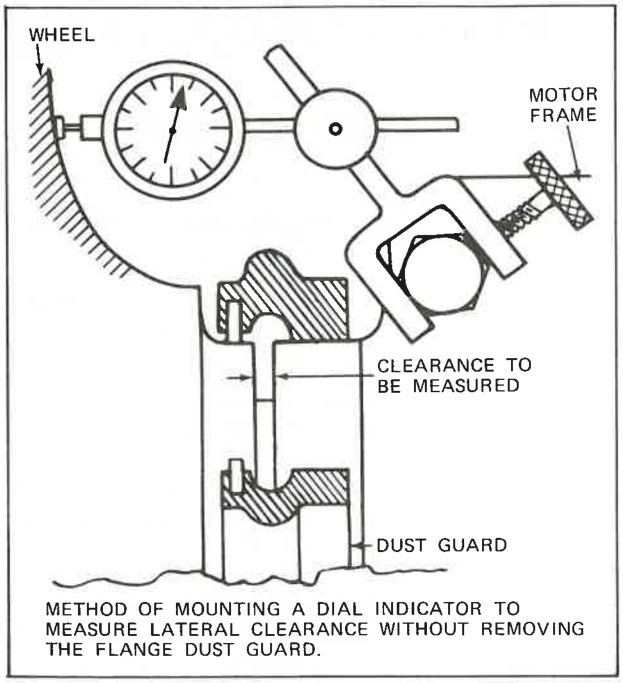


FIG. IV-12. USING DIAL INDICATOR TO MEASURE END-PLAY.

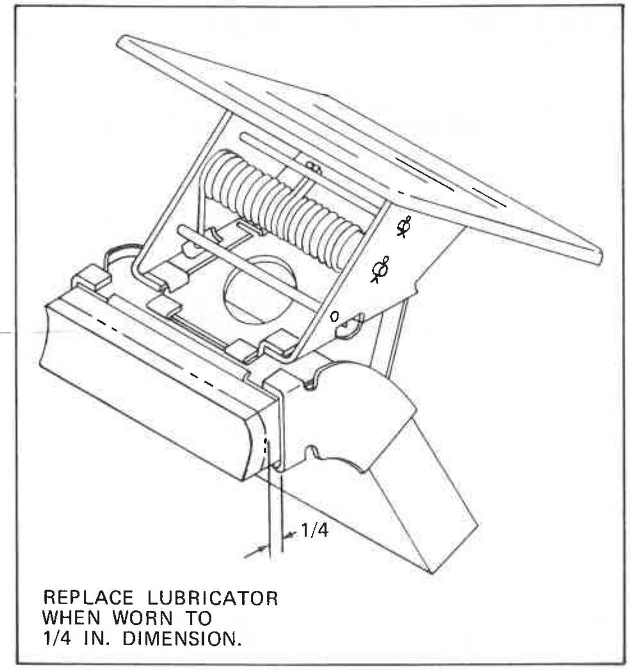


FIG. IV-14. CONDEMNING LIMIT FOR FELT WICK LUBRICATOR.

11. Remove the felt-wick lubricators and examine them for the following defects:

    a. Wear in excess of 1/4 in., Fig. IV-14.

    b. Burned or hardened wick surface which is no longer absorbant.

    c. Damaged wick or wick holder.

LUBRICATION

Armature Bearings

Roller bearings are packed at the time of motor assembly with ball-bearing grease GE Spec. D6A2C4. No access is provided for the addition of grease during the operation of the motor between overhaul periods.

Axle Bearings

The motor is equipped with large oil capacity axle caps having felt-wick lubricators to conduct the oil to the axle and bearing.

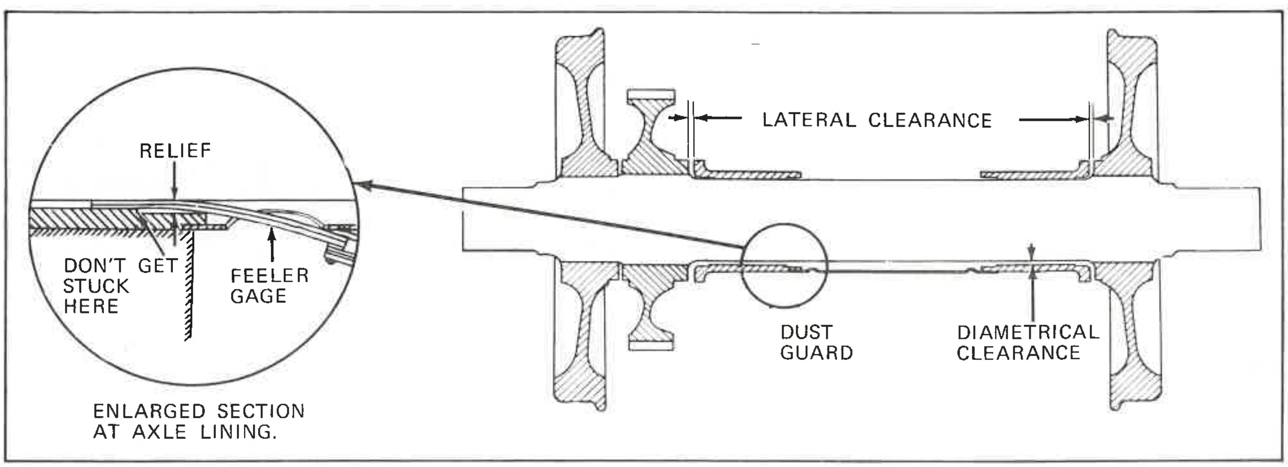


FIG. IV-13. MEASURING DIAMETRICAL CLEARANCE OF LININGS.

FIG. IV-12, E-6026
FIG. IV-13, E-6027A
FIG. IV-14, E-8502A

Where the presence of water, dirt or other contaminants is suspected, examination of the oil is recommended. This can be done readily by drawing out a sample from the bottom of the oil well with a piece of glass tubing. If contaminated, change the oil. Use AAR Spec. M-906-56 oil to maintain the level to the bottom of the filler cap opening.

Gearing

The spur gearing is lubricated with a heavy gear compound GE Spec. D50E8C contained in the gear case.

CAUTION: *Never permit the gears to run dry. The result will be extreme wear of gear and pinion teeth.*

CAUTION: *Do not overfill the gear case. Doing so may cause the gear compound to enter the armature bearing and cause bearing failure.*

REPLACING AXLE LININGS ON THE LOCOMOTIVE

To replace axle linings without removing the motor from the truck, place the truck over a pit, drain oil from axle caps, remove the flange dust guard, axle caps and the axle dust guard. Replace as follows:

1. Use a pinch bar to force the motor towards the commutator end so clearance will be maintained for easy removal of pinion-end lining.

2. Remove the three gear-case mounting bolts.

3. Loosen the bolts that hold the two sections of the gear case together and allow the bottom half to drop about 1 in.

4. Insert two 3/4-in. pieces of wood between the gear-case halves (one piece at each end) to hold them apart.

5. Lift the motor weight off the axle by supporting the axle side of motor with jacks. To free the inner axle lining, force the motor away from axle by using a jimmy bar.

6. Rest a pinch bar against the inner flange of the wheel and apply enough leverage against the gear case to raise it free from the axle lining. Then, roll the axle lining out.

7. Remove the inner lining by rotating it away from the key around top of the axle. Check journals for roughness. Install new lining by rotating inner half into position over the top of the axle.

8. Install outer half of new lining in position and reassemble the axle cap after giving it a thorough cleaning.

NOTE: *Axle caps are machined with the magnet frame and are not interchangeable with other motors. Each cap is stamped with the serial number of the frame with which it was originally machined. The axle cap must always be assembled to the motor frame having a corresponding serial number.*

   Never use shims between faces of magnet frame and axle caps. This will destroy the clamping effect and result in loose linings. Axle linings, when correctly assembled, are tightly clamped between the magnet frame and axle caps to prevent movement and wear on the outside diameter of the linings. Axle cap bolts are drawn down until the face of the cap and the face of the magnet frame are a tight fit.

9. Tighten axle cap bolts at 800 lb.-ft. torque. Lubricate axle cap bolts with white lead and oil before tightening. Lock the bolts with wire through bolt heads. Replace the dust guards and fill the caps with four qt. of AAR Spec. M-906-56 car oil. Replace the gear case and add 12 lb. of GE Spec. D50E8C lubricant.

RESURFACING COMMUTATOR IN THE LOCOMOTIVE

Locomotive Preparation

1. Place the locomotive over a pit.
   a. Cut out the air brakes on the truck requiring motor maintenance.
   b. Block wheels on the axles not being worked on so the locomotive cannot move.
   c. Set the air brakes on the other locomotive trucks.

2. Axles equipped with roller journal bearings may be raised by placing a wooden block between the pedestal tie bars and the journal boxes of the axle to be rotated. The block should be thick enough to fill all the space. Jack up the end of the truck until the wheels clear the rails.

3. Raise all the brushes except the two, located 180 degrees apart which will be used to run the traction motor.

4. If the diesel engine is to be run, insert a baffle in the motor air duct so dust will not be blown about.

IV

WARNING: *An environment potentially hazardous to personnel in the immediate area is created when resurfacing. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

IV

5. Install commutator grinder, Part 8837582G1, in the bottom commutator opening located on the suspension side. This is the safest place and will allow most of the grinding dust to fall out. See Fig. IV-15. The grinder assembly consists of a "Midget" grinder, K-8828708G1 (Part 100X371), mounting bracket, Part 8843149P6, resurfacing stones, Part 8824492P8, and various capscrews and set screws as indicated on Fig. IV-16. Install the grinder as follows:

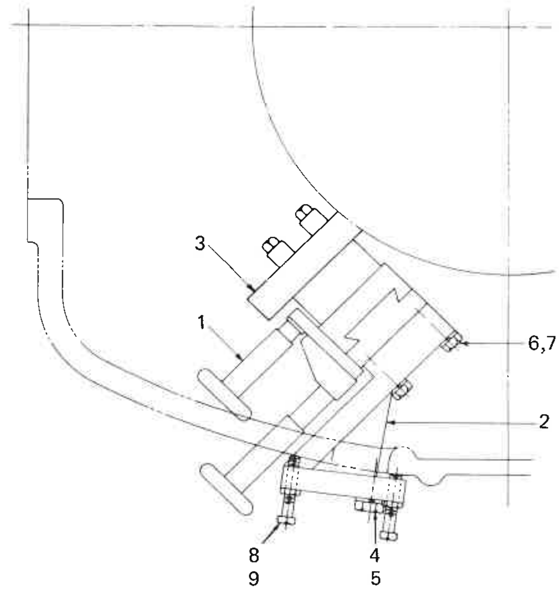
   a. Bolt the grinder to mounting bracket with four capscrews (6), Fig. IV-16.

   b. Remove the cover from the bottom inspection hole on the suspension side.

   c. Install the grinder in the motor by bolting it into the cover bolt holes. Use two capscrews and lockwashers (4 and 5) provided with the fixture. The base of the mounting bracket will be on the outside of the frame.

   d. Place the two jam nuts (9) on the set screws (8) and screw them into the tapped holes in corners of the base of the mounting bracket. These adjust the position of the grinder with respect to the commutator.

   e. Install medium-grade resurfacing stones in the grinder, Fig. IV-15.



REF.	DESCRIPTION
1	COMMUTATOR GRINDER
2	MOUNTING BRACKET
3	RESURFACING STONE
4	CAPSCREW
5	LOCKWASHER
6	CAPSCREW
7	LOCKWASHER
8	SET SCREW
9	JAM NUT

FIG. IV-16. COMMUTATOR GRINDER PART 8837582G1.

FIG. IV-16, E-5981

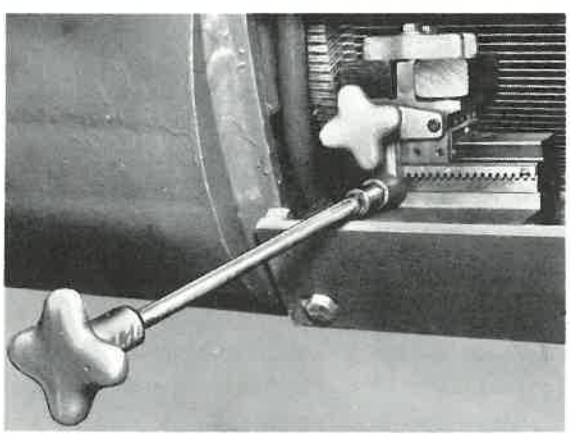


FIG. IV-15. MIDGET COMMUTATOR GRINDER INSTALLED IN GE752 MOTOR.

FIG. IV-15, E-10677

   f. After the stones are installed, traverse the grinder to one end of the commutator and check clearance between the commutator surface and one stone with a feeler gage. Traverse the grinder to the other end of the commutator and check the clearance under the same stone. The clearance should be the same at both ends. If the clearance is different, adjust the mounting bracket by means of the set screws (8) until the clearances are the same at both ends. When clearances are the same, tighten the jam nuts (9) on the set screws to maintain adjustment while grinding.

   g. Turn the feed control to back the stones away from the commutator while the motor is being started.

6. Connect the motor to a source of controlled power to drive it at a speed of 1000 to 1500 rpm. This power can be obtained from an outside source of power or from the locomotive power plant.

FIG. IV-17, E-671A

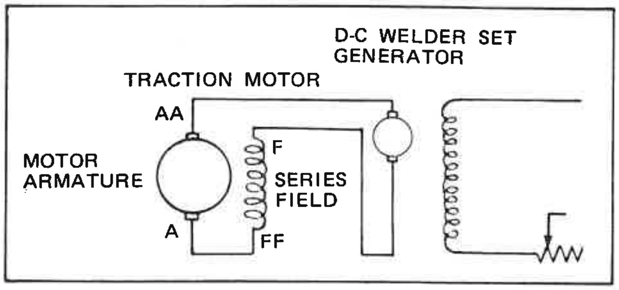


FIG. IV-17. DIAGRAM OF CONNECTIONS TO RUN TRACTION MOTOR FROM WELDING SET.

a. Disconnect the motor leads from the locomotive wiring and connect motor as a series motor to an outside source of power such as a 3 to 5 kw at 100 v welding set if an outside power supply is to be used. See Fig. IV-17.

b. The motor can also be run from the diesel-electric locomotive power plant. With all wheels blocked except those connected with the motor to be worked on, the motor can be run for stoning the commutator without disturbing locomotive connections by placing the Throttle handle in the first operating position. Current required to run the motor is so low no damage will result to the blocked stationary motors through which current will flow.

> **WARNING:** *To protect personnel from physical harm, following safety precautions must be adhered to:*
>
> *Block the locomotive wheels to protect the locomotive from moving during the grinding operation. Make blocking positively secure.*
>
> *A second person must be at the power control station ready to shut-off power in case of an emergency during the grinding operation.*
>
> *The grinding operator should wear goggles and a dust mask when grinding or blowing out the commutator.*

7. Apply power to the traction motor and gradually bring the speed up to 1000 to 1500 rpm.

8. Move the fixture back and forth along the commutator while slowly advancing the stones toward the commutator surface. Use extreme caution in advancing the stones to obtain a fine cut and to avoid chatter.

NOTE: *Use the medium stones for the rough cuts. For finishing, use fine stones and run the motor in the opposite direction.*

9. Grind the commutator until a uniformly smooth surface is obtained and all flat spots have been removed. Do not remove more copper than necessary.

10. After the final cut, traverse the stones back and forth longitudinally without changing the feed until there is no more cutting action.

11. Remove power from the motor and remove the grinding fixture.

12. Scrape the slots between the bars to remove projecting mica fins or copper whiskers.

> **WARNING:** *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

13. Run the motor again at 1000 rpm and polish the commutator with 00, or finer, sandpaper. Blow dust from the commutator and interior of the motor with dry compressed air. Hold the end of the hose about one or two inches from the commutator surface and sweep longitudinally to blow away copper chips and loose mica.

14. Remove power and make the necessary mechanical and electrical changes to place the motor back in service on the locomotive.

15. Install new brushes.

NOTE: *Do not grind the commutator to a depth where the mica undercut has been removed.*

COMMUTATOR MAINTENANCE

DESCRIPTION

The commutator, Fig. IV-18, is a vital part of every d-c motor and generator; therefore, it deserves the very best care. The fact that a commutator usually shows signs of distress before trouble actually occurs, is a big help to the maintainer. If you can recognize these signs and know what to do, you can often correct the trouble before it becomes serious.

A commutator has three functions:

1. It provides the required sliding electric contact between the fixed brushes and the moving armature to remove or apply electrical energy to the machine.

IV

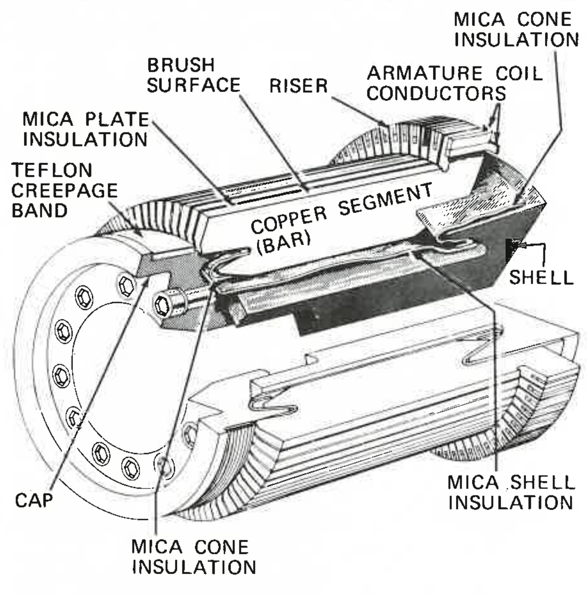


FIG. IV-18. CUTAWAY SECTION OF THE COMMUTATOR.

2. It acts as a reversing switch. As the ends of the armature coils pass the brush positions, the commutator switches them from one circuit to another where the current is flowing in the opposite direction. Thus all the coils have current flowing through them in the proper direction at all times.

3. It also brings the voltage of each armature coil in the circuit to the brush surface. These voltages add up bar by bar between brushes. As a result, the total operating voltage of the machine appears at the brushes.

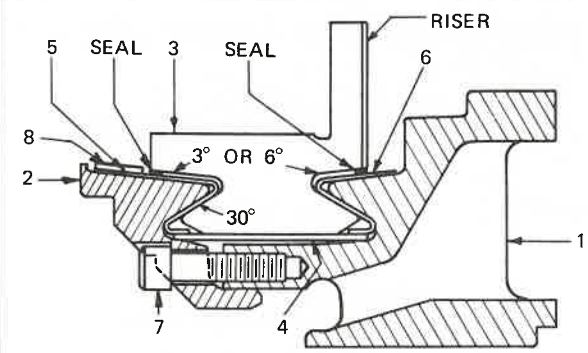
CONSTRUCTION

A commutator, Fig. IV-18, is formed of alternate copper segments and mica plates. Copper segments are often called bars so hereafter, in this publication, we will use the term bar instead of segment.

The mica plates physically separate and electrically insulate the bars and provide arch pressure essential to commutator stability. The plates are undercut below the commutator surface to prevent interference with the sliding action of the brushes on the surface of the commutator.

The bars are wedge shaped and form a cylinder when assembled. Each bar has a riser at one end to make armature coil connections.

The bars are held in position by the clamping action of a steel cap bolted to a steel shell, Fig. IV-19.



REF.	DESCRIPTION
1	COMMUTATOR SHELL
2	COMMUTATOR CAP
3	COMMUTATOR SEGMENT
4	SHELL INSULATION
5	CONE INSULATION
6	CONE INSULATION
7	CAPSCREW, HEX SOCKET
8	CREEPAGE BAND

FIG. IV-19. ARCH-BOUND COMMUTATOR ASSEMBLY.

Mica cones, contoured to fit between the shell and cap, insulate the bars from ground (armature).

A Teflon* creepage band, applied on the exposed cone insulation, protects the mica from damage and presents a smooth creepage surface that is easy to keep clean.

SURFACE CONDITIONS

A commutator cannot work properly unless the brushes make good electrical contact. This requires a smooth, polished, cylindrical surface that runs true with its center.

Surface Film

The successful operation of all d-c machines depends on maintaining a proper film on the surface of the commutator, Fig. IV-20. This film of carbon, graphite, copper oxide and water vapor is deposited on the commutator surface by electrochemical action. It is formed by the wiping action of the brush against the commutator and by the normal current flow between the brush and the commutator.

The importance of maintaining a proper commutator surface film cannot be overemphasized. With this film established and properly maintained, good brush performance (reduced brush and commutator wear) and satisfactory commutation (no destructive sparking) is assured. Changes in color from copper to deep brown or chocolate should give no cause for worry, as long as the surface is smooth and has a polished glossy appearance.

*E.I. du Pont de Nemours and Co., Inc.

FIG. IV-18, E-5018

FIG. IV-19, E-3059B

FIG. IV-20, E-8761A

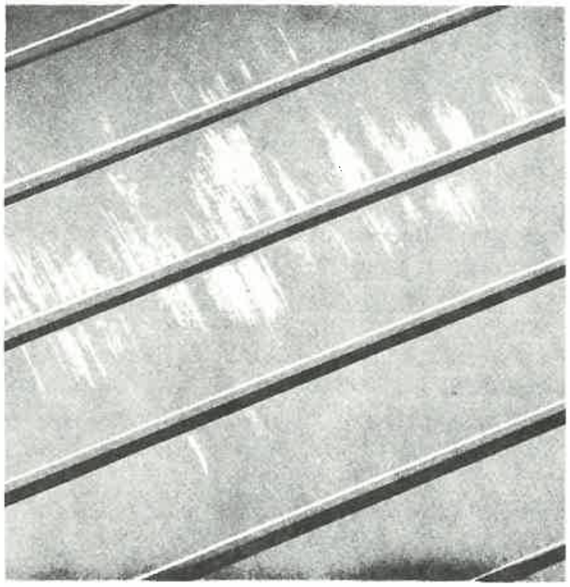


FIG. IV-20. GOOD COMMUTATOR FILM OF UNIFORM COLOR.

FIG. IV-21, E-8762A

FIG. IV-22, E-8763

Color Pattern

This term indicates only that the color of the commutator bars is not uniform and a definite pattern exists. The pattern is almost always related to the arrangement of coils in the armature slots. In itself, this condition is not a sign of damage. The color pattern may show up in several sequences, Figs. IV-21 and IV-22. As long as there is a definite pattern around the whole commutator, do not be concerned.

A check for surface damage should be made at scheduled commutator inspection periods. If no damage exists, no further action is required.

Marking, Etching and Flat Spots

The following conditions indicate discoloration and/or etching of commutator bars – but in varying degrees. Possible causes of etching and discoloration include:

1. Excessive load on the machine
2. Electrical adjustment off; such as, wrong shims behind commutating poles or wrong interpole gap
3. Wrong brush grade
4. Uneven or rough commutator surface
5. Contaminated atmosphere

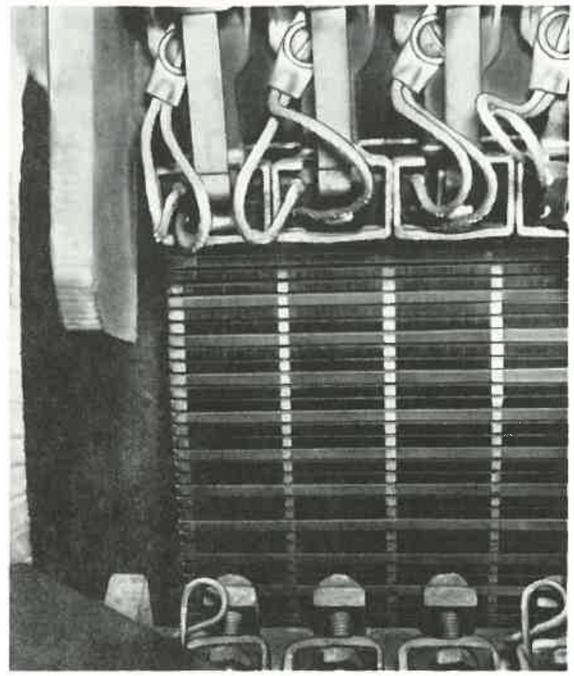


FIG. IV-21. ONE LIGHT — TWO DARK, THREE-COIL PER SLOT COLOR PATTERN.

6. Incorrect brush spacing
7. Incorrect brush shift.

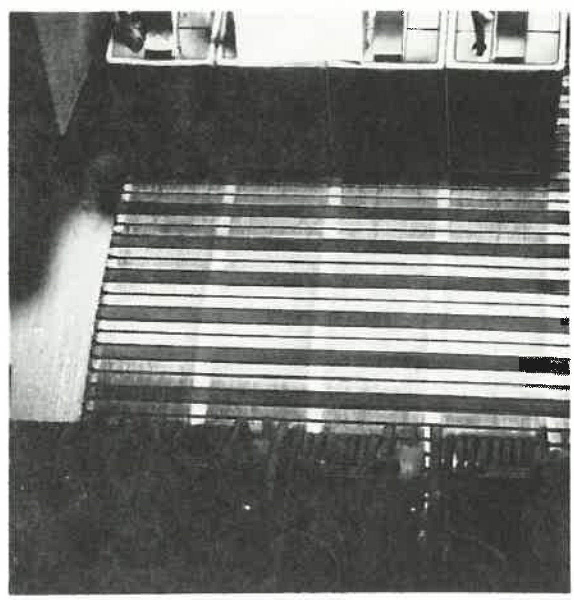


FIG. IV-22. ONE DARK — TWO LIGHT, THREE-COIL PER SLOT COLOR PATTERN.

IV

The best way to overcome these conditions is to determine the cause and make the necessary corrections. If damage has not progressed too far, it may clear itself once the cause has been eliminated. If it is determined that some resurfacing of the commutator is necessary, it should be done sparingly.

Marking

This condition appears as an opaque darkened surface or black deposit on the bars, usually at their trailing edge, with no etching or corrosion of copper underneath.

Check for this condition quickly by using a common pencil eraser to remove the deposit; then examine the copper surface for roughness or pitting. If none is seen, the condition is marking, which can readily be removed with a canvas cloth. See Fig. IV-23.

Bar Surface Etching

This condition gives the appearance of severe marking and a pencil eraser uncovers pitting, eroded or burned bar surfaces. Such a condition results from arcing between the brush and the copper commutator bars and the etching is usually visible with the naked eye when the marking is removed. See Figs. IV-24 and IV-25.

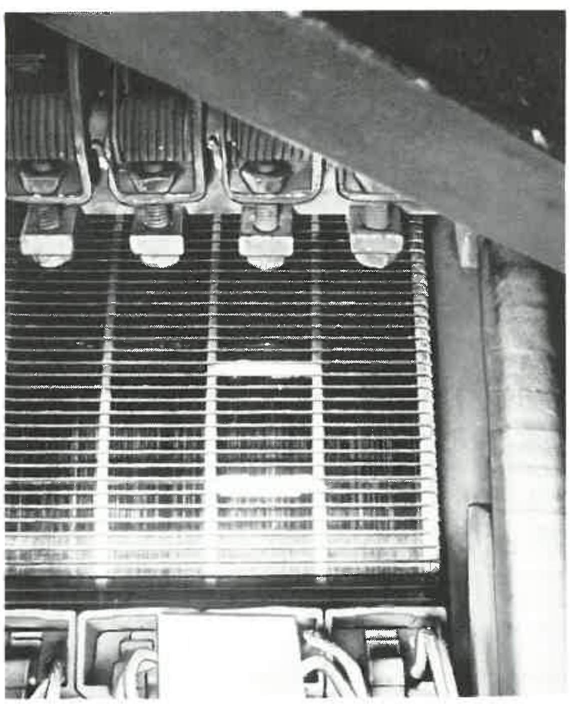


FIG. IV-23. COMMUTATOR FILM REMOVED WITH A PENCIL ERASER TO SHOW A SMOOTH COPPER SURFACE UNDERNEATH.

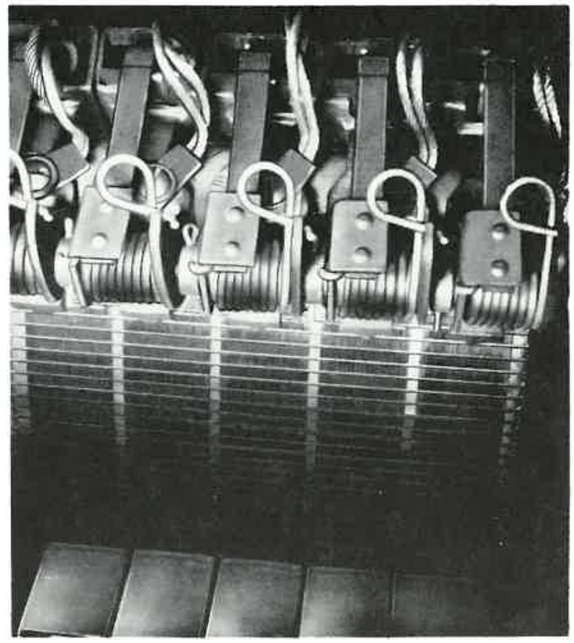


FIG. IV-24. HEAVY ETCHING ON A TWO-COIL PER SLOT COMMUTATOR.

Bar Corner Etching

When this condition prevails, the corner of the bar is eroded leaving a chamfered corner but little or no evidence of marking or bar surface etching.

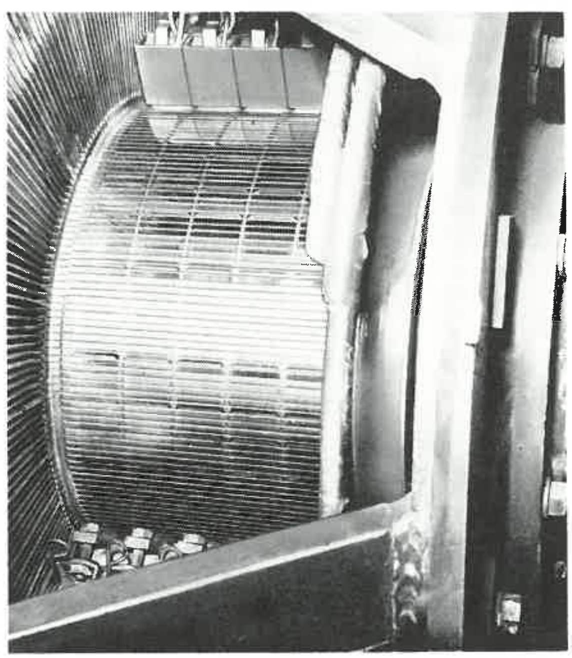


FIG. IV-25. IRREGULAR FILM AND ETCHING CAUSED BY A ROUGH COMMUTATOR.

FIG. IV-23, E-8764

FIG. IV-24, E-8765A

FIG. IV-25, E-8766

FIG. IV-26, E-8767

FIG. IV-27, E-8768A

FIG. IV-28, E-5023

Bar corner etching may be best seen by holding a light source at an angle which will reflect light from a chamfered corner to the eye.

Flat Spots

If etching is not corrected and progresses too far, flat spots will develop. Flat spots may also develop from a mechanical disturbance, such as the vibration from a defective bearing. As a rule, however, flat spots result from failure to correct some faulty condition which is first indicated by burned bars. See Fig. IV-26.

Threading

Threading is a commutator surface condition that shows as circumferential grooves on the commutator. Threading is the result of abrasive or electro-chemical action of the brushes.

In light threading, grooves may be just barely apparent where the surface film or color is disturbed or different. In heavy threading, a rippled surface can be felt if you rub a fingernail along the surface of a bar. See Figs. IV-27 and IV-28.

The brush faces wear to fit these grooves. When the commutator shifts due to armature end-play, the brushes are lifted out of the grooves. Then contact between the brush and the commutator is disturbed, sparking occurs and commutation is disrupted.

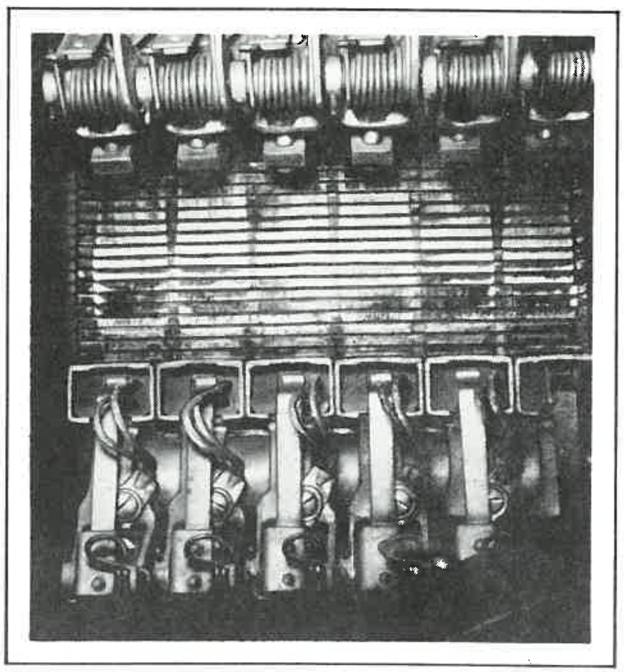


FIG. IV-26. FLAT SPOT ON A COMMUTATOR THAT ALSO SHOWS FLASHOVER DAMAGE.

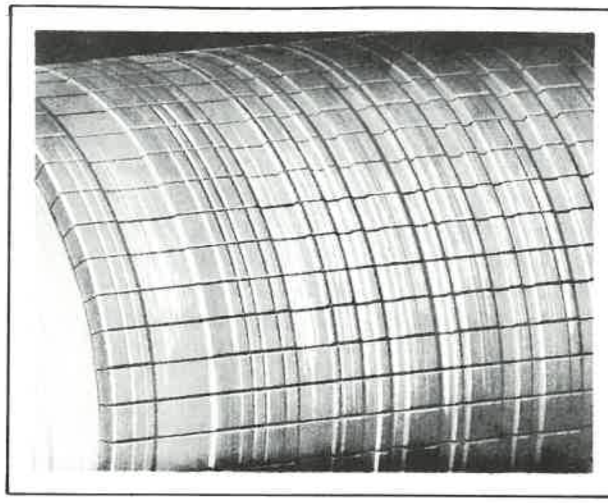


FIG. IV-27. HEAVY THREADING OF COMMUTATOR.

Possible causes of threading include:

1. Low current-density in the brush (machine is not heavily loaded).
2. Abrasive dirt or other foreign material imbedded in the face of the brush.
3. Mica flakes or copper imbedded in the brush face.
4. Wrong brush grade.

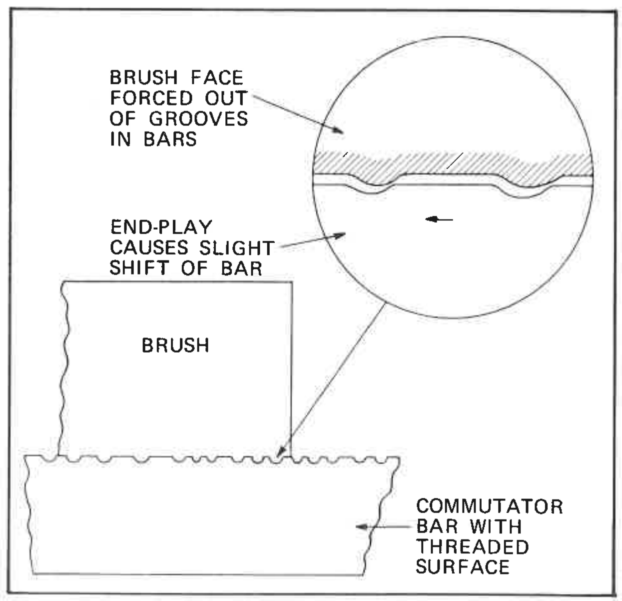


FIG. IV-28. ILLUSTRATION OF THREADING OF COMMUTATOR SURFACE.

IV

Copper Drag

Under certain conditions copper is dragged over the trailing edges of the commutator bars and has the appearance of small metal flakes or feathers. Copper drag is caused by particles of copper, copper oxide and contaminates that do not bond firmly to the surface of the commutator. As the commutator rotates, the brushes shove small flakes of this material toward or into the commutator slots. This decreases the distance between the bars. An arc formed at any brush can then be more easily carried over to an adjacent brush resulting in a flashover.

Copper drag should not be confused with bar corner etching. See Figs. IV-29 and IV-30.

Possible causes of copper drag include:

1. Contaminated atmosphere
2. Copper imbedded in brush face
3. Hard spot in brush
4. Wrong brush grade
5. Excessive vibration
6. Low current density.

A temporary solution to copper drag is to clean the commutator occasionally with a light brush-seater stone. If drag has progressed too far, the slots must be raked and cleaned.

Banding

Banding is a surface defect in the form of bands around the commutator in which the surface film has been partially or completely removed. These bands may be quite narrow (not to be confused with threading) or they may extend over a sizeable percentage of the brush path. See Fig. IV-31 for example of banding.

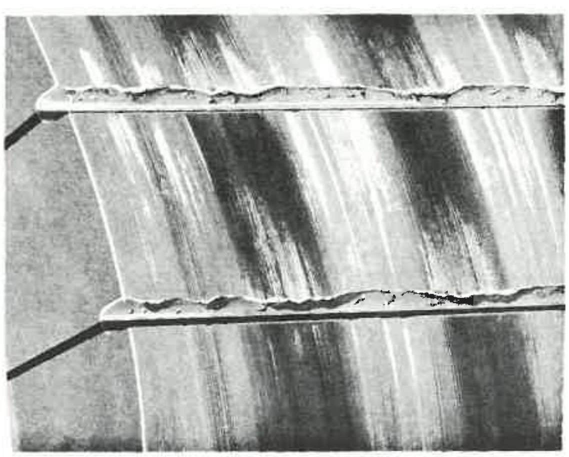


FIG. IV-29. COPPER DRAG ON TRAILING EDGE OF COMMUTATOR BARS.

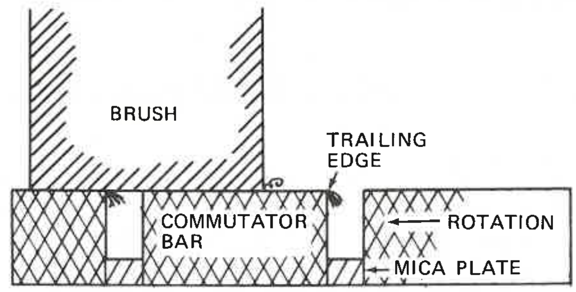


FIG. IV-30. ILLUSTRATION OF COPPER DRAG.

Possible causes of banding include:

1. Brush film too heavy (film tears from surface)
2. One brush is the wrong grade
3. Hard spot in a brush.

Banding can be corrected by hand-stoning after the cause has been eliminated.

Eccentricity

Even though a commutator surface is smooth, it can be running off center. This is a common fault and is usually the easiest of all surface variations for the brushes to follow. They simply rise and fall in the holders with each revolution. However, as speed goes up, this eccentric motion becomes faster. Finally, the brushes begin to break contact and gradually burn the commutator surface. As this continues, the burning causes still further surface destruction. See Fig. IV-32.

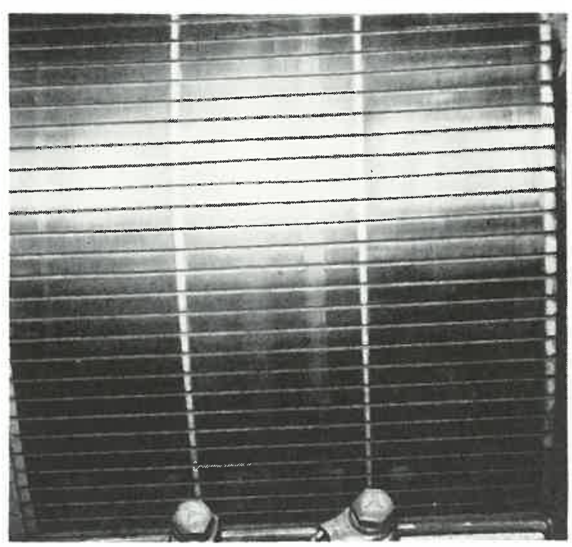


FIG. IV-31. EXAMPLE OF BANDING.

FIG. IV-29, E-8769A

FIG. IV-30, E-8770

FIG. IV-31, E-8771

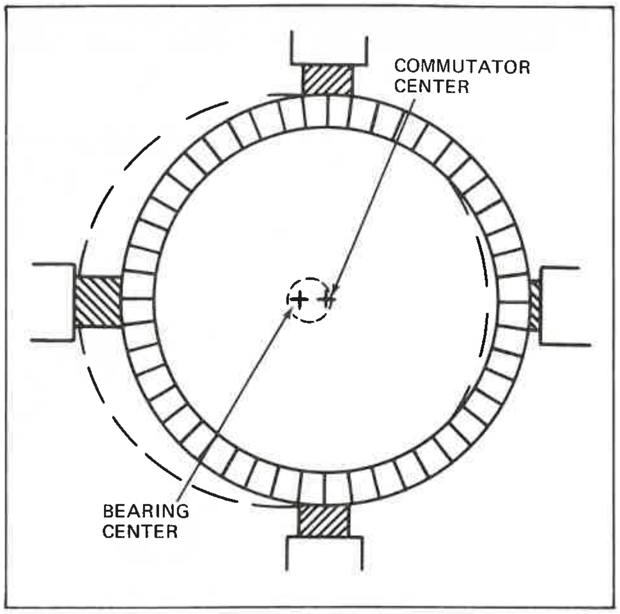


FIG. IV-32. EXAMPLE OF ECCENTRIC COMMUTATOR (EXAGGERATED FOR PURPOSES OF ILLUSTRATION).

Possible causes of eccentricity include:

1. Bent shaft
2. Bearings not running true
3. Commutator machined on bad shaft centers
4. Distortion caused by wide temperature changes and high speed
5. An offset coupling in single bearing traction generators.

Determine the cause of eccentricity and resurface the commutator using a rigidly-mounted grinding fixture. Eccentricity cannot be corrected by hand-stoning.

Surface Breaks

Sometimes a sharp step occurs on a commutator surface. This may be caused by a bump or blow to the commutator. Though the change in surface level may be very small, not even a heavy spring load will keep the brush in contact with the depressed bars. The brush may "ski-jump" from the higher level or, if rotation is reversed, the step strikes the brushes and "kicks" them away from the surface. This causes sparking, followed by electrical erosion and flat spots on the surface of the commutator. At high speed this kick may be hard enough to shatter the brushes. See Fig. IV-33.

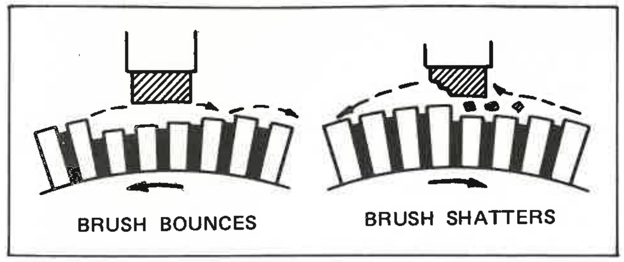


FIG. IV-33. EFFECTS OF DEPRESSED BARS AND REVERSAL OF ROTATION.

Possible causes of surface breaks include bumping of commutator surface during handling or striking commutator with a heavy tool, etc.

Resurface the commutator with a rigidly-mounted grinding fixture to remove the surface break.

High Bars

If a motor armature does not rotate while power is applied, the commutator bars under the brushes will overheat and expand. Expansion will cause these bars to rise above the adjacent bars. When the armature rotates, the high bars kick the brushes which, in turn, arc and burn the commutator surface. If this condition is not corrected, the brushes may shatter and a flashover could occur. See Figs. IV-34 and IV-35.

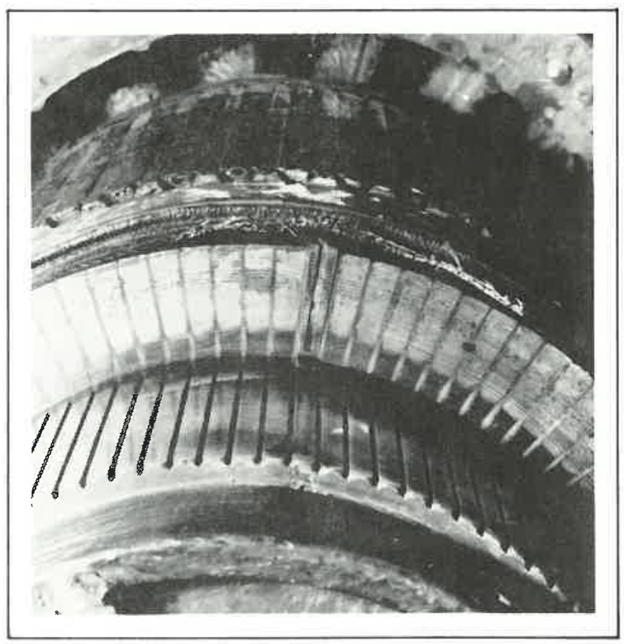


FIG. IV-34. EXAMPLE OF A SOFT COMMUTATOR BAR WHICH HAS LIFTED AT HIGH SPEED.

FIG. IV-32, E-8773A
FIG. IV-33, E-8774
FIG. IV-34, E-5022

IV

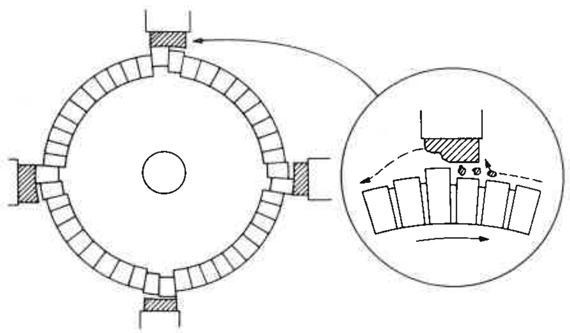


FIG. IV-35. EFFECTS OF HIGH BARS ON BRUSHES.

In severe cases, bar temperature may rise high enough to anneal the copper and destroy the binder in the mica plates. When this happens, flakes of mica will shift from the pressure areas and reduce the clamping action on the bars. Annealed bars wear differently than normal bars and being loose, will lift at high armature speed.

Annealed bars can be detected with a scleroscope or some equivalent means. Sometimes they can be spotted by discoloration of the bar ends outside the brush track.

High mica refers to the height relationship between the surface of the mica plate and the surface of the commutator bars. See Fig. IV-36-A for correct relationship.

In normal use, the surface of the commutator is gradually worn down. As the copper is worn away, the depth of the undercut (slots) is reduced until the edges of the mica plates are even with (or slightly higher than) the surface of the commutator, Fig. IV-36-B. At this point, the mica is called high mica.

High mica can be the result of either normal electro-mechanical wear, or failure to undercut the mica after resurfacing operations.

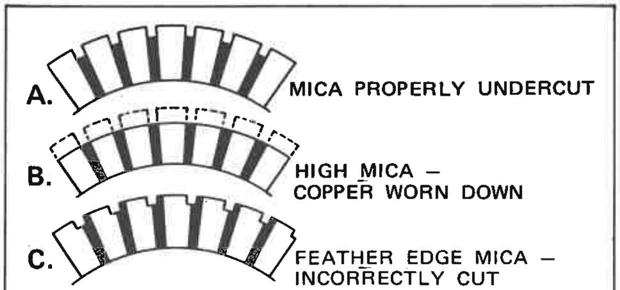


FIG. IV-36. HIGH OR FEATHER-EDGE MICA.

Feather edge mica results from the incorrect undercutting of high mica, Fig. IV-36-C, which leaves feather edges of mica level with the commutator surface.

Either form of high mica disrupts the process of commutation. This, in turn, increases wear on the commutator bars and the brushes to expose more mica to further disrupt commutation.

Flashover Damage

Any condition or defect which causes arcing on the surface of the commutator must be regarded as a potential cause for a flashover. When arcing becomes severe enough, the surrounding air changes into a conductive gas and allows power to spill over between the brushes in a flashover. A flashover is the commutator's final protest against neglect and abuse. Evidence that a machine has flashed over will be found in the form of copper splatter on the surface and ends of the commutator bars, on the brushholders and nearby insulation and on the frame as shown on Fig. IV-37.

If a flashover occurs, clean the commutator, the Teflon creepage band, and the brushholders. Examine these parts for damage and check the condition of the brush faces. Repair or replace damaged parts as necessary.

FIG. IV-37. EQUIPMENT BADLY DAMAGED BY FLASHOVER.

FIG. IV-35, E-5021A

FIG. IV-36, E-8776

FIG. IV-37, E-18333

FIG. IV-38, E-8778

FIG. IV-39, E-8779

FIG. IV-40, E-5024A

IV

RESURFACING THE COMMUTATOR

WARNING: *An environment potentially hazardous to personnel in the immediate area is created when resurfacing. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

Commutator troubles may often be corrected by resurfacing. This is the name given to any process which restores a true, cylindrical, polished surface to the commutator.

Polishing

If the commutator surface is merely smudged, you can clean it by polishing with canvas. When this is not sufficient, or if the commutator is slightly rough, crocus cloth or fine (4/0) sandpaper may be used. This should be mounted on a wooden block curved to fit the surface of the commutator as shown in Fig. IV-38.

CAUTION: *Never use emery cloth on a commutator. The abrasive particles not only scratch the surface, but they are conductive and lodge between commutator segments. This leads to short circuits.*

Stoning

If the commutator surface is mildly grooved, etched, or burned, and only a small amount of copper has to be removed to correct the defect, a hand stone is most suitable. The stone should have a surface curved to fit the commutator. Also, it should be long enough to bridge the defect to be removed; otherwise, the stone will ride in and out of the defect and do nothing to correct it. The length of the stone will usually be limited by the space between brushholders. If there is not enough space, a brushholder should be removed to make room for a larger stone, Fig. IV-39.

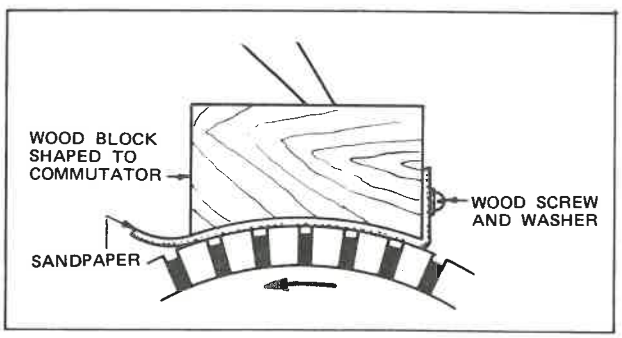


FIG. IV-38. FINE GRAIN SANDPAPER ON A SHAPED WOODEN BLOCK.

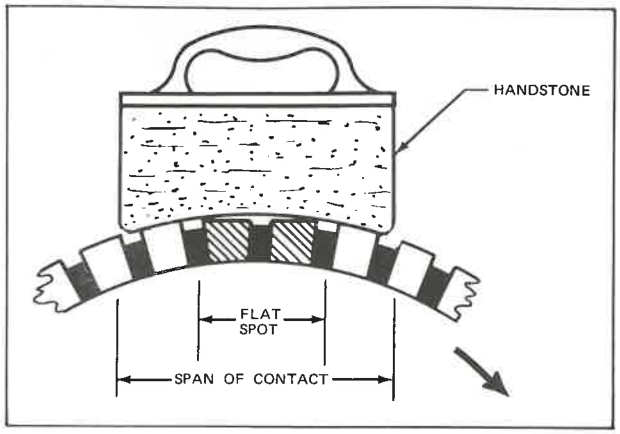


FIG. IV-39. PROPER USE OF HANDSTONE.

Hand stoning will not correct an out-of-round commutator. It is a fairly difficult operation and should be performed only by knowledgeable, skilled personnel.

Undercutting

After a commutator has been resurfaced, check the depth of the undercut of the mica between bars. If undercutting is necessary, it should be done carefully with a proper tool of correct size. The tool must have a sharp edge to cut the mica freely. A dull blade or saw produces small cracks in the mica into which dirt or moisture may find its way and break down the insulation between commutator bars.

Some common mistakes are shown in Fig. IV-40. Avoid these mistakes, refer to the device instruction book for the slot width and depth dimensions.

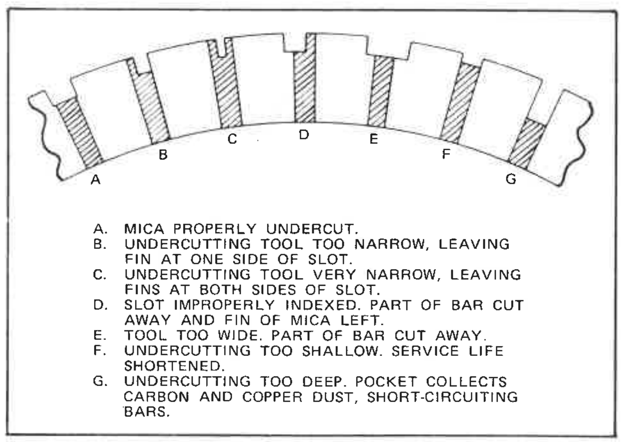


FIG. IV-40. COMMON MISTAKES IN UNDERCUTTING THE MICA BETWEEN COMMUTATOR SEGMENTS.

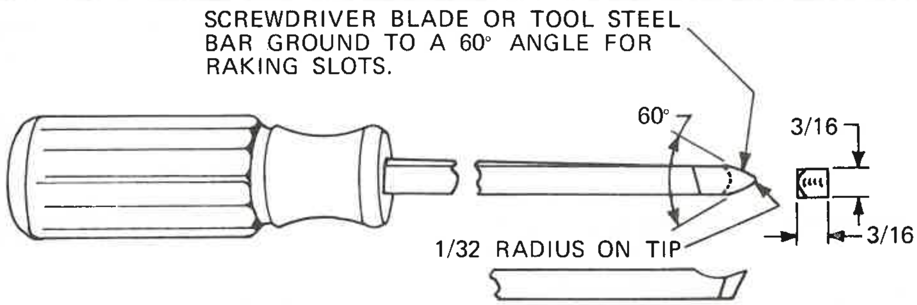
Slot Raking and Brushing

Resurfacing operations usually leave copper particles and slivers on the edges of the commutator bars and in the slots. These must be removed before the machine is placed in service as they could cause a flashover. Use a brush with stiff nylon bristles, a piece of fiberboard or a special tool ground to fit the slot, Fig. IV-41-B, C, and clean the slots thoroughly. Use a slot raking tool, Fig. IV-41-A, and break the sharp edges of the bars.

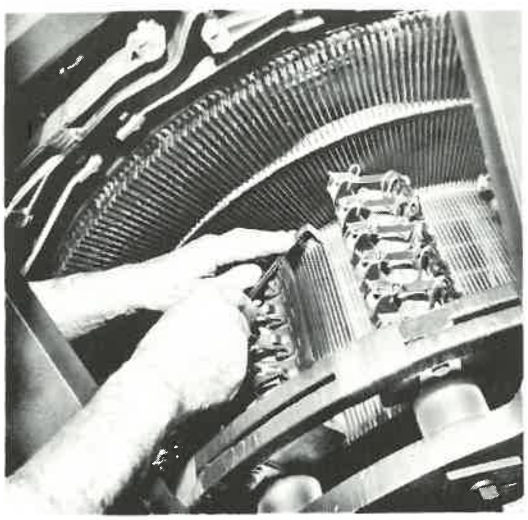
If resurfacing has produced considerable copper-drag on the bar edges, a "V" shaped slot-raking tool should be used to remove fins and ragged edges from the bars. Insert the point of the tool in the slot so the sides of the tool will scrape the edge of the bar on each side of the slot as the tool is dragged along the slot.

After the slots have been cleaned, it may be necessary to use very fine sandpaper or crocus cloth to remove small burrs and slivers from the edges of the bars. Don't use emery cloth.

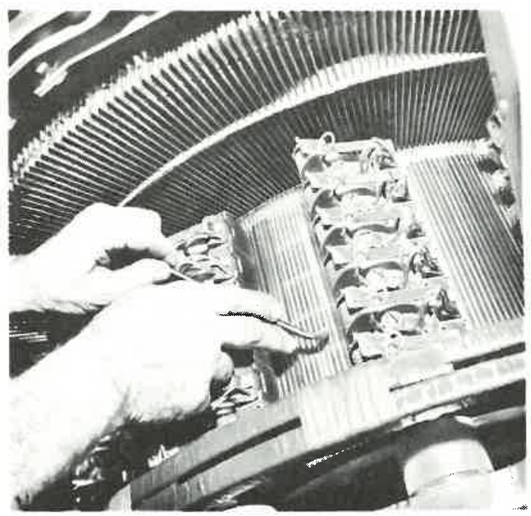
IV



(A) SLOT RAKING TOOL



(B) CLEANING OUT SLOTS IN INNER BRUSH PATH.



(C) CLEANING OUT SLOTS ON OUTER BRUSH PATH.

FIG. IV-41. CLEANING COMMUTATOR SLOTS.

FIG. IV-41, E-25145

NOTES:

IV

IV

NOTES:

NOTES:

TRANSPORTATION SYSTEMS BUSINESS DIVISION

ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

MECHANICAL EQUIPMENT

CONTENTS

INTRODUCTION

This section covers the mechanical equipment and vendor equipment, such as the cab heater, on Series-7 Locomotives. It should be noted that variations in equipment will exist between different models of locomotives and between railroad customers.

SHAFT ALIGNMENT

DIESEL ENGINE DRIVEN ACCESSORIES

Description

The following instructions cover the alignment of the equipment blower, the air compressor, the radiator-fan gear unit and their respective driveshafts, Fig. V-1.

Shafts become misaligned as a result of many natural and unavoidable causes. Heat, vibration, bearing wear and settling of foundations or bases all tend to alter initial alignment.

In general, coupling life is increased when shafts are carefully aligned. If this is not done and a coupling is heavily stressed due to unnecessary torque or other forces, it will have little reserve to accommodate misalignment stresses and probably will not provide the length of service intended.

During alignment, there are two measurements to be checked: parallel and angular alignment, Fig. V-2. If the sub-bases have not been damaged, the positioning dowels serve to maintain the correct horizontal alignment.

Engine to Air Compressor Driveshaft

Removal

1. Drain the oil back from the filter to the engine free-end cover.
2. Disconnect wiring and remove the HOTS and LOTS temperature switches.

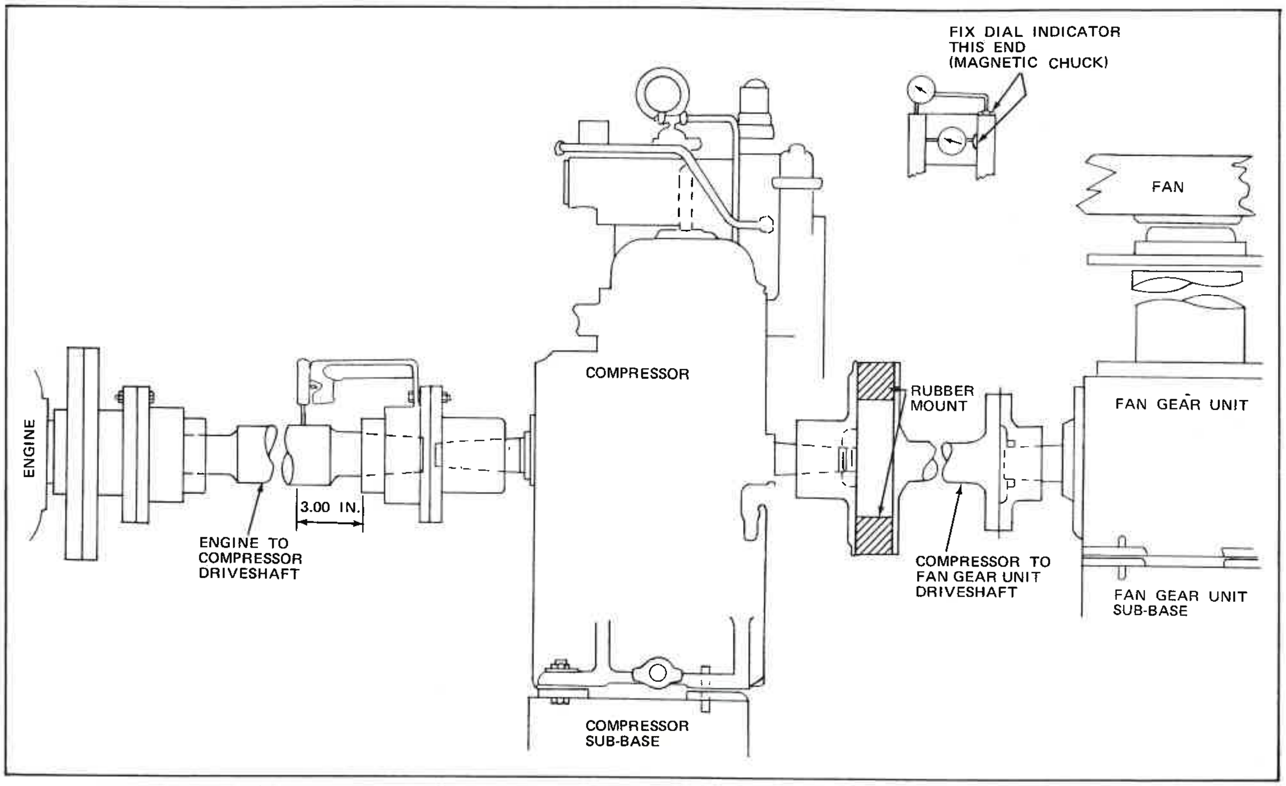


FIG. V-1. ENGINE, COMPRESSOR AND FAN GEAR UNIT ARRANGEMENT.

3. Remove long shaft guard, Fig. V-3, from engine to compressor compartment bulkhead. Remove guard, Fig. V-4, over compressor coupling, in the compressor compartment.

4. Working through the summer/winter door in the clean air chamber, place blocking under the compressor driveshaft to prevent it from dropping when the coupling at the compressor is separated. Also block the shaft at the engine coupling, Figs. V-5 and V-6.

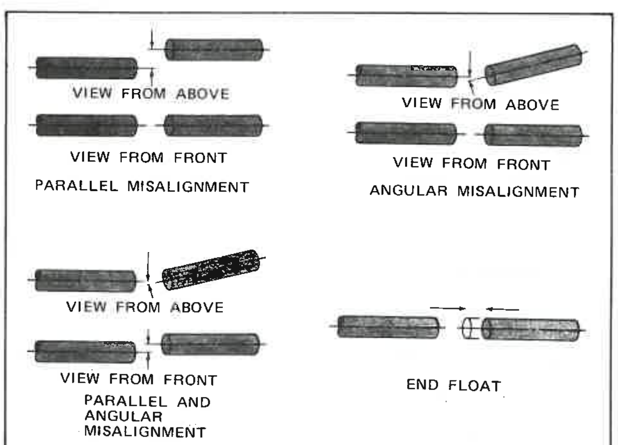


FIG. V-2. COUPLING MISALIGNMENT.

5. Locate a receptacle under each coupling to catch the grease that will flow out when the coupling sleeves are separated, then separate the sleeves.

6. Using manpower, slide the driveshaft forward (toward the engine) and to the side of the unit, until it has been moved out far enough to be picked up by a crane with sling. Approximate weight of the complete shaft is 350 lb.

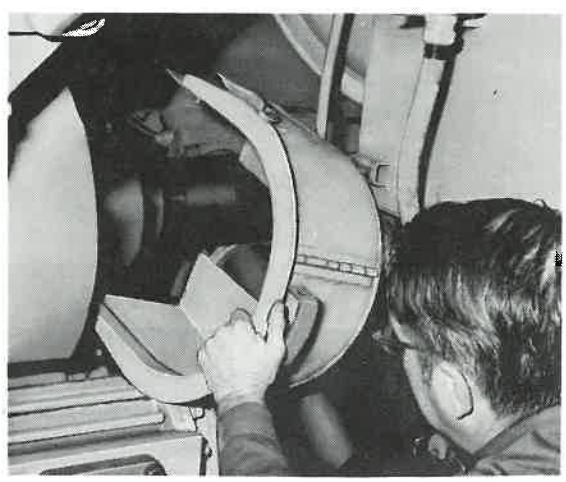


FIG. V-3. LONG SHAFT ENGINE TO COMPRESSOR GUARD.

FIG. V-1, E-24233A

FIG. V-2, E-24234

FIG. V-3, E-24235

FIG. V-4, E-24236

FIG. V-5, E-24237

FIG. V-6, E-24238

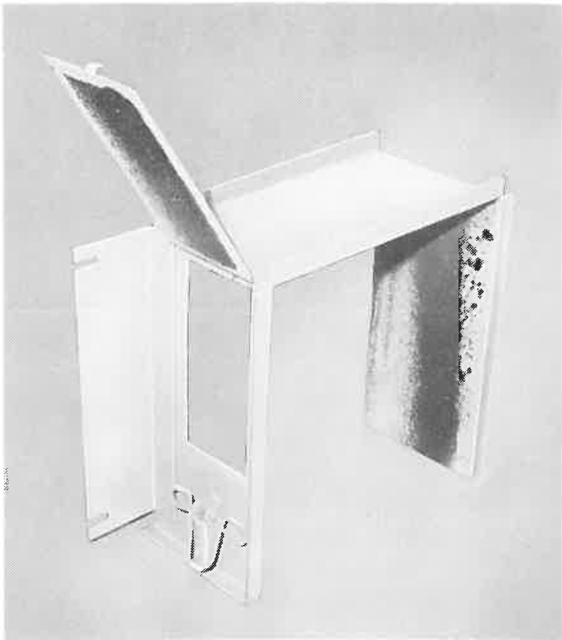


FIG. V-4. GUARD OVER COMPRESSOR COUPLING.

7. Set shaft on the floor on blocks where it is protected and repairs may be made if necessary.

Installation and Alignment

1. Apply a 0.062-in. bead of Permatex* circumferentially on the flange faces within the bolt circle on both couplings; Fig. V-7.

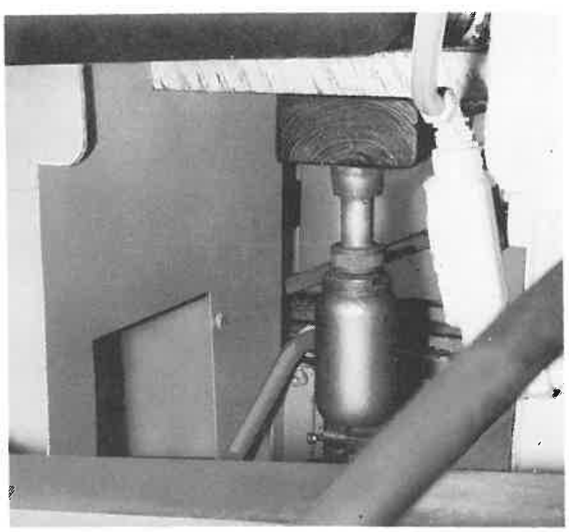


FIG. V-5. BLOCKING LONG SHAFT AT COMPRESSOR END.

*Product of Permatex Co., Inc.

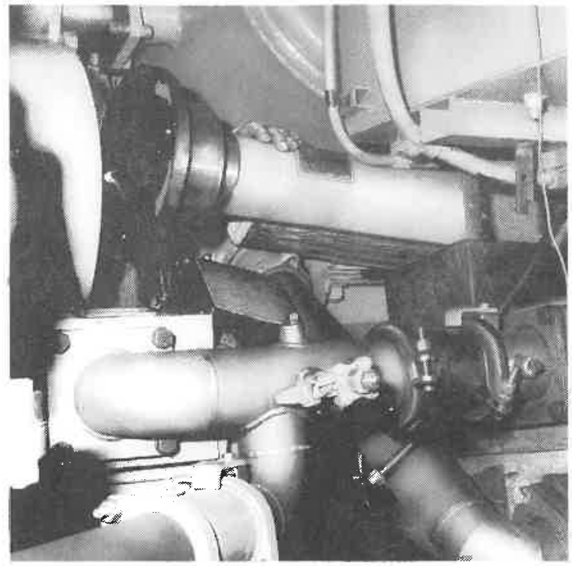


FIG. V-6. BLOCKING LONG SHAFT AT ENGINE END.

2. Lift shaft with crane and insert shaft into unit as far as possible. Remove sling.

NOTE: *Care should be taken to keep from catching the hub flange on any obstacle which will cause the flange or sleeve to slide off the hub, at the compressor end. Several layers of electrician's tape, wrapped around the hub, might prevent this from happening.*

3. Again using manpower, slide shaft into the proper position to connect the couplings.

CAUTION: *Extreme care must be exercised when installing the driveshaft, to prevent damage to the finished surface (O-ring surface) of the flexible-coupling gear hubs. Do not allow the teeth of the sleeve assembly of the flexible coupling to contact the finished surface of the gear hub. If the surface is damaged, the finish may be restored by cleaning with NALCO* and then silver-soldering the scratches, using flux and an acetylene torch, followed by polishing the surface with 150-grit emery cloth (for contour) and crocus cloth (for finish). If the scratches are very shallow (several thousandths), they may be removed by polishing the surface with crocus cloth, omitting the silver-soldering operation.*

4. Install the flange bolts, omitting one at each end, and torque bolts with 280-310 lb.-ft. torque.

*Product of NALCO Chemical Co.

V

5. Mount an indicator on the engine and compressor coupling flanges, utilizing the empty bolt hole. Rotate the shaft 360 degrees and indicate. Total indicated runout, taken 3 in. from hub, is to be within 0.050 in., Figs. V-1, V-8 and V-9.

6. Remove indicators; insert and torque final bolt. Lubricate coupling by turning shaft until pipe plugs are horizontal, then remove both plugs. Insert grease fitting in one hole and pump GE-D50E21 grease into coupling until it comes out other hole. Remove grease fitting and reinstall pipe plugs.

Air Compressor

Removal

1. Drain water and oil from compressor.

2. Disconnect all piping (water, oil and air) and remove air intake filter housing and filters.

3. Remove guard over the engine-to-compressor driveshaft and coupling, and the guard over and the oil pan under the fan gear unit coupling and driveshaft.

4. Remove bulkhead between the air compressor chamber and the fan gear-unit chamber. Also remove the door post that supports this bulkhead on the left side of the unit. Remove section of handrail in this immediate area, Fig. V-10.

5. Working through the summer/winter door in the clean air chamber, place blocking under the compressor driveshaft to support it when the coupling at the compressor is separated, Fig. V-5.

6. Support the compressor to fan gear-unit coupling shaft, using a light chain, sling or rope between the shaft and the wire grill above it, Fig. V-11.

7. Separate both couplings. Protect the rubber donuts of the fan gear-unit coupling from oil and dirt, and place receptacle under compressor coupling to catch the grease that will flow out when the coupling is separated, Fig. V-12.

8. Remove compressor mounting bolts, shims and dowels. Dowel can be removed by putting several washers on the pin between the compressor foot and the dowel nut and tightening the nut down until dowel releases. Mark shims when removing them so they can be reassembled in their original positions when the compressor is reinstalled.

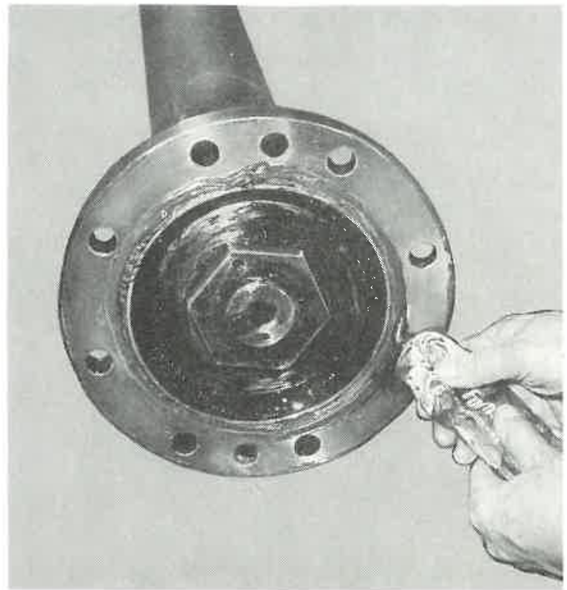


FIG. V-7, E-24239

FIG. V-7. APPLICATION OF PERMATEX BEAD ON FLANGE.

9. Slide the compressor on its mounting base to the side of the unit from which it is to be removed. Blocking must be placed adjacent to the mounting base and extended out on the walkway far enough that an overhead crane hook and cable will clear the radiator overhang and be hooked into the lifting eye on the compressor.

10. Lift compressor from the unit.

Installation and Alignment

1. Shrink the coupling hub onto the compressor input shaft (see "Hub Mounting" section).

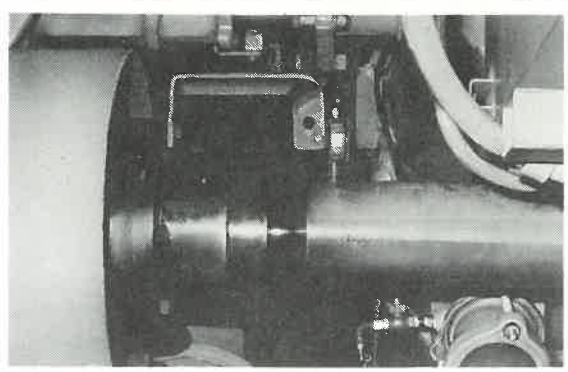


FIG. V-8, E-24240

FIG. V-8. INDICATOR MOUNTED ON ENGINE COUPLING.

FIG. V-9, E-24241

FIG. V-10, E-24242

FIG. V-11, E-24243

FIG. V-12, E-24244

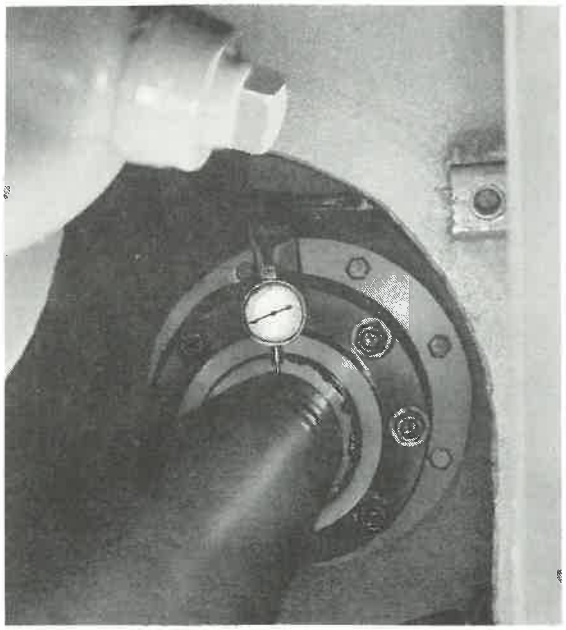


FIG. V-9. INDICATOR MOUNTED ON COMPRESSOR COUPLING.

2. Mount the compressor on its sub-base and, if replacing same machine, align the dowel holes located on each side of the compressor with those in the sub-base. All shims which were removed during the compressor removal must be reinstalled in their original positions.

NOTE: *If the machine being installed is the same one removed, Step 2 should bring the machine very close to the original alignment. If a new or rebuilt*

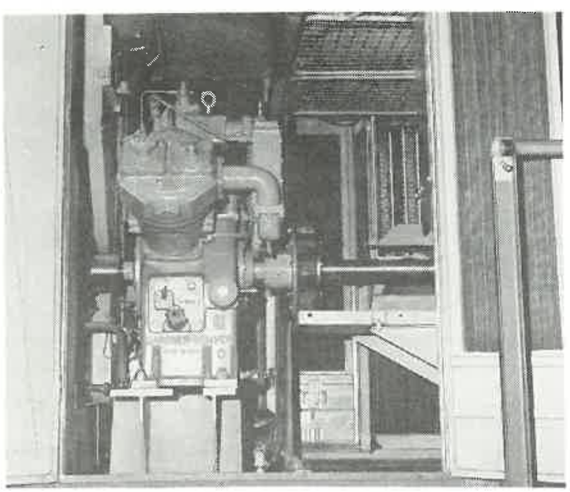


FIG. V-10. VIEW WITH BULKHEAD, DOOR POST AND HANDRAIL REMOVED.

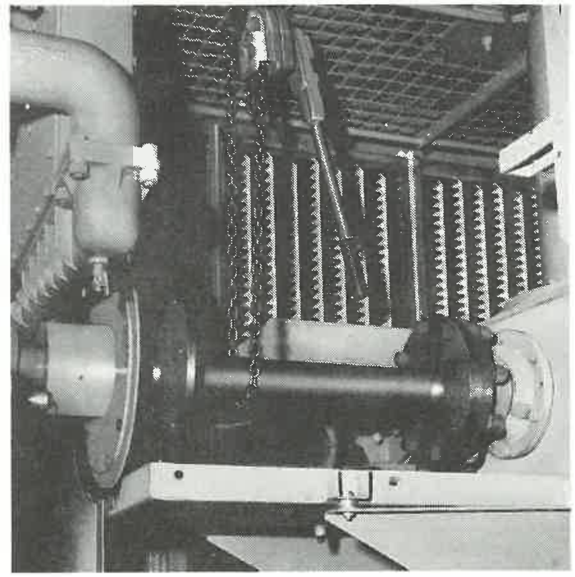


FIG. V-11. SUPPORTING FAN GEAR-UNIT SHAFT.

compressor is being installed, shims may have to be added, or some of the original shims removed, to obtain proper alignment. Also, the dowel holes may require plugging before redrilling.

3. Place the compressor driveshaft coupling into position for assembly to compressor coupling.

4. Lubricate threads of flange bolts with Molykote GN* and install in coupling. Torque bolts to 280-310 lb.-ft.

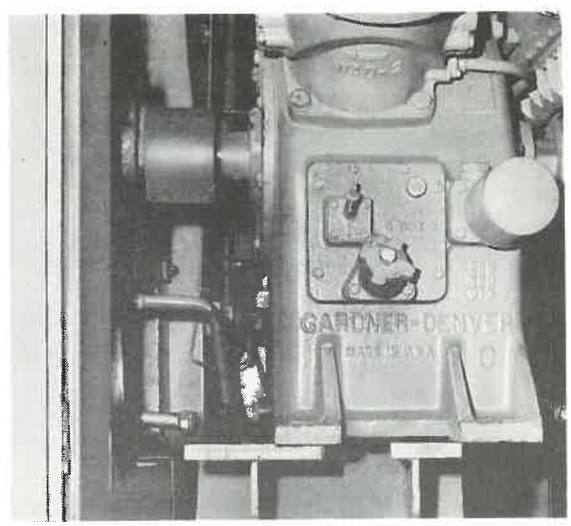


FIG. V-12. LOCATION OF RECEPTACLE TO CATCH GREASE.

*Product of Alpha Molykote Corp., Div. of Dow-Corning (GE Part 147X1143-1).

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5. Install a dial indicator on the engine coupling, Fig. V-13, and one on the compressor coupling, Fig. V-14, to indicate on the shaft 3 in. from each hub. Rotate shaft 360 degrees and read total runout. Total runout, with full fuel tank, should not exceed 0.050 in. Refer to Fig. V-15 for fixture.

6. When the runout noted in Step 5 has been obtained, lubricate the threads of the compressor bolts with Molykote GN. Install the bolts and tighten them to 400-450 lb.-ft. torque. Insert dowel pins in the original holes, if aligned, or ream and install oversized dowels.

7. Rotate shaft until grease plugs opposite each other in the coupling are horizontal. Remove both plugs. Install grease fitting in one hole and insert grease (GE-D50E21) into coupling until it comes out the other hole. Remove grease fitting. Apply liberal coat of Permatex to pipe plug threads and install pipe plugs.

Fan Gear Unit

Removal

1. Remove the radiator compartment hatch and radiators.

2. Disconnect the gear unit coupling.

3. Remove mounting bolts, dowels and shims. Mark shims so they can be reinstalled in their original positions.

4. Remove bolt in end of fan shaft and insert a lifting eye bolt.

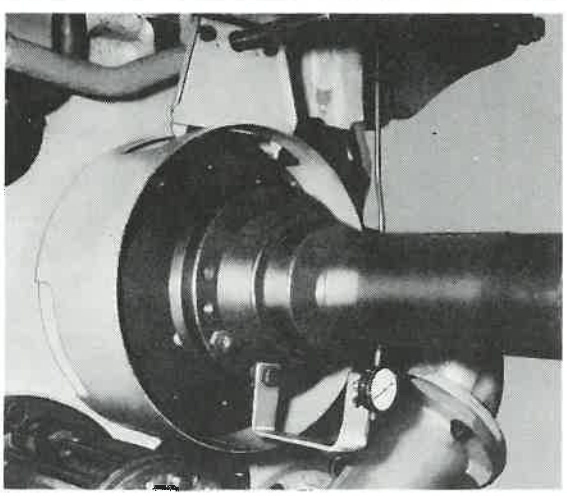

FIG. V-13. CHECKING ALIGNMENT BETWEEN DRIVESHAFT AND DIESEL ENGINE.

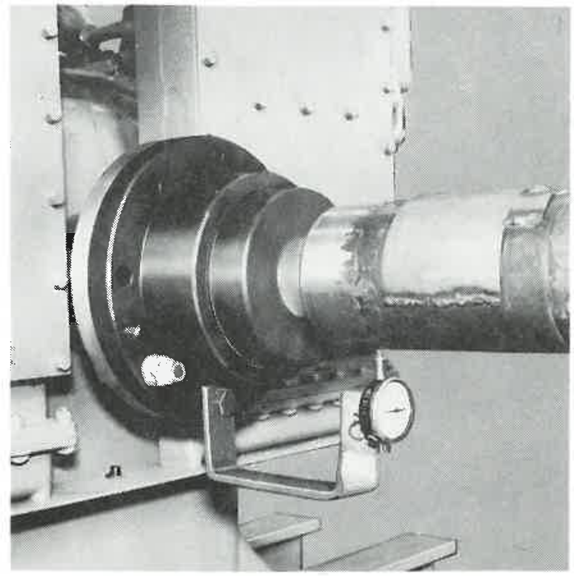

FIG. V-14. CHECKING ALIGNMENT BETWEEN DRIVESHAFT AND COMPRESSOR.

5. Lift the unit vertically. Make sure the fan does not catch on the shroud.

Installation and Alignment

NOTE: *Do not attempt to align the fan gear unit with the air compressor without first obtaining the proper alignment between the engine and compressor. When the correct compressor alignment has been achieved, proceed as follows.*

1. Shrink hub on the fan gear-unit shaft and on compressor output shaft (see "Hub Mounting" section).

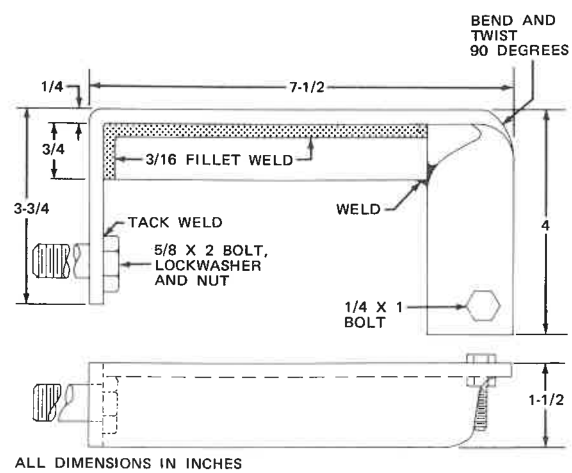

FIG. V-15. INDICATOR HOLDING FIXTURE FOR ALIGNING THE ENGINE TO COMPRESSOR DRIVESHAFT.

FIG. V-13, E-13513

FIG. V-14, E-13514

FIG. V-15, E-24554

FIG. V-16, E-23580A

FIG. V-17, E-24245

FIG. V-18, E-23579

2. Install driveshaft to fan gear-unit shaft hub. Lubricate bolt threads with Molykote GN and tighten to 280-310 lb.-ft. torque.

3. Mount fan gear unit on its sub-base. Replace shims as they were prior to removal. Maintain 3.000 to 3.030 in. between hubs and 3/8 in. between ends of fan blades and fan shroud opening.

NOTE: *If the unit being installed is the same one removed, Step 3 should bring the unit very close to the original alignment. If a new or rebuilt unit is being installed, the shims may have to be adjusted to obtain proper alignment.*

4. Mount an indicator on the large compressor coupling flange and indicate the O.D. of the gear-unit flange. Rotate fan gear-unit flange and check total runout. Total indicated runout should not exceed 0.010 in., Figs. V-16 and V-17.

5. Clean out the bolt hole in the rubber mounts (mounting sandwich). Use the correct length bolt (to prevent bottoming of the bolt and pulling out the nut when tightening the mounting bolts) and install the rubber mounts. Lubricate the bolt threads with Lubriplate* and tighten to 28-30 lb.-ft. torque.

NOTE: *When tightening bolts, avoid twisting the rubber mounts. Molded lines on the mounts should be visibly straight after tightening. Do not over-torque. Reassemble any rubber mount that shows greater than 3 degrees (0.08 in.) twist in either direction after assembly, Fig. V-18.*

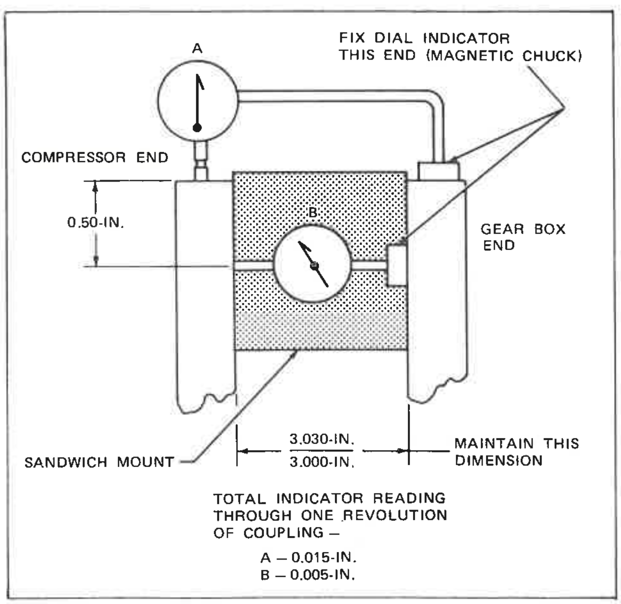

FIG. V-16. INDICATOR MOUNTING.

*Product of Fiske Bros. Refining Co. (GE Part 147X1614).

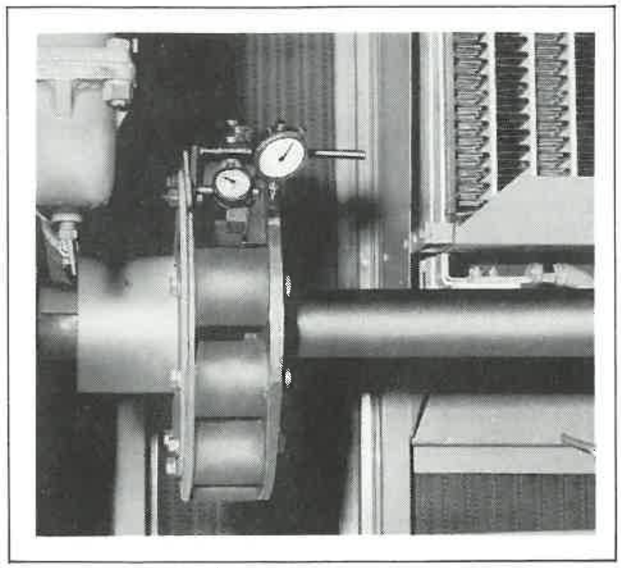

FIG. V-17. CHECKING ALIGNMENT BETWEEN COMPRESSOR AND FAN GEAR UNIT.

6. Mount indicators as shown in Figs. V-17 and V-18. Rotate the fan shaft 360 degrees to check parallel and angular alignment. Total parallel indicator reading should be within 0.015 in. Total angular indicator reading should be within 0.005 in.

NOTE: *To reduce compressor torque, pressurize compressor unloader valves.*

7. After obtaining the proper alignment, bolt down the fan gear unit, using Lubriplate on the mounting bolt threads and tightening bolts to 200-250 lb.-ft. torque. Install dowel pins in original holes or ream holes and install oversized dowel pins.

Equipment Blower ("C" Locomotive)

Removal

At prescribed intervals, the equipment blower must be removed to inspect the bearings. Use the following procedure:

1. Remove blower hatch.

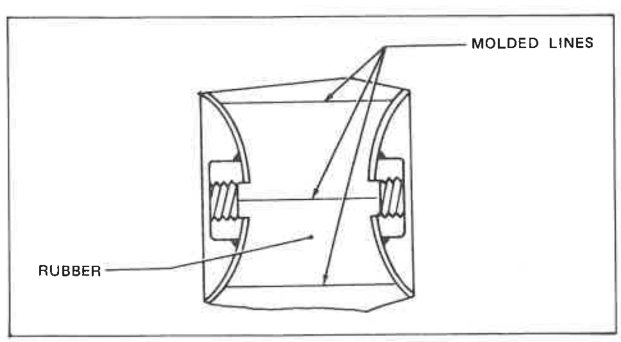

FIG. V-18. CROSS-SECTION OF RUBBER MOUNT (MOUNTING SANDWICH).

V

2. Remove the bolted-in sections of the bulkhead around the blower drive coupling from the generator compartment.
3. Disconnect the flexible coupling by removing two bolts at each end of the coupling, Fig. V-18.
4. Remove the dowel pins and blower mounting bolts. Mark and save shims, since they must be replaced in their original positions upon reinstallation.
5. Insert the lifting eye and lift the blower.

Installation and Alignment

1. Shrink hubs onto power take-off shaft and blower shaft (see "Hub Mounting" section).
2. Mount blower on its sub-base, aligning the dowel holes. Replace shims removed during removal of blower.

NOTE: *If the blower being installed is the same one removed, Step 2 should bring the blower close to the original alignment. If a new or rebuilt blower is being installed, shims may have to be adjusted to obtain proper alignment.*

3. The coupling must be disassembled for installation. Remove two bolts on both ends which secure the coupling flange and flex-pack to the coupling hub, Fig. V-19. Bolt these flanges into the blower and power take-off hubs. Torque flange mounting bolts to 30-35 lb.-ft. torque.
4. Clean bolt, nut and hub threads with a safety solvent, and wipe dry. Apply Loctite Sealant* to bolts which screw into flanges. Assemble bolts and immediately torque the four (4) bolts at each end of coupling to 115-120 lb.-ft.

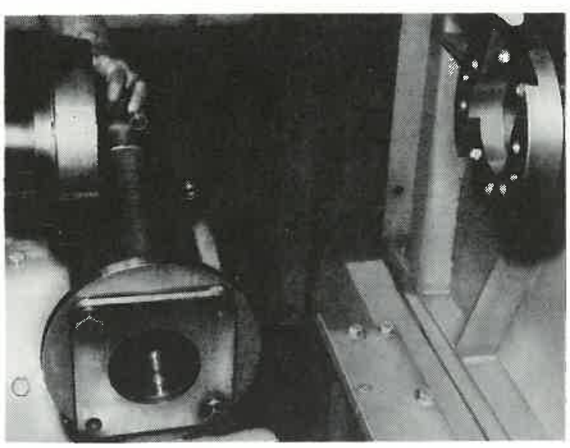

FIG. V-19. BLOWER COUPLING REMOVED.

*Product of Loctite Corp.

5. Mount an indicator on each hub to indicate 5 in. out on shaft at each end, Fig. V-20. Adjust shims under blower until total indicated runout is within 0.020 in. with a full fuel tank. See Fig. V-21 for fixture.
6. When proper alignment is obtained, bolt down blower, using Lubriplate on the bolt threads and tighten bolts to 200 lb.-ft. torque. Install dowel pins in original holes if aligned, or ream holes and install oversized dowel pins.
7. Replace any guards which had to be removed to facilitate removing the blower.

Hub Removal

Using a Hydraulic Pump

Coupling hubs may be removed by the "pop-off" or float method, using hydraulic pressure for quick removal. Steps 1 through 5 may be used to remove all hubs where shaft ends are properly prepared. See Tool Catalog for proper tooling. (Use the same hydraulic pump and adapter employed to float a traction motor pinion.)

1. If a locking nut is assembled on the end of the shaft, loosen the set screw or screws and back off nut 1/4 to 1/2 turn, to act as a back-up plate when the hub pops off.
2. Insert the adapter into the threaded hole in the center of the shaft, and connect it with tubing to the hydraulic pump.

CAUTION: *Do not heat the hubs before removal or use a steel hammer to drive hubs off the shaft. Damage to the equipment or shaft may result.*

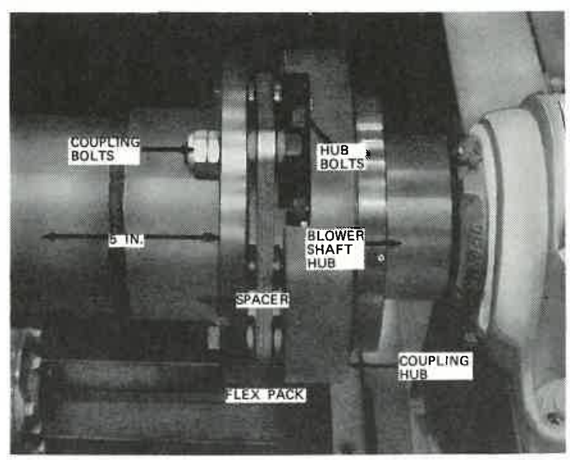

FIG. V-20. EQUIPMENT BLOWER FLEXIBLE COUPLING.

FIG. V-19, E-24246

FIG. V-20, E-24247A

FIG. V-21, E-24555

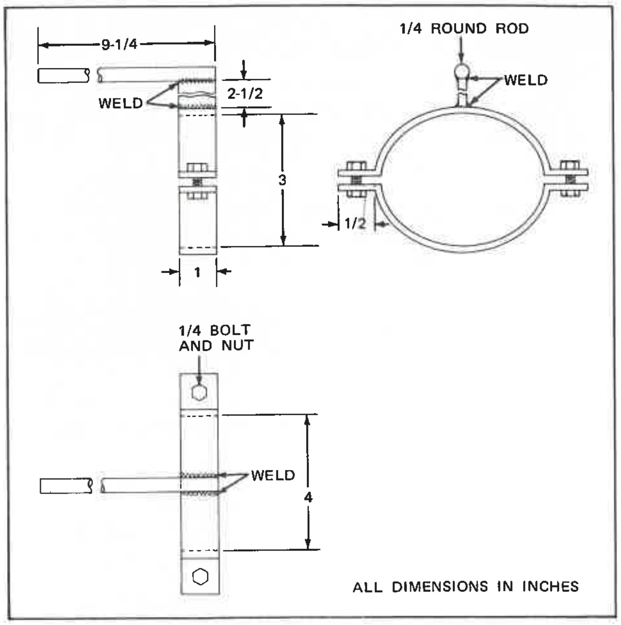

FIG. V-21. INDICATOR HOLDING FIXTURE FOR ALIGNING EQUIPMENT BLOWER WITH POWER TAKE-OFF SHAFT.

3. Pump up enough pressure to force oil into the shaft groove. Ten to twenty strokes is normally sufficient for hub removal.

4. Remove pump assembly from the shaft.

5. Remove nut and slide the hub off the shaft.

Following hub disassembly, carefully inspect all parts, paying particular attention to the internal and external gear teeth and O-rings.

Excessive wear of the gear teeth will require installation of new parts. If the hub or sleeve must be renewed, install a new hub and sleeve as a pair. Do not mate a new gear hub with a worn sleeve, or vice versa.

Using a Mechanical Puller

The hubs on equipment having shaft ends which are not prepared for the hydraulic float method must be removed using a hub puller tool.

Hub Fitting

To prevent the hub from slipping, it should have at least a 75 percent fit on the shaft; that is, at least 75 percent of the tapered bore of the hub is to contact the tapered fit on the shaft. Before heating a hub for mounting, check and correct the fit as follows:

1. Lightly cover the hub bore with blueing compound, such as Prussian blue oil pigment.

2. Snap the cold hub on the shaft. Do not twist the hub after it is in place.

3. Mark the relative position of the hub on the shaft with chalk, then remove the hub.

4. Inspect the taper fit on the shaft; blueing of hub bore should have transferred to and should now show on the shaft. If at least 75 percent of the shaft surface shows traces of blueing, the fit is satisfactory. If, however, only a few spots of blueing show on the shaft, the fit is insufficient.

5. Where necessary, dress down the blue spots on the shaft very lightly, using an emery cloth.

6. Blue the hub again as in Step 1, wipe blueing off the shaft end, and repeat Steps 2, 3 and 5. Be careful to place the hub on the shaft in the same position as indicated by the chalk marks.

The fit generally will be improved, but the procedure given in Steps 1 thru 6 may have to be repeated several times.

CAUTION: *Under no circumstances use a lapping compound, since lapping will produce a shoulder at the large end of the tapered fit. This shoulder will prevent a perfect fit when the hub is mounted hot in the advanced position.*

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Hub Mounting

Proper hub mounting is essential for successful operation of the coupling. Proceed as follows:

1. Thoroughly clean the hub fit on the shaft and the bore of the hub.

NOTE: *Do not use kerosene or other cleaner which will leave an oil film.*

2. Remove any scarring on the shaft or hub bore.

3. Spot the cold hub on the shaft by hand, and check for 75-percent fit (see "Hub Fitting" section).

4. Trial-mount the hub on the shaft. Measure and record the position of the hub with respect to the shaft. Make measurements with a micrometer or a pinion advance gage. Mark the points of measurement across the end of the shaft and hub face so the hub, when heated, can be mounted in exactly the same angular position and the advance measurement can be made from the same points.

5. Heat the hub in an oven until the entire hub has reached a uniform temperature, as specified in the "Data" section.

   Some accurate method must be used to measure the hub and shaft temperatures quickly before mounting the hub. This can be done best with a pyrometer (see Tool Catalog), Fig. V-22. Measure the temperature of the shaft and hub with the same instrument.

6. Quickly mount the hot hub on the shaft in the same angular position as when cold, using the chalk marks as a guide. When the hub is ready for engagement with the taper fit (not in actual contact), snap it forcibly into place with a quick push. It is important that the hub be instantly snapped into position before it has cooled appreciably; otherwise, it will "freeze" to the shaft and will not be further adjustable. Fig. V-23 shows the hub being mounted on the shaft.

NOTE: *The coupling sleeve and O-ring seals must be placed over the shaft before the hubs are installed.*

7. Check the "hot" (or shrunk-on) position of the hub on the shaft with a gage, located in the same relative position as used to measure the position before hub was heated.

Proper advance is shown in the "Data" section. If the advance is not within the limits given, remove the hub and repeat the procedure. Fig. V-24 shows the hub advance being checked.

Insufficient advance can result from not "soaking" hub at elevated temperature for sufficient time or not having temperature high enough. Remember the temperature shown in the "Data" section is the difference that oven should be above shaft temperature. Insufficient advance can cause a slipped coupling.

Less often achieved, but just as great a problem, is the case of over-advancement. This can cause cracked hubs and resulting failure.

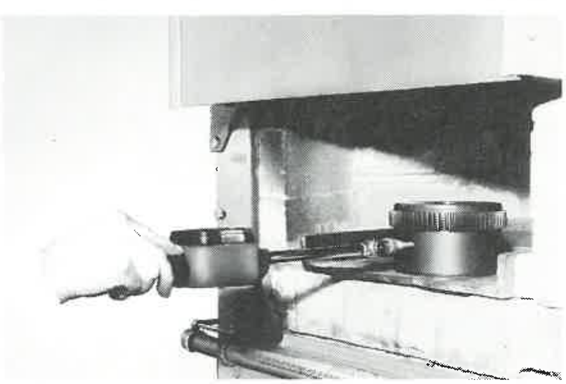

FIG. V-22. USING PYROMETER TO CHECK HUB TEMPERATURE.

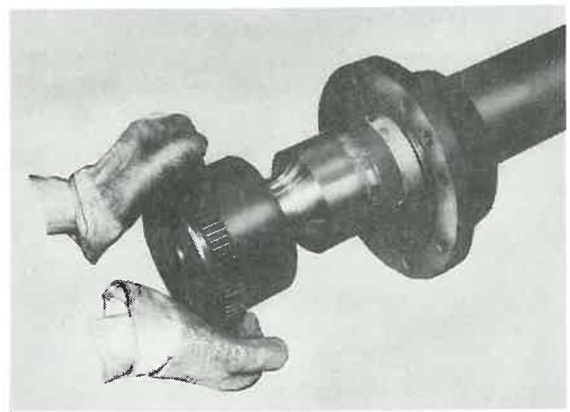

FIG. V-23. APPLYING HEATED COUPLING HUB TO COMPRESSOR DRIVESHAFT.

FIG. V-22, E-25401

FIG. V-23, E-25402

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Data

Hub To Shaft Contact Fit	To Mating Part
Compressor Driveshaft Hubs	75%
Compressor Input and Output Hub	75%
Fan Gear-Unit Hub	75%
Blower Hub	75%
Power Take-Off Shaft Hub	75%

Temperature (Degrees Above Shaft Temperature) Required For Proper Hub Advance

	Advance (in.)	Temp.
Compressor Driveshaft Hubs	0.035 to 0.040	214 F
Compressor Input Hub	0.035 to 0.040	235 F
Compressor Output Hub	0.030 to 0.035	212 F
Fan Gear-Unit Hub	0.035 to 0,040	235 F
Blower Hub	0.050 to 0.055	350 F
Power Take-Off Hub	0.040 to 0.045	275 F

Engine To Compressor Alignment (With Fuel Tanks Full) (in.)	
Total Runout (3 in. From Hubs)	0.050
End-Play	Free to 0.500
Compressor To Fan Gear-Unit Alignment (in.)	
Parallel Alignment Runout	0.015
Angular Alignment (2-1/2-in. Radius From Centerline)	0.010
Blower Alignment (With Full Fuel Tanks)	
Total Runout (in.)	0.050
Torque Values (lb.-ft)	
Compressor Driveshaft Coupling Flange Bolts	280-310
Rubber-Sandwich Mounting Bolts	28-30
Blower Coupling Flange Mounting Bolts	30-35
Blower Coupling Flange Bolts	80
Compressor Mounting Bolts	400-450
Fan Gear-Unit Drive Flange Bolts	280-310
Fan Gear-Unit Mounting Bolts	200-250
Equipment Blower Mounting Bolts	200

FIG. V-24, E-13520

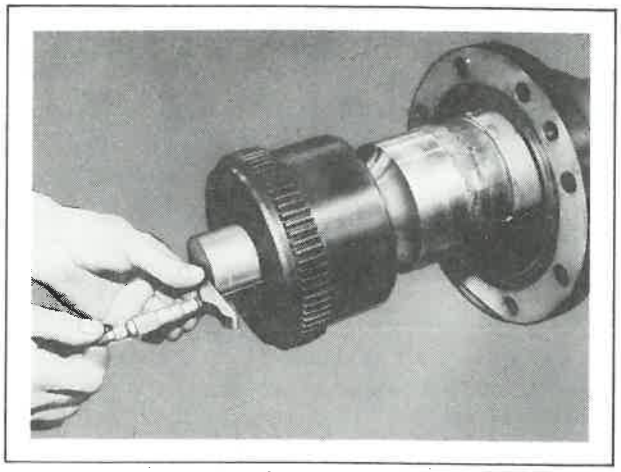


FIG. V-24. CHECKING HUB ADVANCE.

FIG. V-25, E-24583

Equipment Blower ("B" Locomotive)

NOTE: *The equipment blower on a "B" locomotive is located in the radiator compartment. The rotor of the blower is mounted on the stub shaft of the fan gear unit. Since the fan gear unit is driven by the diesel engine, the blower will operate whenever the engine is running.*

Therefore, since the rotor is mounted on the stub shaft of the fan gear unit, a "shaft alignment" procedure is not necessary.

Removal

If, for any reason, the removal of the fan gear unit (Figs. V-25 and V-26) is required, the rotor must be removed from the fan gear-unit shaft, and the blower housing must be slid to the rear of the radiator cab. To do so, proceed as follows:

1. Remove the six (6) bolts holding the inlet guard in place and remove guard.

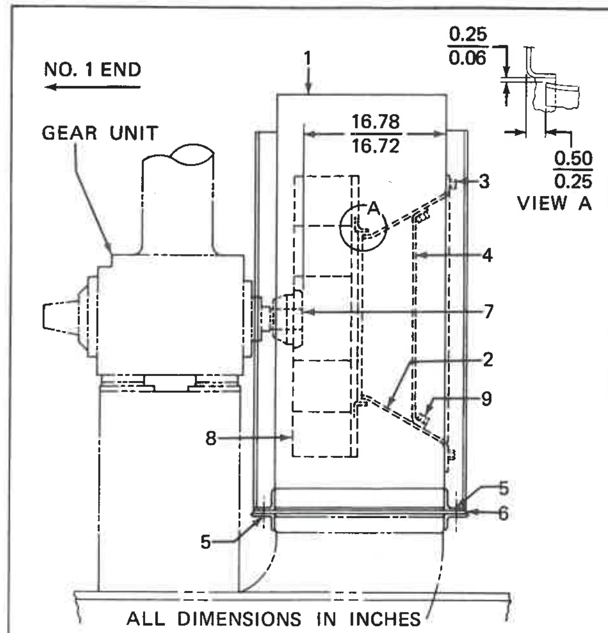
2. Remove the sixteen (16) nuts holding the inlet cone to the housing and remove cone.

3. Remove rotor as follows:

   a. Remove the two (2) allen-head mounting screws.

   b. Insert one of the screws in the jacking (removal) hole, and torque down. If bushing does not loosen, tap on rotor hub while applying torque to screw.

   c. Slide rotor from stub shaft and housing.



REF.	DESCRIPTION
1	HOUSING
2	INLET CONE
3	INLET-CONE MOUNTING BOLTS
4	INLET GUARD
5	HOUSING MOUNTING BOLTS AND SHIMS
6	SEAL
7	HUB AND BUSHING
8	ROTOR
9	INLET GUARD BOLTS

FIG. V-25. EQUIPMENT BLOWER ASSEMBLY.

4. Remove dowels from blower mounting flange and blower support.

5. Remove housing mounting bolts and slide housing out of the way.

NOTE: *Mark the shims removed so they may be placed in their original positions when gear unit is reinstalled on blower.*

FIG. V-26, E-16160

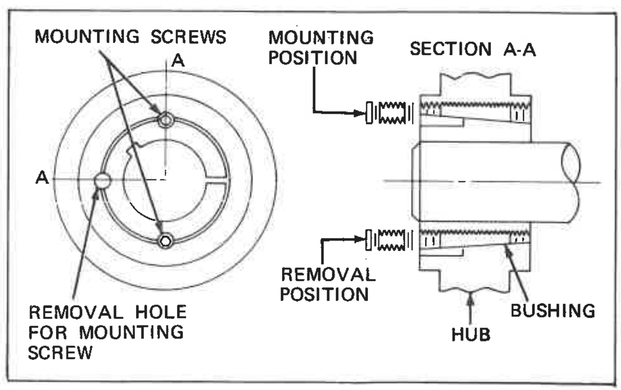


FIG. V-26. TAPER LOCK HUB AND BUSHING.

V

Installation

With gear unit installed and aligned with compressor and/or engine, proceed as follows:

1. Be sure the blower support is free of dirt and oil by cleaning with safety solvent (mineral spirits D-588).
2. If seals on blower support are damaged, replace them by activating the adhesive on new seals using safety solvent, and apply the new seals to blower support.
3. Position the blower housing, aligning the dowel holes and replacing the shims in their original positions, on the blower support. Align the 5.50-in. diameter opening in the housing with the fan gear-unit shaft to within ±0.60 in. on the radius.
4. Align the inlet side of the blower housing to within 17.030-16.970 in. vertical and horizontal to the end of the shaft using sweep tool, Figs. V-27 and V-28.
5. Bolt housing in place. Torque mounting bolts to 180-215 lb.-ft.
6. Assemble rotor as follows:

   a. Clean fan gear-unit shaft, key and fan hub bore with mineral spirits. Make sure cleaner is completely removed before assembly. Polishing the surfaces with clean paper towels is recommended.

   b. Insert bushing in hub, matching the half holes.

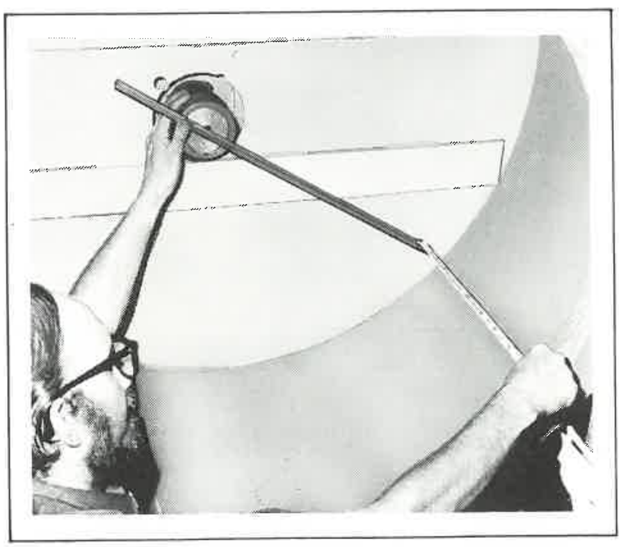


FIG. V-27. MAKING SWEEP TOOL MEASUREMENT.

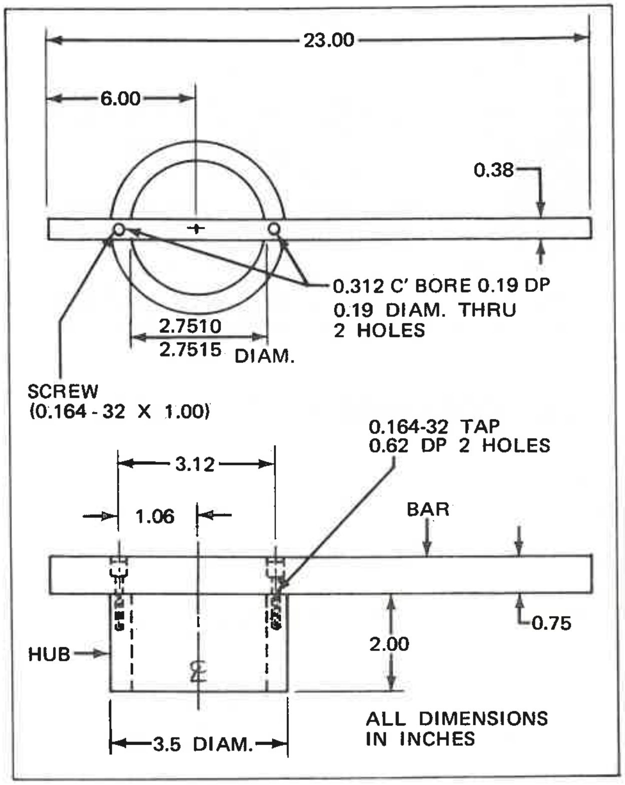


FIG. V-28. SWEEP TOOL.

   c. Coat set screws with oil and insert them loosely in the two holes that are threaded in the hub-side of the hole.

   d. Slip the fan assembly onto the shaft with the key in the keyway.

   e. Tighten the bushing screws alternately to 800 lb.-in. torque. The hub face should be flush with the shaft end within 0.02 in.

   f. Hammer against large end of bushing using a hammer and brass block or sleeve to avoid damage. Retorque screws. Repeat this alternate hammering and screw tightening until the specified wrench torque no longer turns the screws. Fill other holes with grease to exclude dirt.

7. Replace the inlet cone. Use caulking between housing and cone. Adjust cone so the dimensions between the rotor and cone, Fig. V-25, are met. Tighten the sixteen nuts.
8. Replace the inlet guard, using caulking between cone and guard and tighten the six bolts.
9. After alignment, drill and ream two holes 0.500 in. through No. 2 end of blower mounting flange and blower support. Insert new dowel pins.

FIG. V-27, E-24584

FIG. V-28, E-24585

CAB HEATER

DESCRIPTION

The cab heater is a self-contained unit for electrically heating the locomotive cab located in the short hood. The cabinet houses the heating elements, the motor and blower, the overheat switches and terminals for external power connections. Cab air enters the unit through the lower opening in the cab front wall, flows through the blower and is returned over the heating elements to the cab through the upper opening. Clean air from the platform air duct, controlled by a Fresh Air lever, Fig. V-29, on the left-side of the heater, may also be introduced into the heater air chamber.

This heater has five heating elements capable of delivering 11.25 kw of heat. The overheat switch, which is manually reset by pressing a red button on top of the switch, can be reached through the hinged access door on the left-side of the heater, Fig. V-30. To prevent overheating the cab, a return air thermostat which opens at 100 F and resets automatically at 90 F, is incorporated in the electrical circuits.

The heater operates on 74 vdc. The heating elements are rated at 2250 w at 74 v. The two-speed blower motor is rated at 0.167/0.220 hp, 860/1160 rpm, 3 or 4 amps. at 74 vdc. Motor speed is varied by switching a 100-ohm, 100-w field resistor.

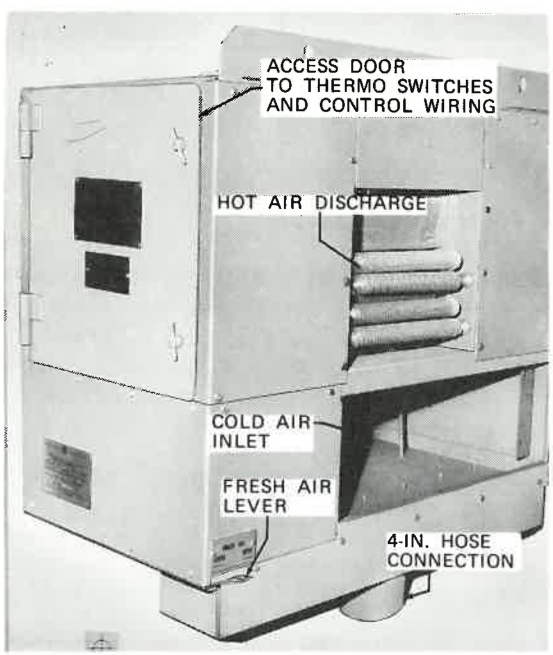


FIG. V-29. HEATER AIR INLETS AND OUTLETS.

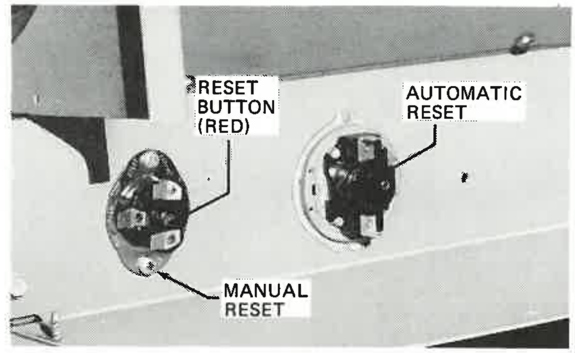


FIG. V-30. TOP REMOVED SHOWING THERMO SWITCHES.

ELECTRICAL CIRCUITS

Because of several modifications to the original heater, attention is called to the necessity of working with the correct circuit diagram in connecting or servicing the heater.

NOTE: *If the heater circuits match Figs. V-31 and V-32, contact the GE serviceman for the necessary equipment to up-date the heater to the latest schematic diagram, Fig. V-33.*

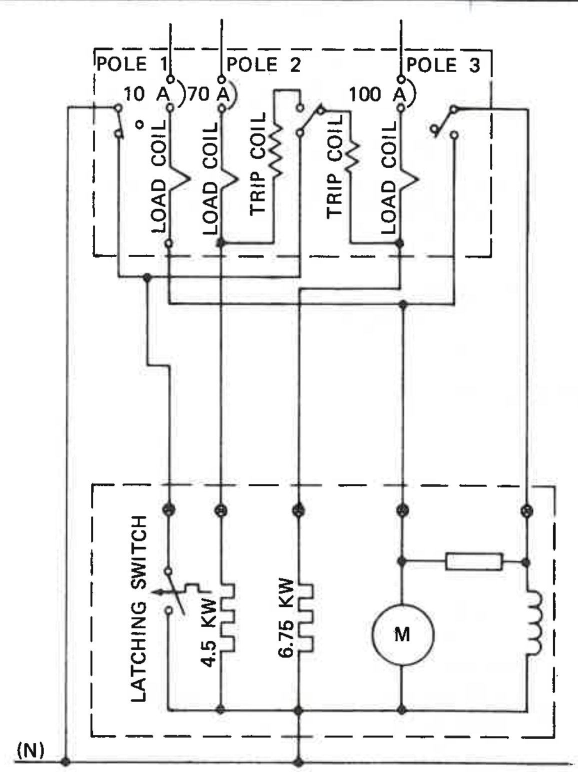


FIG. V-31. ORIGINAL WIRING.

FIG. V-29, E-25130
FIG. V-30, E-25131
FIG. V-31, E-25132

V

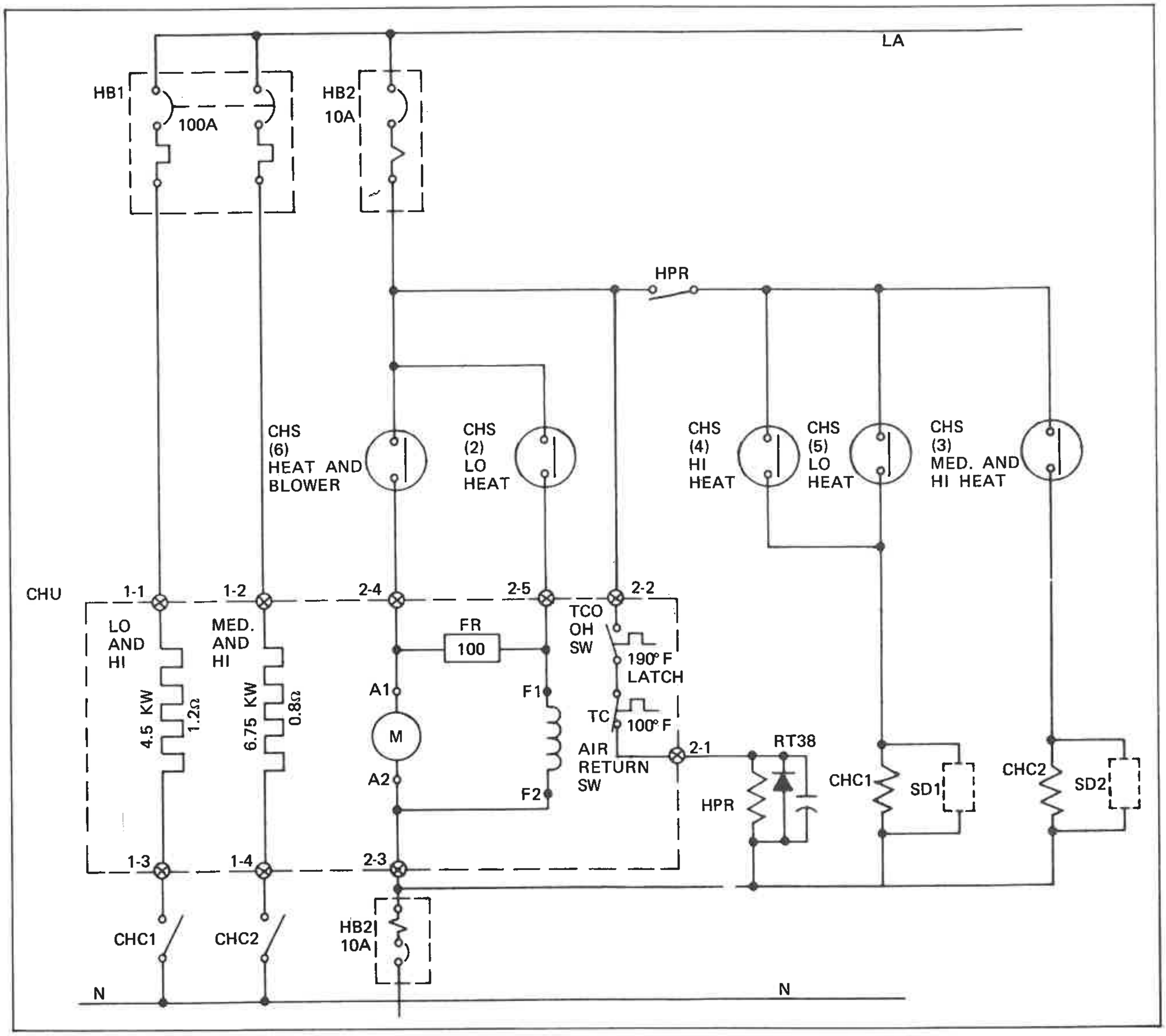


FIG. V-32, E-25133

FIG. V-32. CAB HEATER SCHEMATIC, FIRST MODIFICATION.

OPERATION

1. Close circuit breakers HB1 and HB2, Fig. V-33, located in the toilet compartment.

2. Set the Cab Heater Switch (CHS) at the BLOWER ONLY position. In this position, only Contact 6 is closed allowing the fan motor to run at full speed (1160 rpm).

3. With Switch CHS set at LOW HEAT, Contacts 2, 5 and 6 are closed causing the fan motor to run at reduced speed (860 rpm); and with Cab Heater Contactor (CHC-1) picked-up, the 4.5 kw heater element is energized furnishing low heat to the operator's cab.

4. With Switch CHS set at MEDIUM HEAT, Contacts 3 and 6 are closed causing the fan motor to run at high speed; and with Contactor CHC-2 picked-up, the 6.75 kw heater element is energized furnishing medium temperature heat to the operator's cab.

5. With Switch CHS set at HIGH HEAT, Contacts 3, 4 and 6 are closed, causing the fan motor to run at high speed; and with Contactors CHC-1 and CHC-2 picked-up, both the 4.5 and 6.75 kw heater elements are energized, furnishing high temperature heat to the operator's cab.

6. With the heater switch in any heat position, air is circulated from the cab, through the heater back into the cab. If outside air is desired, a small lever,

FIG. V-33, E-25134

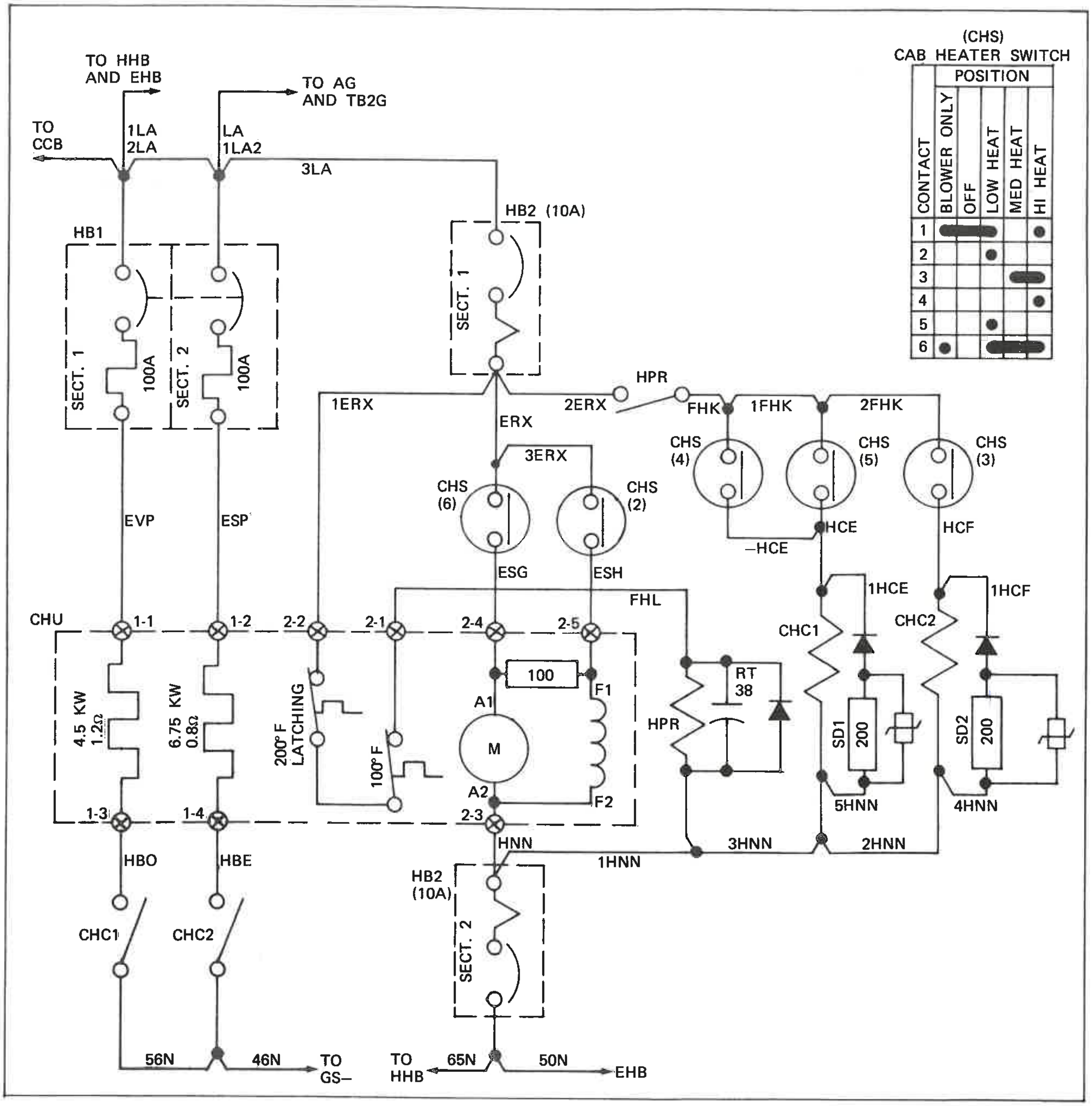


FIG. V-33. CAB HEATER SCHEMATIC, SECOND MODIFICATION.

Fig. V-29, protruding from the lower left-side of heater, must be moved to the right to open a holed slide allowing cleaned, outside air to mix with the inside air for maximum heat flow.

SAFETY DEVICES

There are two thermo switches, Fig. V-30, in the electrical circuits; one with Automatic Reset and the other a Manual Reset switch.

When the temperature reaches 100 F, the Automatic Reset thermo switch opens de-energizing the Heater Pressure Relay (HPR) which, in turn, cuts power to the heaters by de-energizing Contactors CH1 and CH2. The fan motor will still run at high speed. When the temperature drops to 90 F, the switch will automatically reset.

Should the Automatic Reset thermo switch fail when the temperature reaches 200 F, the Latching Switch opens, and again power is cut-off to the heaters. To reset this switch,

V

open the door or remove the cover on the left-side of heater housing. Reach thru the trough over the heat elements and push the red button down on the thermo switch.

> **WARNING:** *This area and surrounding metal may be hot; therefore, care should be taken to prevent getting burned.*

When this Latching Switch trips, it is advisable to check the heater thoroughly to determine why the 100 F switch did not trip. Replace it if found defective.

REMOVAL OF HEATER

1. Remove hatch on short hood or nose cab.
2. Disconnect 4-in. hose from air inlet pipe at bottom of heater.
3. Remove two 0.50-13 x 1.25-in. bolts holding heaters (at the bottom) to its mounting brackets.
4. Remove top side cover or open-hinged door on left-side of heater, and disconnect and temporarily insulate the power supply cables.
5. Remove two, 5.5 x 5.5 in. plates on top of heater housing. Attach slings on crane hook to lifting lugs provided inside housing, and take slight strain on sling.
6. Remove two, 0.50-13 x 1.25 in. bolts and secure top of heater to bulkhead.
7. Carefully lift heater from locomotive.

REMOVAL OF FAN MOTOR (Fig. V-34)

Remove heater from locomotive, then:

1. Remove wrap-around top, end-side covers.
2. Loosen or remove the set screw holding the fan on the motor shaft.
3. Disconnect motor leads at motor.
4. Remove six mounting screws holding motor mount to heater housing. Pull motor from unit; fan will remain in unit.
5. Loosen bolts in mounting bracket band and remove motor from mounting bracket.

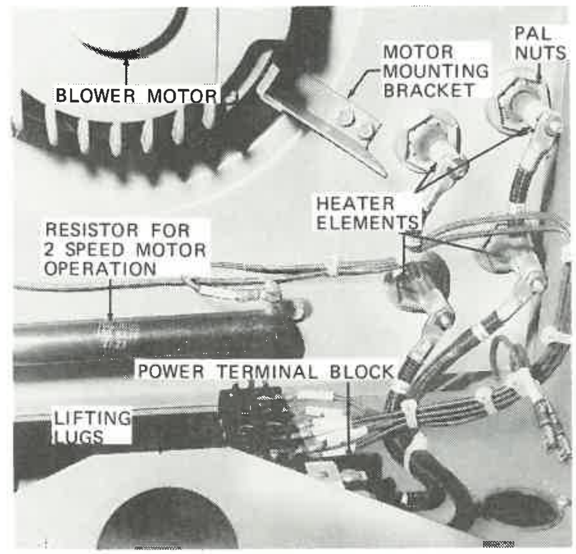


FIG. V-34. MOTOR BRACKET AND HEATING ELEMENTS.

FIG. V-34, E-25135

HEATER ELEMENT REPLACEMENT (Fig. V-34)

Remove heater and fan motor from locomotive, then:

1. Disconnect leads to element or elements to be replaced.
2. Remove PAL nuts and washers holding elements in place.
3. Slide elements out of unit.

INSTALLATION OF HEATER

1. With crane, carefully lower heater into nose cab and guide it to set on lower mounting brackets with mounting holes aligned. Insert and tighten the two 0.5-13 x 1.25 in. bolts.
2. Align slotted holes at the top of the heater with holes in bulkhead. Insert and tighten 0.5-13 x 1.25 in. bolts.
3. Insert power cables into heater and connect per schematic diagram.
4. Remove sling. Replace all covers previously removed.
5. Reconnect 4-in. air intake hose at bottom of heater.
6. Reinstall nose cab hatch.

INSTALLATION OF FAN MOTOR

Reverse the removal procedure.

INSTALLATION OF HEATER ELEMENT

Reverse steps in removal of elements.

TROUBLE-SHOOTING

Use of the trouble-shooting table (Table V-I) will help to identify possible causes of trouble. Once the cause is determined, the procedure for eliminating it will, in most cases, be evident. Because the power to operate the cab heater is supplied by the locomotive auxiliary generator, the unit cannot operate unless the engine is running.

The heater may be operated in the shop if supplied with 74 vdc power. Control switches and breakers must be supplied for off-locomotive operation.

TABLE V-I, TROUBLE-SHOOTING THE CAB HEATER

Problem	Possible Cause	Correction
Fan won't run.	Fan motor circuit open	Correct wiring
	Motor brushes faulty	Replace brushes.
	Blower wheel blocked	Free blower wheel.
Fan speed excessive.	Open field circuit	Correct circuit or replace motor.
	Open resistor (if set on high speed)	Replace resistor.
No heat (fan running).	Overheat switch tripped	Reset OH switch.
	Open wiring in heater circuit	Correct wiring.
	Defective fan/heater interlock circuit	Correct circuit.
	Defective heating elements	Replace elements.
Low heat (lower than normal).	Open wiring to one or more elements	
	Open (defective) heating element.	
Unit overheats with fan on low or high speed.	Air flow restriction and one of following: 1. Open circuit in OH switch wiring 2. Breakers or contactors fail to open on signal 3. OH switch failed	Clear air flow restriction and: 1. Correct wiring 2. Repair or replace breaker or contactor 3. Replace OH switch.

V

NOTES:

V

NOTES:

V

TRANSPORTATION SYSTEMS BUSINESS DIVISION

ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

TRUCKS

CONTENTS

INTRODUCTION

This section covers the truck assembly. The truck assembly, two per locomotive, is located under the locomotive body. Also, it performs as a conveyance to transport the locomotive.

The truck assembly consists basically of the following:

1. A steel frame to provide a mounting platform.
2. A truck bolster to support the locomotive body.
3. Two (or three) wheel-and-axle assemblies to provide means of transportation.

BRAKE RIGGING FLOATING BOLSTER TWO-AXLE TRUCKS

INSPECTION

Daily or trip, inspect for wear and also for loose, broken or missing parts. Renew brake shoes when they are worn. Check the brake-cylinder piston travel, Fig. VI-1.

LUBRICATION

Do not lubricate the pins, bushings or wear plates. It has been found that grit and dirt sticking to the exposed oil surfaces causes more wear than when the parts are dry.

VI

ADJUSTMENT

1. Exhaust the air from the brake cylinders.
2. Remove the pin connecting the compression bar to the brake lever.
3. Reapply the pin in another slack adjustment hole to obtain 2-1/2 in. brake-cylinder push rod travel.
4. The maximum brake-cylinder push rod travel allowed is 6 in.

BRAKE SHOE REMOVAL

1. Exhaust the air from the brake cylinder.
2. Move the shoes as far as possible from the wheel tread by adjusting the manual slack adjuster and/or picking-up the coarse adjustment.
3. Hammer the keys out of the brake-shoe head.
4. Knock the shoes loose from the brake head, and remove them by sliding them up the wheel and out.

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GENERAL ELECTRIC

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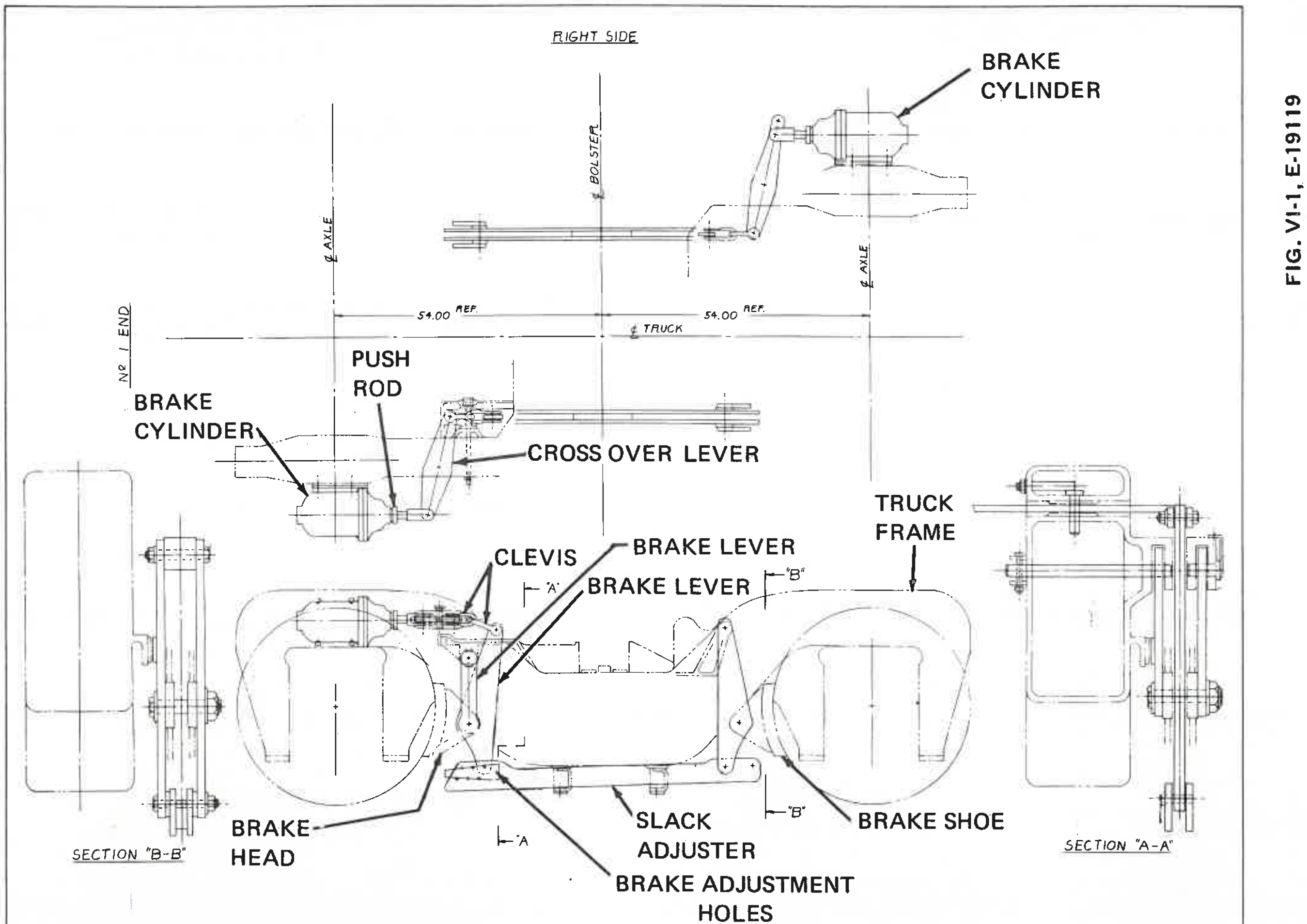
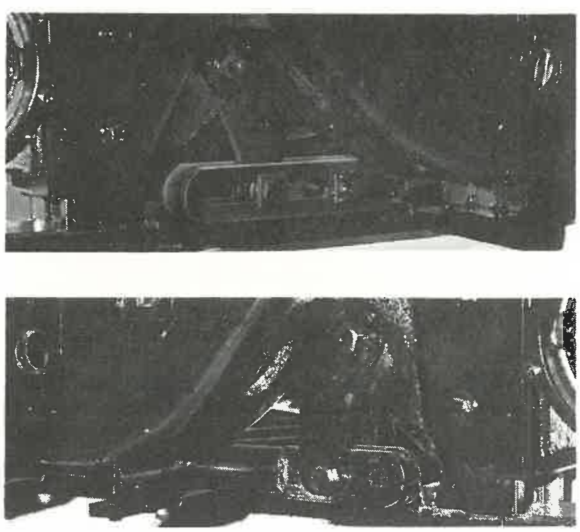
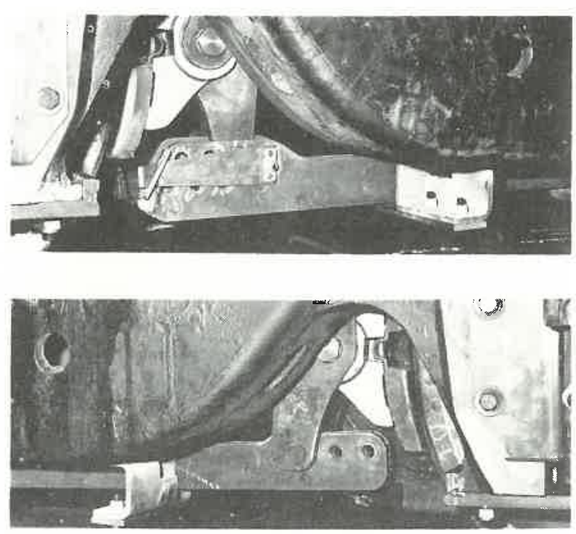




PREVIOUS SLACK ADJUSTER HOLE ARRANGEMENT.



CURRENT SLACK ADJUSTER HOLE ARRANGEMENT.

FIG. VI-1. BRAKE-RIGGING ARRANGEMENT.

FIG. VI-2, E-13506B

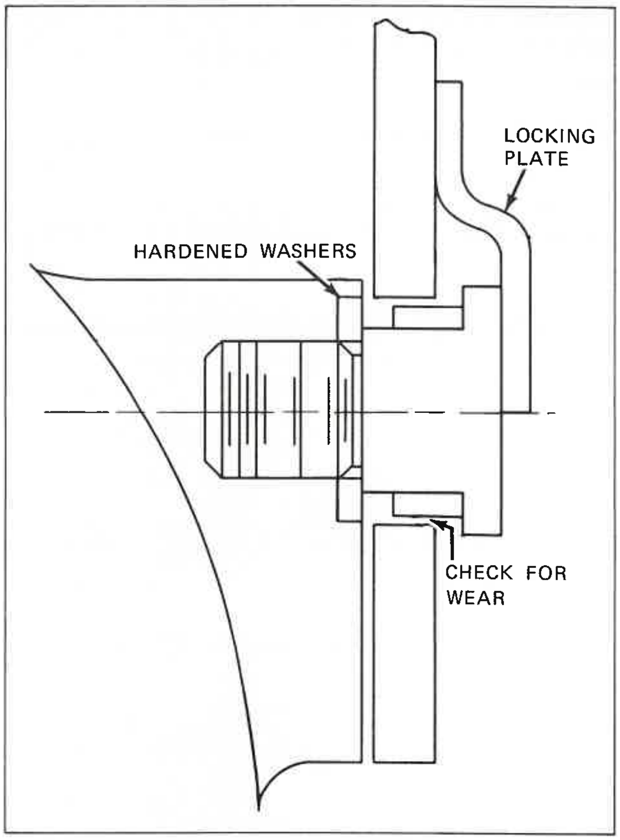


FIG. VI-2. BRAKE-CYLINDER SUPPORT.

BRAKE SHOE INSTALLATION

1. Insert new shoes in the brake heads and line up the keyways.
2. Drive the keys in place and check the shoes for tightness.
3. Adjust the manual slack adjuster to obtain dimensions previously described under Adjustment section.
4. Make sure that the brake-cylinder cut-out cocks are open when the work is finished.

BRAKE RIGGING FLOATING BOLSTER THREE-AXLE TRUCKS

INSPECTION

Daily or trip, inspect for wear and loose, broken or missing parts. Renew the brake shoes when they are worn. Check the brake-cylinder piston travel, Fig. VI-2.

LUBRICATION

Do not lubricate pins, bushings or wear plates. It has been found that grit and dirt sticking to exposed oil surfaces causes more wear than when the parts are dry.

VI

ADJUSTMENT (See Fig. VI-3)

1. Exhaust the air from the brake cylinders by turning the truck cut-out cock under the deck.

FIG. VI-3, E-13505B

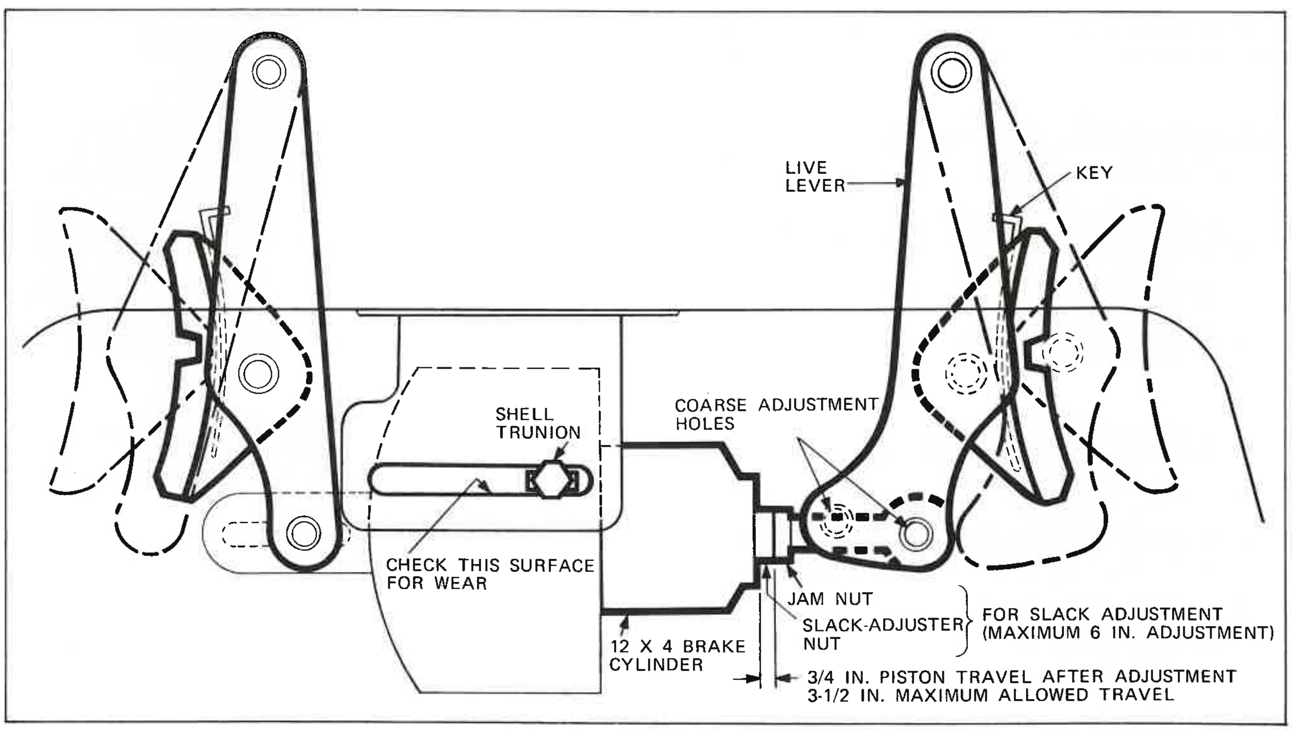


FIG. VI-3. BRAKE-RIGGING ARRANGEMENT.

2. Loosen the jam nut on the piston push rod, and turn the adjusting nut. To reduce piston travel, turn the nut to move the shoes closer to the wheels; to increase piston travel, move the shoes away from the wheels. After adjustment, tighten the jam nut.
3. Piston travel should be held as close as possible to a low limit of 3/4 in. Travel should not exceed 3-1/2 in. maximum.
4. When piston travel cannot be adjusted with slack-adjuster movement alone, a coarse adjustment becomes necessary. To make a coarse adjustment, reconnect the lower end of the live lever to another set of coarse adjustment holes in the live lever, and reconnect to the cylinder push rod.

BRAKE SHOE REMOVAL

1. Exhaust the air from the brake cylinder.
2. Move the shoes as far as possible from the wheel tread by adjusting the manual slack adjuster and/or picking-up the coarse adjustment.
3. Hammer the keys out of the brake-shoe head.
4. Knock the shoes loose from the brake head, and remove them by sliding them up the wheel and out.

BRAKE SHOE INSTALLATION

1. Insert new shoes in the brake heads and line up the keyways.
2. Drive the keys into place and check the shoes for tightness.
3. Adjust the manual slack adjuster to obtain 3/4 in. brake-cylinder piston travel.
4. Assure the brake-cylinder cut-out cocks are open when the work is finished.

HANDBRAKE

On three-axle floating-bolster trucks with low hung brake cylinder, a QR, or quick-release valve, is provided which removes the air in the brake cylinder which is in handbrake leverage system. Handbrake chain must trip the stem of the QR valve and no trapped air is permitted in the brake cylinder. Otherwise, if locomotive air pressure leaks off, the locomotive can roll on down the track.

NOTE: *Air is not reapplied to affected cylinder with release of handbrake, only with reapplication of air brakes, and stem is not tripped.*

TWO-AXLE FLOATING BOLSTER TRUCK

DESCRIPTION

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

The truck frame is a one-piece steel casting and rests on coil springs which are seated on the journal housing, Fig. VI-4.

TRUCK REMOVAL

1. Disconnect the ground lead cables and four power cables at each traction motor.
2. Disconnect the ground cable between the bolster and the platform.
3. Disconnect all the sander hoses from the sander nozzles on the truck.
4. Disconnect the air brake hoses from the truck brake-cylinder pipes.
5. Disconnect the axle alternator cables from the junction box on the journal housing adapter. Coil and secure the cable so it will not be damaged. Also disconnect the speed control governor drive or cable.
6. Remove or secure the flange lubricators (if used).
7. Remove the retaining bolts for safety hook pins, and the safety hook pins (two per truck) from trucks or truck to be removed.
8. Disconnect the handbrake chain from the brake lever.
9. Disconnect the traction motor air boot from the traction motors.
10. Raise the locomotive platform clear of the trucks with jacks or crane, or lower the trucks on drop table watching that the cables, air ducts and hoses will not be damaged. If the trucks are to be pulled out sideways, the platform will have to be raised (or trucks lowered) at least 10 in. on locomotive. Fig. VI-5 shows lifting hook and loading pad.
11. After the truck is removed from under the locomotive, cover the air duct openings on all the traction motors and cover the truck centerplate to prevent entrance of dirt and other foreign matter.

FIG. VI-4, E-19120

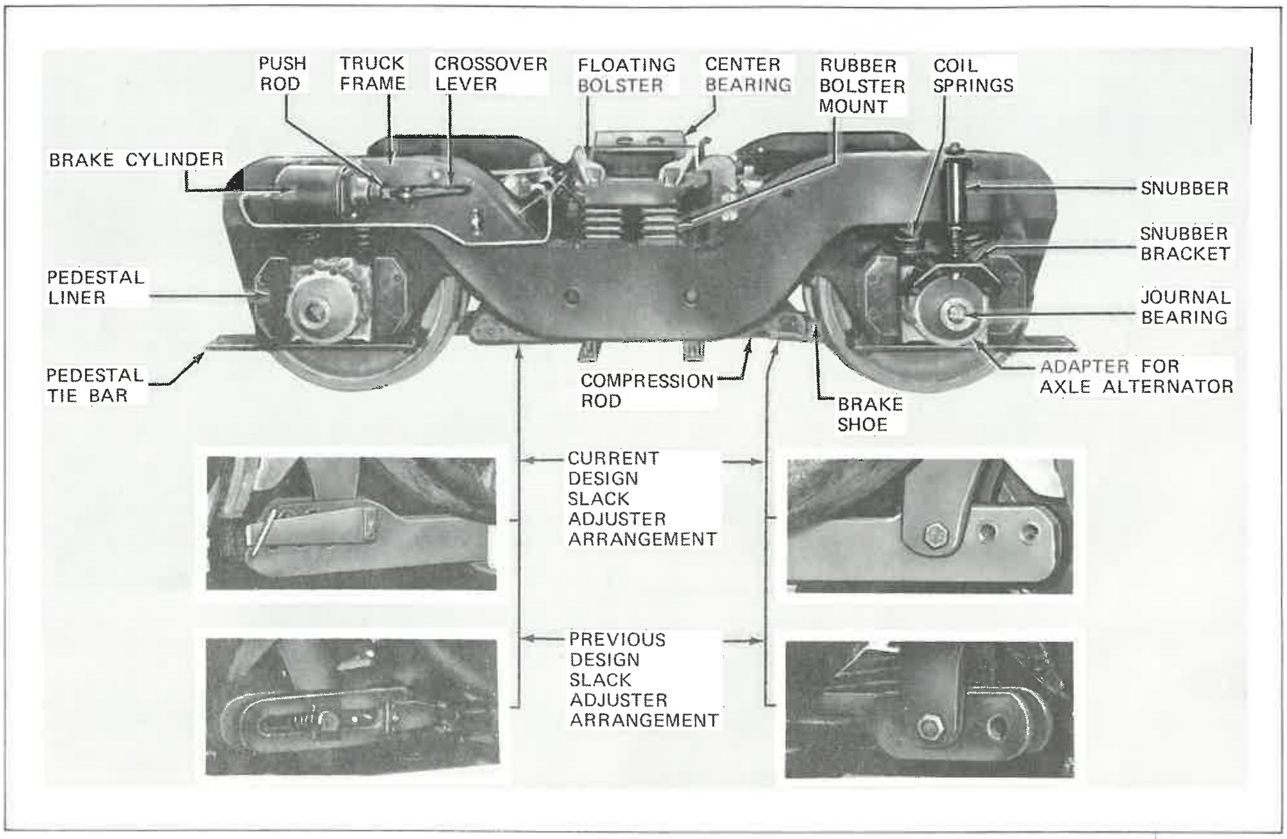


FIG. VI-4. TRUCK ASSEMBLY.

Removal of One Truck

1. Prepare the truck to be removed as outlined in Truck Removal section.

FIG. VI-5, E-19121

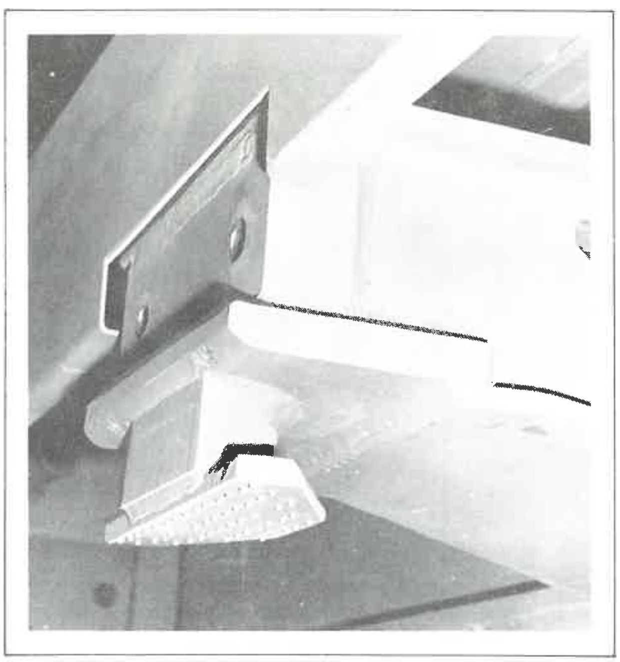


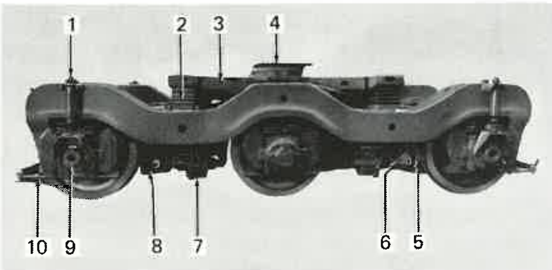
FIG. VI-5. LIFTING HOOK AND LOADING PAD.

2. Remove the safety hooks on both trucks.
3. Raise the platform high enough to disengage both centerplates; otherwise the centerplate may be damaged from cocking. Roll the truck from beneath the platform. If this work is done with a drop table in pit, the second truck does not have to be touched.

TRUCK INSTALLATION

1. Space the trucks for a centerplate-to-centerplate spacing of 30 ft. 8 in. The No. 1 truck has the speed record on the No. 1 journal and on the right-side of the locomotive. Handbrake is also on the No. 1 truck.
2. Inspect the truck centerplates and clean out any dirt, metal chips, etc. Lubricate the centerplates by adding 3 pt. mixture of car oil and dry graphite to each centerplate. The mixture proportions are 1 gal. of car oil to 1/2 lb. of dry graphite.
3. Install the dust guard and the retaining clamp.
4. Remove the covers from motor air duct openings.
5. Lower the platform onto truck (or raise truck on drop table), carefully engaging the centerplates.

VI



REF.	DESCRIPTION
1	SNUBBER
2	BOLSTER MOUNT
3	BOLSTER
4	CENTER BEARING
5	BRAKE SHOE
6	BRAKE HANGER
7	BRAKE CYLINDER
8	TRACTION MOTOR
9	JOURNAL BEARING
10	PEDESTAL TIE BAR

FIG. VI-6. TYPICAL TRUCK ASSEMBLY (WITH 12 X 4 BRAKE CYLINDER).

VI

6. Attach all safety hook pins and pin retainers.
7. Connect the ground lead cables and the four motor cables to each traction motor.
8. Connect the ground cable between the bolster and the platform.
9. Connect the air brake hoses from the platform to the brake cylinder pipes on truck. Be sure to open the cut-out cocks in these pipes under the platform before placing the locomotive in service.
10. Install the hoses from the sand pipes on the platform to the sander nozzles on the trucks.
11. Connect the handbrake chain to the brake lever.
12. Connect the axle alternator cables to the journal housing junction box. Also connect the speed control governor cable.
13. Be certain that the journal bearings, traction motor gear cases and traction motor suspension bearings are lubricated before moving locomotive.
14. Adjust the brake rigging.
15. Check the traction motor rotation.

THREE-AXLE FLOATING BOLSTER TRUCK

DESCRIPTION

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

The truck frame is a one-piece steel casting and rests on coil springs which are seated on the journal housing, Fig. VI-6.

FIG. VI-6, E-16145

TRUCK REMOVAL

1. Disconnect the ground lead cables and all four power cables at each traction motor.
2. Disconnect the ground cable between the bolster and the platform.
3. Disconnect all the sander hoses from the sander nozzles on the truck.
4. Disconnect the air brake hoses from the truck brake-cylinder pipes.
5. Disconnect the axle alternator cables from the junction box on the journal housing adapter. Coil and secure the cable so it will not be damaged. Also disconnect the speed control governor drive or cable.
6. Remove or secure the flange lubricators (if used).
7. Remove the retaining bolts for safety hook pins, and the safety hook pins (two per truck) from trucks or truck to be removed.
8. Disconnect the handbrake chain from the brake lever.
9. Disconnect the traction motor air boot from the traction motors on the end motors only.
10. Disconnect the snubbers or shock absorbers from the journal box housing.
11. Raise the locomotive platform clear of the trucks with jacks or crane, or lower the trucks on drop table watching that the cables, air ducts and hoses will not be damaged. If the trucks are to be pulled out sideways, the platform will have to be raised (or trucks lowered) at least 10 in. on locomotive. Fig. VI-7 shows lifting hook and loading pad.

FIG. VI-7, E-5559

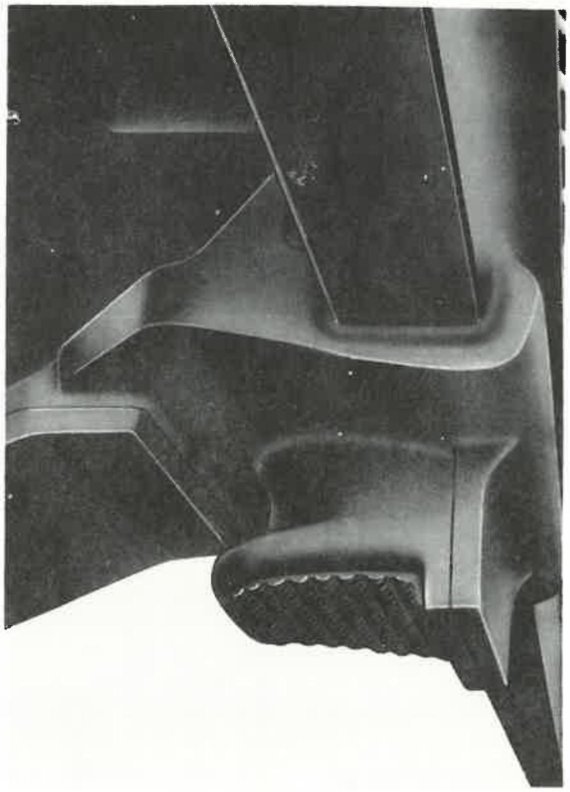


FIG. VI-7. LIFTING HOOK AND LOADING PAD.

12. After the truck is removed from under the locomotive, cover the air duct openings on all the traction motors, and cover the truck centerplate to prevent entrance of dirt and other foreign matter.

Removal of One Truck

1. Prepare the truck to be removed as outlined in Truck Removal section.
2. Remove the safety hooks on both trucks.

> **CAUTION:** *Raise the platform high enough to disengage both centerplates; otherwise the centerplate may be damaged from cocking.*

3. Roll the truck from beneath the platform. If this work is done with a drop table in pit, the second truck does not have to be touched.

TRUCK INSTALLATION

1. Locate the trucks for a centerplate-to-centerplate proper spacing. The No. 1 truck usually has the speed recorder on the No. 1 journal and on the right-side of the locomotive. A handbrake is normally fitted on the No. 1 truck.
2. Inspect the truck centerplates and clean out any dirt or metal chips. Lubricate the centerplates by adding 3 qt. mixture of car oil and dry graphite to each centerplate. The mixture proportions are 1 gal. of car oil AAR Spec. M-906 to 1/2 lb. of dry graphite AAR Spec. M-913.
3. Install the dust guard and the retaining clamp.
4. Remove the covers from motor air duct openings.
5. Lower the platform onto trucks (or raise truck on drop table) carefully engaging the centerplates.
6. Attach all safety hook pins and pin retainers.
7. Attach the snubbers to the journal housings, if not already attached.
8. Connect the ground lead cables (if used) and the four motor cables to each traction motor.
9. Connect the ground cable between the bolster and the platform (if used).
10. Connect the air brake hoses from the platform to the brake cylinder pipes on truck. Be sure to open the cut-out cocks in these pipes under the platform before placing the locomotive in service.
11. Install the hoses from the sand pipes on the platform to the sander nozzles on the trucks.
12. Connect the handbrake chain to the brake lever.
13. Connect the axle alternator cables to the journal housing junction box. Also connect the speed control governor cable.
14. Assure the journal bearings, traction motor gear cases and traction motor suspension bearings are lubricated before moving locomotive.
15. Adjust the brake rigging.
16. Check the traction motor rotation.

VI

TRANSPORTATION SYSTEMS BUSINESS DIVISION

ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

COMPRESSED AIR EQUIPMENT

CONTENTS

INTRODUCTION

This section covers the Gardner-Denver Types WBO and WBG Air Compressor. The air compressor, during normal locomotive operation, supplies the high-pressure air needed for the air brake system.

AIR COMPRESSOR
(Gardner-Denver Types WBO and WBG)

DESCRIPTION

This instruction applies to three or six-cylinder, two-stage, water-cooled air compressors. The low-pressure cylinders are mounted at an angle on each side of the machine, and the high-pressure cylinders are mounted vertically in the center of the machine. One air suction valve and one discharge valve are located in the head over each cylinder bore. A water-cooled intercooler is provided to cool the air as it passes from the low-pressure to the high-pressure cylinders, Fig. VII-1.

INSPECTION AND LUBRICATION

General

Oil level in the crankcase must be maintained in the RUN ZONE on the oil level gage. Add oil as required to maintain the correct level.

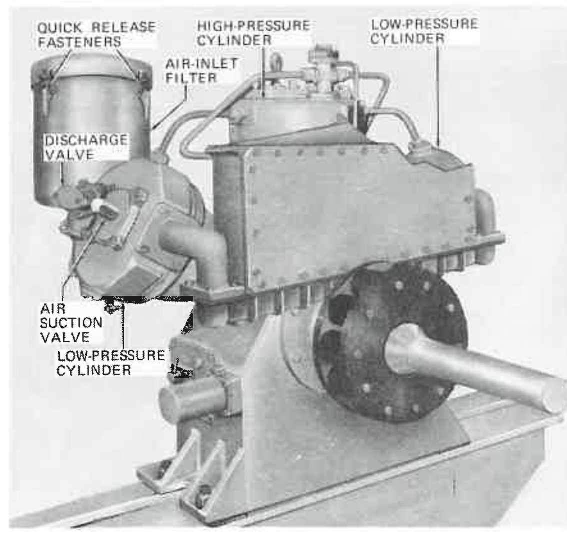


FIG. VII-1. GARDNER-DENVER AIR COMPRESSOR, TYPICAL (SHOWN UNDER ASSEMBLY).

Oil pressure should be set 18-20 psig at engine idle (450 rpm), when the compressor lube oil is at 140 F. Oil pressure is controlled by an oil-relief valve mounted on the side of the crankcase at the intercooler end, Fig. VII-2. Oil pressure is adjusted by adding or removing shims beneath the pressure-adjusting cap on the oil-relief valve (adding shims reduces pressure).

Thoroughly clean the crankcase each time the oil is changed. Dirt and sludge, if left in the crankcase, will be picked up by the pump; if allowed to accumulate, will eventually plug the pump section. Thereby, lubrication will be obstructed and possible damage to moving parts will result.

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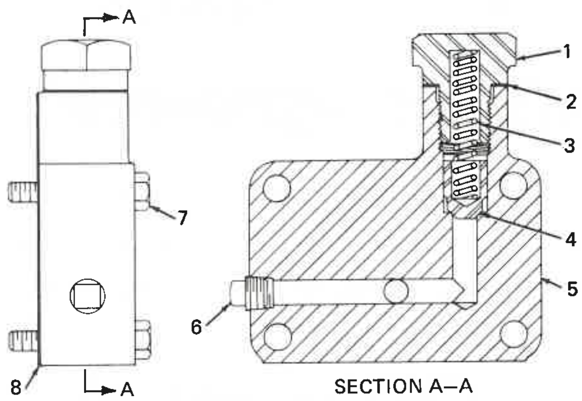

REF	DESCRIPTION
1	CAP
2	PRESSURE ADJUSTING SHIMS
3	SPRING
4	RELIEF VALVE
5	VALVE HOUSING
6	PIPE PLUG
7	SCREW
8	GASKET

FIG. VII-2. OIL RELIEF VALVE ASSEMBLY.

FIG. VII-2, E-15087A

VII

CAUTION: *An explosion inside the machine can occur if gasoline or kerosene is used for cleaning the crankcase.*

Use a regular flushing oil and wipe out the crankcase with clean, lint-free cloths.

INTERCOOLER

Drain the condensate from the intercooler through the drain valves in the bottom of the shell.

Operate the intercooler safety valve to be sure it functions properly. Note the intercooler gage pressure (when provided) while the compressor is operating. Normal operating pressure should be approximately 45 psig for WBO, and 35 psig for WBG.

The safety valve used on both machines is set for 65 psig. A defective high-pressure suction and/or discharge valve may cause the safety valve to "pop" continuously. Check safety valve for correct opening pressure. If the popping persists, refer to Table VII-II for corrective action.

ORIFICE TEST
(Per DOT Regulations)

On Locomotive

1. Use an accurate air gage and an orifice holder with an orifice bored through a 1/16-in. thick plate; leave edges square (see Table VII-I). Place the orifice and gage in the drain cock of the reservoir farthest from the compressor. Refer to Table VII-I for correct orifice.

2. Run the compressor until normal working temperature is indicated.

TABLE VII-I, ORIFICE TESTING
RESERVOIR PRESSURES (PSIG) AT VARIOUS ALTITUDES

	rpm	0	1000	2000	3000	4000	5000	6000	7000	8000
New or Repaired Compressor	450	63	60	58	55	53	50	48	45	43
	550	77	74	70	68	65	61	58	55	52
	650	91	87	83	80	76	72	69	65	62
	750	105	101	96	92	88	83	79	76	71
	850	120	115	110	105	100	95	91	85	81
	950	134	128	123	118	112	107	102	96	91
	1050	147	140	135	130	124	119	112	107	101
Condemning Limit	450	54	52	49	47	45	43	41	39	37
	550	66	64	61	58	55	53	50	48	45
	650	79	76	73	69	66	63	60	57	54
	750	92	88	83	80	79	73	69	66	63
	850	104	100	96	92	88	83	79	75	71
	950	117	113	108	104	98	94	89	84	79
	1050	129	125	120	115	110	105	100	95	90
WBO, 7-7/8 in. and 5-3/4 in. x 5 in., three cylinder – Use orifice 0.28125 (9/32) in. in 1/16 in. plate.										
WBG, 7 in. and 5-3/4 in. x 5 in., six cylinder – Use orifice 0.359 (23/64) in. in 1/16 in. plate.										

3. Open the reservoir drain cock in which the orifice is installed.

4. Run the compressor for two minutes; then, take and record a speed-pressure reading for the points on the chart in Table VII-I.

5. Run the compressor for 15 minutes; then, repeat Step 4.

6. Compare the speed-pressure readings with the data in Table VII-I. If the points fall below the condemning limit curve, remove and overhaul the compressor.

REPAIRING COMPRESSOR ON LOCOMOTIVE

If general repairs are necessary, repair the compressor without removing it from the locomotive if possible. Exercise care to assure cleanliness when any part is removed from the compressor.

When an orifice test of the compressor indicates the actual delivery of air is below the required minimum, this condition may be traceable to defective valves, worn piston rings or worn cylinders. The valves should be examined and, if necessary, replaced. If heavy carbon formation is present around the valves, the heads should be removed for thorough cleaning. Should the compressor still fail to meet requirements of the orifice test, the cylinders and pistons should be removed.

While the cylinders and pistons are thus removed, the crankcase oil should be drained and the crankcase cleaned and washed with an approved solvent to remove all sludge deposits.

WARNING: *Solvents may be toxic or flammable and cause harmful or fatal injury. Use only with adequate ventilation, avoid contact with skin, avoid inhalation of fumes and do not expose to flame or sparks.*

After the compressor is completely reassembled and before it is released for service, fill the crankcase to the proper level with recommended lubricating oil.

The cylinders and pistons removed from the compressor should be reconditioned for future use.

When ring removal is necessary, the old rings should be discarded and replaced with new ones. To insure the rings are installed with the minimum possibility of damage, a ring installation tool should be used. As an alternate, use thin, narrow strips of metal to bridge the vacant ring grooves

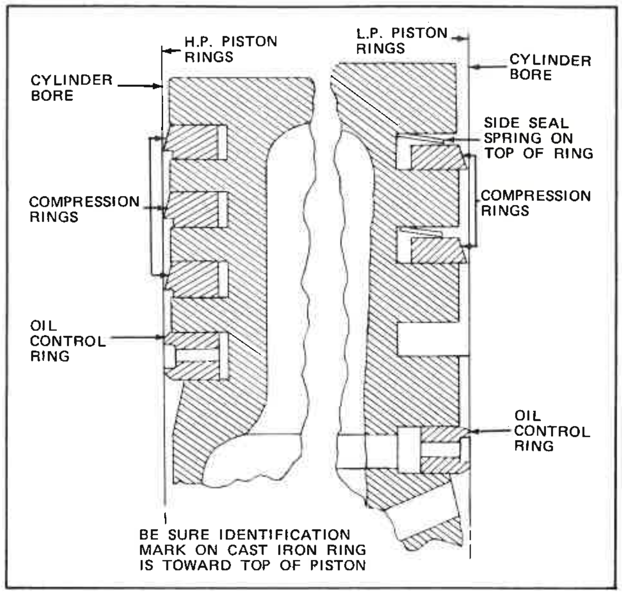

FIG. VII-3. PROPER PISTON RING ARRANGEMENT.

when applying the rings. Taper-face rings must be installed with the scraping edges arranged to force the oil towards the crankshaft. The side that goes up can be identified by a special mark, or word "TOP." Do not apply straight-face rings. They are slow in seating and do not control oil carry-over as well as the original-equipped taper-face type.

NOTE: *Compression rings are marked on top with an identification mark to insure proper application, Fig. VII-3. The oil control rings are not marked, as they may be applied with either side up.*

On the low-pressure piston, the compression rings with side seal springs are applied to the first two top grooves. The third groove is left open. The side seal spring is always above the ring.

Oil control rings are always in the bottom groove of the piston.

NOTE: *For air compressor shaft alignment, refer to the Mechanical Equipment section of this composite manual.*

Oil Pump

Plunger Type

The oil pump should fit the crankshaft to the limits listed in the Data section. If the clearance limit is exceeded, a new oil pump eccentric will be required. The plunger-type oil pump should be inspected for scoring and excessive wear. If the clearance limit is exceeded as given in the Data section, a new pump assembly should be installed.

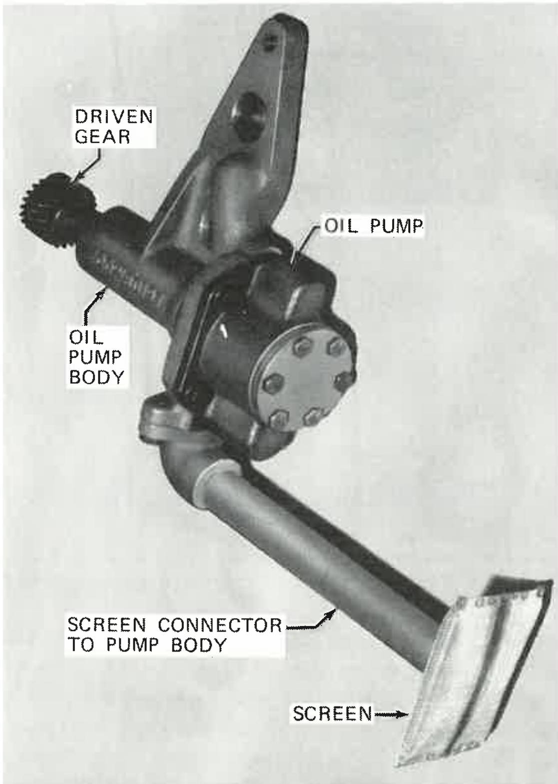

FIG. VII-4. NEW GEAR TYPE LUBE PUMP (STARTING WITH WBG-9510 AND WBO-9516).

Gear Type (See Figs. VII-4 and VII-5)

The condition of the pump can be determined best by removing the head plate and checking the internal parts for excessive wear. End clearance is set by adding or removing plastic gaskets until the pump shaft can be rotated freely by hand.

The lube-pump drive shaft end-play should be between 0.001 and 0.004 in. Push tapered roller bearing on tang end of shaft up with adjusting nut until shaft end-play is within limits. Advance adjusting nut to next locking position and secure with locking washer. Refer to Fig. VII-6 for internal clearances.

Lube Oil Filter

Take oil pressure readings at the two tapped openings on the side of the oil-relief valve body. When a difference of 14 psig in the two readings is reached at engine idle (450 rpm), replace the filter.

Oil-Pressure Relief Valve

The oil-pressure relief valve should be completely disassembled, thoroughly cleaned and inspected. All passages should be blown out, using compressed air. The valve should then be reassembled. Reset after installation on compressor.

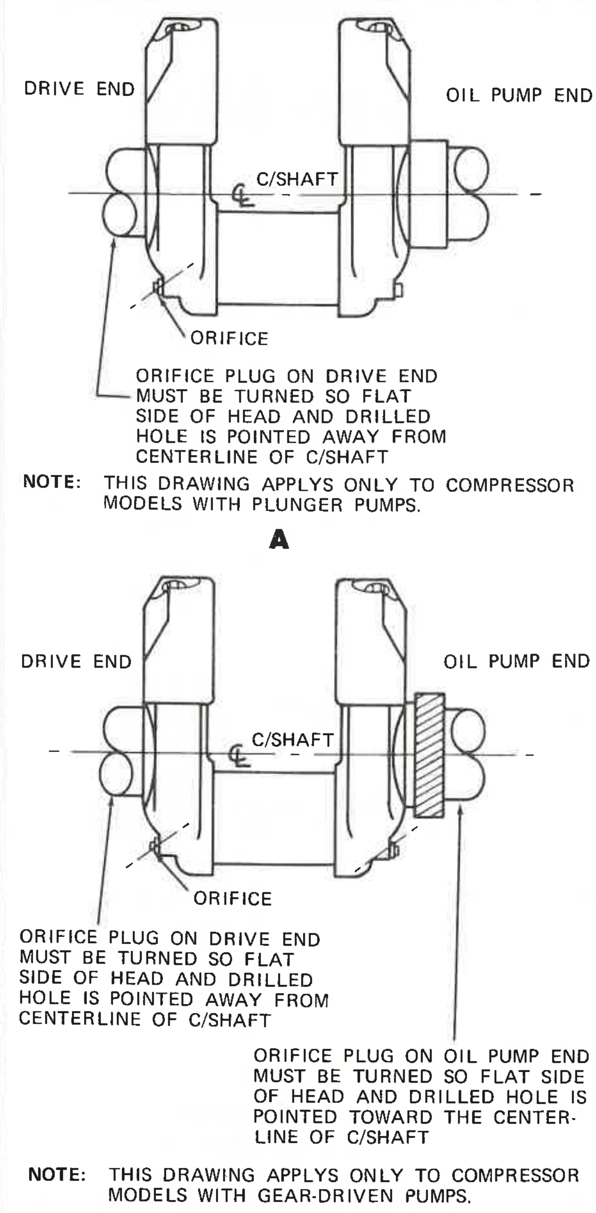

FIG. VII-5. CRANKSHAFT ORIFICE PLUG ARRANGEMENT.

FIG. VII-4, E-21088

FIG. VII-5, E-21090

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

VII

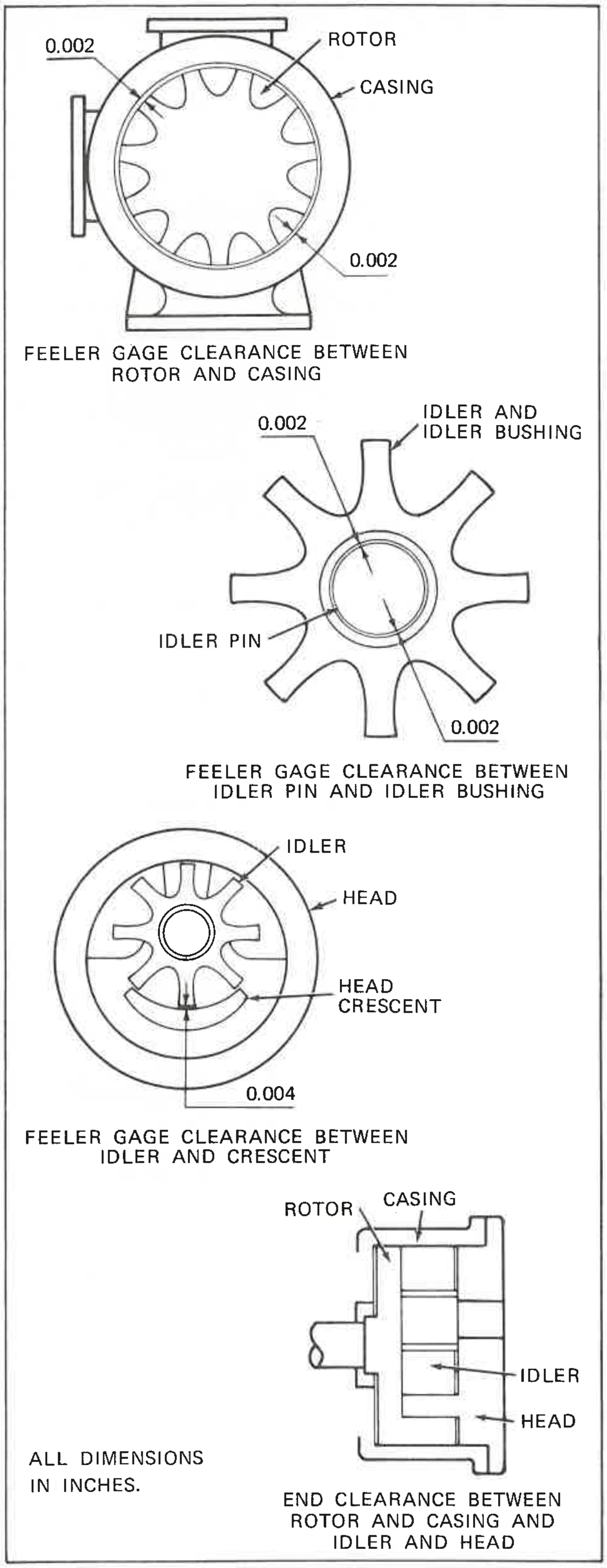

FIG. VII-6. GEAR TYPE LUBE PUMP INTERNAL CLEARANCES.

Intercooler

Intercoolers should be removed when compressor is overhauled for cleaning inside and out. Accumulated dirt and oil residue should be removed from air passages to assure maximum efficiency. Back plate should be disassembled to clean cooling water passages to assure full coolant flow. These passages will become plugged with long service operation.

DATA

Crankcase Capacity (gal.)	
WBO Series	10-1/2
WBG Series (Small Crankcase)	3-1/2
WBG Series (Large Crankcase)	17-1/2
Clearances (in.)	
Low-Pressure Cylinder, Oil Control Ring Gap (Min.)	0.008
Low-Pressure Cylinder, Piston to Cylinder (Min.)	0.0035
High-Pressure Cylinder, Oil Control Ring Gap (Min.)	0.006
High-Pressure Cylinder, Piston to Cylinder (Min.)	0.003
Connecting-Rod Bearing to Crankpin Diameter Clearance (Min.)	0.0012
Connecting-Rod Side Clearance (Total for Three Rods) (Min.)	0.013
Piston Pin to Bushing Clearance (Min.)*	0.001
Oil Pump Eccentric to the Crankshaft	
Minimum	0.001
Maximum	0.003
Oil-Pump Plunger to Oil-Pump Body Clearance	
Minimum	0.001
Maximum	0.003
Main Bearings End Clearance (Cold)	
WBO	0.008-0.010
WBG	0.010-0.012

TROUBLE-SHOOTING

The intercooler is an important part of a compressor and should receive special attention during inspection and maintenance. In a two-stage compressor, the air drawn into the cylinders of the low-pressure stage is heated by compression and forced into the intercooler at a pressure of approximately 35 to 45 pounds. The intercooler then removes a large portion of this heat before the air enters the high-pressure stage.

Whenever it is necessary to determine if a valve is faulty, begin by checking at the intercooler, Table VII-II.

*Current units have caged roller bearings in high pressure pistons.

VII

Considerable time can be saved by using the following procedure for locating a defective valve:

1. Remove pipe plug in intercooler and apply a 0-75 psi air gage.

2. If the intercooler pressure is abnormally high ONLY when pumping, inspect the high-pressure suction and discharge valves.

3. If the intercooler pressure increases slowly when unloaded, check the high-pressure discharge valves or high-pressure suction unloading mechanism.

4. If the intercooler pressure is abnormally low when pumping, and drops to zero pressure in less than three minutes when unloaded, the low-pressure discharge valves should be inspected.

5. If the intercooler pressure is abnormally low when pumping, but drops only a few pounds after being unloaded three minutes, the low-pressure suction valves should be inspected.

6. If it has been determined the trouble is in the low pressure stage, the particular valve at fault will usually have a weak or erratic suction sound, abnormal blowback from the air filter when pumping or an excessively hot discharge-valve cover plate.

NOTES:

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TABLE VII-II, TROUBLE-SHOOTING

CAUSE ↓ / EFFECT →	Higher Than Normal Inter-Cooler Pressure (Loaded)	Higher Than Normal Inter-Cooler Pressure (Un-Loaded)	Lower Than Normal Inter-Cooler Pressure (Loaded)	Inter-Cooler Pressure Drops To Zero (Un-Loaded)	Inter-Cooler Pressure Rises (Compressor Stopped and Un-Loaded and Pressure In Main Reservoir)	Compressor won't Pass Orifice Test	Excessive Carbon Build-Up On Valves	Abnormal Wear Of Valve Components Cylinders, & Rings	Piston Rings Plugged and/or Stuck In Grooves	Noisy Valve	Disc Breakage	Low Oil Pressure Indication	Excessive Blow Back Through Suction Filter (Loaded)	Inter-Cooler Safety Valve Pops
Low Pressure Suction Valve Leaking			●			●								
Low Pressure Discharge Valve Leaking			●	●		●								
High Pressure Suction Valve Leaking	●					●								●
High Pressure Discharge Valve Leaking	●	●			●	●								●
Valve Seat Gasket Leaking	●	●	●	●		●							●	●
Lower Unloader Spring Broken										●				
Broken Valve Disc	●	●	●	●		●							●	●
Valve Spring Collapsed or Broken	●									●	●			
Valve Clamp Loose										●				
Suction Filter Plugged			●			●								
Defective Air Filter							●	●	●					
Piston Rings Worn, Stuck and/or Broken						●	●							
Cylinder Worn and/or Scored						●	●							
Defective Safety Valve														●
Wrong Lube Oil							●	●			●			
Defective Gage												●		
Broken Oil Pressure Relief Valve Spring												●		
Oil Relief Valve Set Too Low												●		
Excessive Wear:														
Conn Rod Bearings and Crankshaft Throw												●		
Oil Pump Eccentric Strap and Crankshaft Eccentric												●		
Oil Pump Plunger and Oil Pump Body												●		
Oil Pump Inlet and/or Check Valve Leaking												●		

Plugged Crankcase Breather or Vent Tube — Effect: 1. Pressure Build-up in Crankcase 2. Oil Seal Leaks

VII

TRANSPORTATION SYSTEMS BUSINESS DIVISION
ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

SYSTEMS

CONTENTS

INTRODUCTION

This section presents a diesel-electric locomotive analysis and also covers the various electrical systems on-board the locomotive. Those systems that support the diesel engine are covered in the Engine Support Systems section (Section X).

The intent of this section is to provide an understanding of how individual items of equipment contribute to the functioning of each pertinent system. This will aid maintenance personnel in diagnosing malfunctions and determining the correct procedure to be followed to resolve problems. It also is intended to be used in conjunction with the Trouble-Shooting section (Section XII), the Engine Support Systems section (Section X) and the applicable locomotive system schematic to diagnose problems when they occur.

It should be noted that variations in the systems will exist between different models of locomotives and between railroad customers. Also, because of the complexity of the systems, liberties have been taken in the method of presentation. Some systems are presented as block diagrams and some as line drawings. One additional system, Engine Systems Monitor (ESM), is presented as a separate entity. In all cases, the diagrams and drawings are intended for the general guidance of personnel.

DIESEL-ELECTRIC LOCOMOTIVE ANALYSIS

The intent of this section is to present a very brief, functional analysis of a diesel-electric locomotive. Fig. VIII-1 reflects the partitioning of the locomotive into five (5) basic areas. The major items of equipment that pertain to these areas are covered elsewhere within the composite maintenance manual.

VIII

DIESEL ENGINE POWER SOURCE

The diesel-electric locomotive utilizes an 8, 12 or 16-cylinder, four-stroke diesel engine rated up to 3600 horsepower. The engine and its associated systems are shown in Fig. VIII-2.

POWER TRANSMISSION AND CONVERSION

The power transmission and conversion equipment, Fig. VIII-3, is used to generate a force at the coupler for pulling (or pushing) a train. The mechanical power from the diesel engine is converted to electrical power by a directly-coupled traction alternator. The a-c from the alternator is rectified by the three-phase power rectifier

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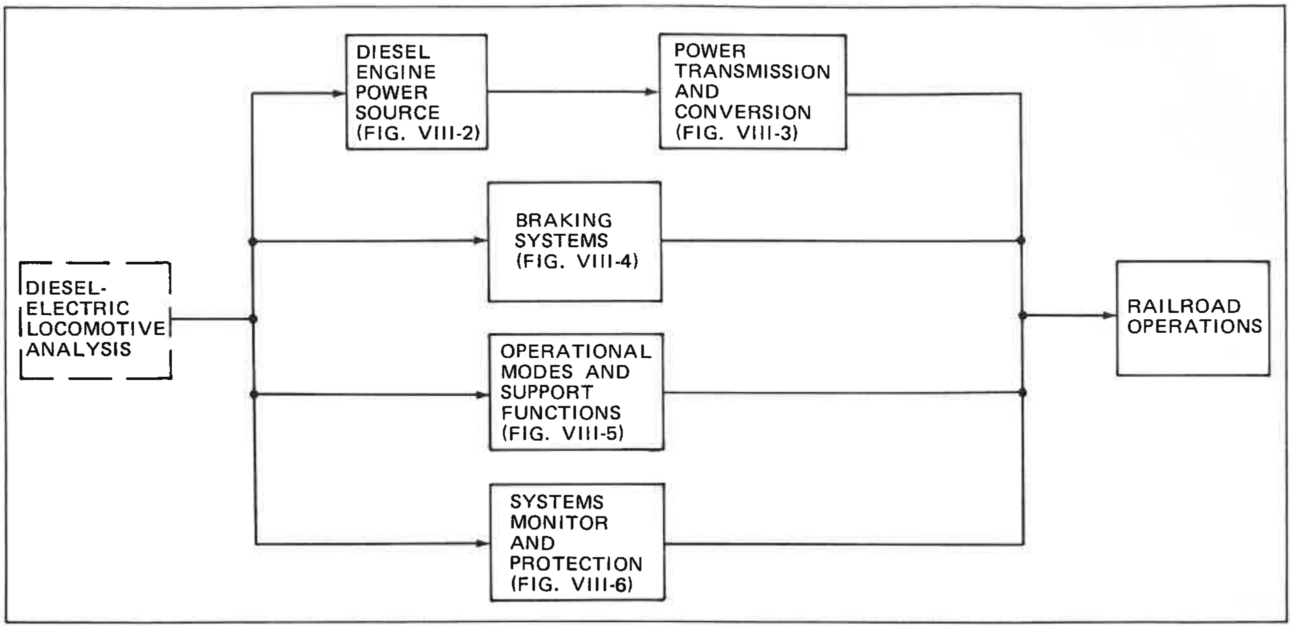


FIG. VIII-1. DIESEL-ELECTRIC LOCOMOTIVE ANALYSIS.

FIG. VIII-1, E-25257

into d-c and transmitted to the traction motors which are geared to the locomotive axles/wheels. Tractive effort developed between the wheels and the rail is transmitted through the locomotive platform to produce the required force at the coupler.

BRAKING SYSTEMS

VIII

There are three basic braking systems, Fig. VIII-4, on the locomotive with a fourth system available as a customer option.

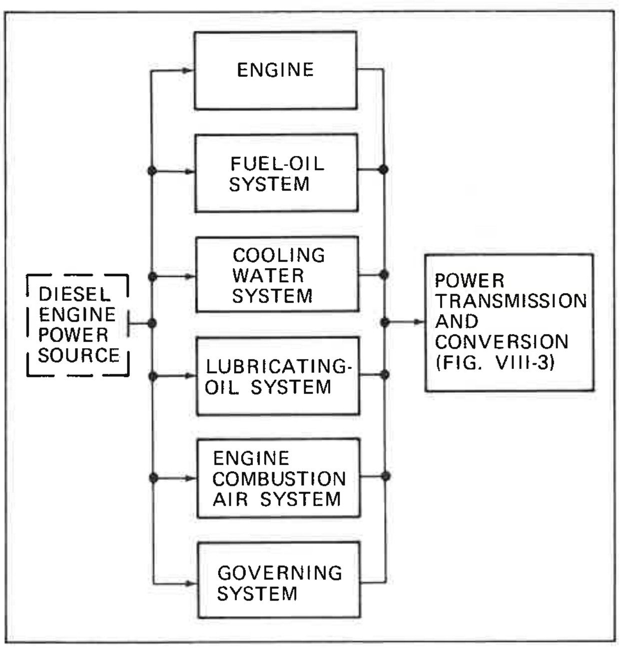


FIG. VIII-2. DIESEL ENGINE POWER SOURCE.

FIG. VIII-2, E-25258

Air Brake

The air brake system regulates the air brake applications, whether Service or Emergency, in proportion to the position of either brake handle. The air brake system utilizes the following equipment and components:

1. An air compressor regulated to maintain air pressure within a preset range in the main reservoirs
2. Two main reservoirs which store a supply of air for the system
3. A brake valve at the operator's position for application of air brakes
4. Tread brake units to provide friction braking on the wheels
5. The necessary piping, pressure switches and control valves for controlled braking.

Dynamic Braking

The dynamic braking system provides a means of reducing train speed by converting inertia into heat energy. This is accomplished by operating the traction motors as generators whose output power is dissipated into resistor grids. Configuration of the traction motor circuits for dynamic braking is controlled by moving the Throttle handle to IDLE position and the Braking handle to SET-UP position. This operates a sequence of interlocking relays and switch contactors which connect the traction motor

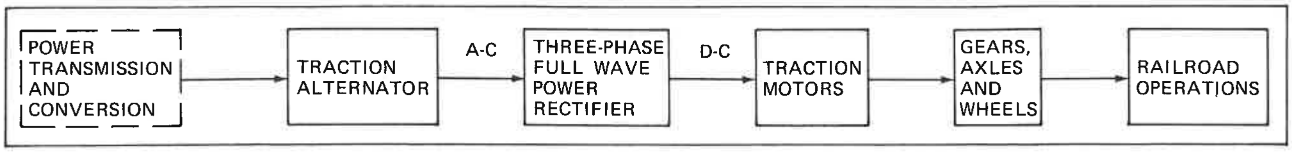


FIG. VIII-3. POWER TRANSMISSION AND CONVERSION.

fields in series to the rectified traction alternator output, and connects the traction motor armatures to the grid resistors.

The magnitude of the dynamic braking power is controlled by setting the braking control potentiometer between the minimum-maximum positions using the Braking handle. Feedback from the Braking Current Reactor (BCCR) is used to measure the magnitude of the current in the braking resistor grid. At high train speeds the braking current is held constant for any setting of the Braking handle by comparing the feedback current with a reference value set by the Braking handle position. The Constant Horsepower Excitation Control (CHEC) circuits adjust the traction motor field current to the value needed to produce the required braking current.

As train speed is reduced, the required field current increases until the rated field current is reached. As train speed is further reduced, the maximum rated traction motor field current is held constant and braking current is reduced linearly with speed.

Blended Braking

Blended braking, which is a customer option, is usually used on high-speed locomotives used in passenger service. Blended braking, basically, is a combination of air and dynamic braking systems.

Handbrake

The handbrake is used primarily as a parking brake and is applied manually. It is a mechanical system.

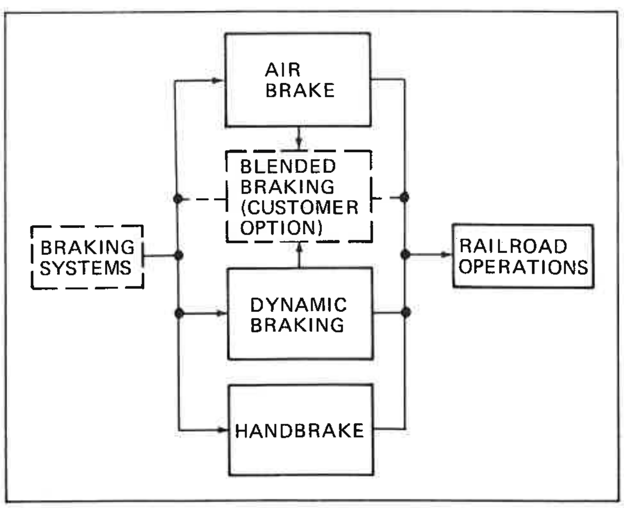


FIG. VIII-4. BRAKING SYSTEMS.

OPERATIONAL MODES AND SUPPORT FUNCTIONS

Fig. VIII-5 depicts the relationship of several operational modes and their supporting functions. The horizontal line on Fig. VIII-5 between Engine Start/Run and Engine Stop may be thought of as an idle state from and to which other modes may be entered or exited. Motor Cut-Out is a special case of motoring which may be entered while the Engine Control switch is in the START position.

Engine Start/Run

The function of the Engine Start/Run subsystem is to provide the switches, circuit breakers and relay interlocks needed to configure the starter, generator, pre-lube pump and fuel pump for starting and running the diesel-engine.

Motor Cut-Out

The Motor Cut-Out operation is an optional capability to allow motoring with one (or more) traction motor(s) electrically disconnected from the traction-alternator power output circuit. This mode of operation may be necessary if for some reason a malfunction in the traction motor circuitry prevents normal motoring operation. On six-axle locomotives, traction motors are usually cut-out in pairs.

Self-Load

The Self-Load mode is an optional capability provided to allow testing of the locomotive under load without actually developing tractive effort.

In this mode, the grid resistors normally used in dynamic braking are used as a load for the traction alternator output and power to the traction motors is disconnected. Interlocking is provided to prevent switching into or out of self-load while under power. Also, while in the self-load mode, engine speed and excitation control continue to function as in normal motoring.

Motoring

The function of the Motoring mode of operation is to provide the throttle controls, relays, logic and reference circuits needed to control powered operation of the locomotive.

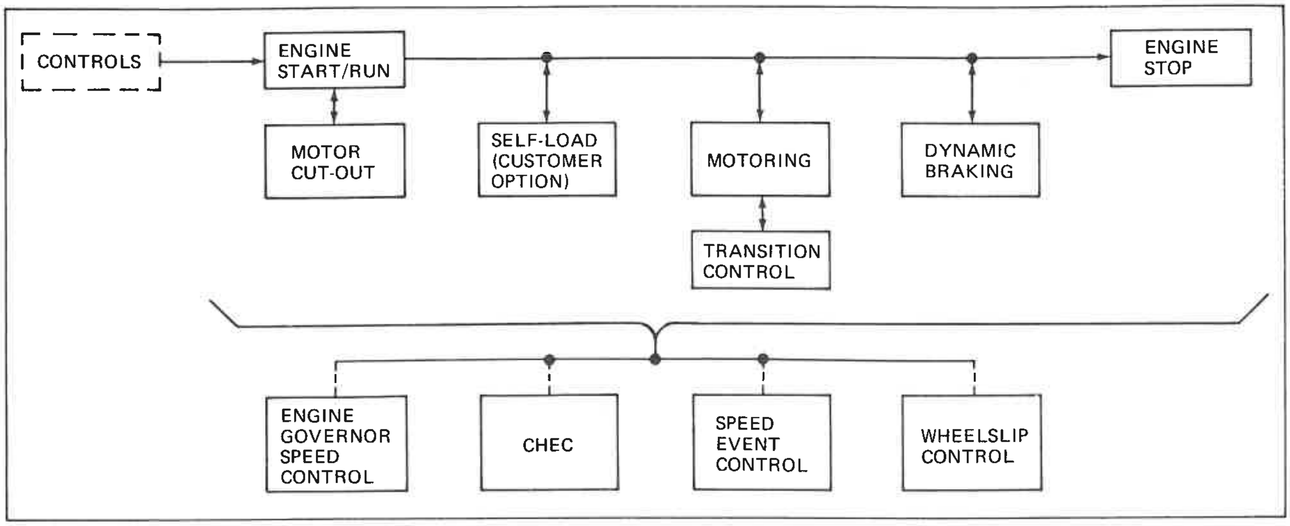


FIG. VIII-5. OPERATIONAL MODES AND SUPPORT FUNCTIONS.

FIG. VIII-5, E-25261

The Throttle handle located on the operator's control console has eight notch settings plus IDLE and STOP. Movement of the Throttle handle controls the diesel engine speed for each notch setting, sets current, voltage and power limits for each notch setting and provides control relay interlocks for the motoring functions.

The Reverse handle located on the operator's control console has two positons; FORWARD and REVERSE. These two positions control the direction of travel of the locomotive by setting the Reverser switch contactors in the FORWARD or REVERSE position.

VIII

Transition Control

The function of the Transition Control mode is to change the configuration of the traction motors from a series-parallel configuration to an all-parallel configuration when the locomotive increases speed above the transition speed point (approximately 25 mph). It will also change from an all-parallel configuration to a series-parallel configuration when the locomotive decreases speed 2 mph (approximately) below the transition speed point.

The transition control circuit senses locomotive speed from an axle-mounted alternator which develops a signal proportional to locomotive wheel speed. This speed signal is compared with a reference speed signal within the Speed Event Panel and the output of this comparison function then generates a transition control signal that initiates the transition action.

The reason for having a transition control circuit is because very high traction motor currents are required to initially start the train moving. Conversely, very high motor voltage is required to operate the train at the higher speeds. (The motoring operation covers train speeds up to approximately 70 mph.) In order to reduce the output requirements of the traction alternator to practical values of current and voltage, the traction motors are operated in a two-series/two-parallel configuration for four-axle locomotives (two-series/three-parallel for six-axle locomotives) at low train speeds and in a four-parallel (six-parallel for six-axle locomotives) at high train speeds. The transition control circuitry provides the mechanism for switching back and forth between the series-parallel and parallel configurations as the train speed varies.

Dynamic Braking

The Dynamic Braking mode has been explained in the Braking Systems section. It operates through the CHEC system to control the magnitude of the braking current and to limit the current in the field of the traction motors to a rated value.

Engine Stop

The Engine Stop mode consists of two procedures for shutting down the diesel engine; normal shutdown and emergency shutdown.

Normal shutdown involves an orderly shutdown where the Throttle handle is moved to IDLE (load removed) and the operator performs the normal shutdown procedure including pushing the ENGINE STOP push-button.

Emergency shutdown of all engines in a consist is generally reversed for emergency conditions where the normal shutdown is not adequate. In this situation, the Throttle handle is moved to the STOP position to activate the MU3 trainline and de-activate the MU16 trainline. All locomotives in the consist will respond to these signals to cause engine shutdown.

Controls

The controls shown in Fig. VIII-5 provide the support functions for the operational modes. There are many more "controls" that support the operational modes; however, the Engine Governor Speed Control, CHEC, Speed Event Control and Wheelslip Control may be considered as major control circuits. Each of these is explained in detail elsewhere within this publication.

SYSTEMS MONITOR AND PROTECTION

The monitor, alarms and controls systems for engine and crew protection are shown in Fig. VIII-6. As stated before, this is a very brief functional analysis of the overall locomotive systems monitor and protection events. For a more comprehensive explanation of the monitoring of the engine systems, refer to the ENGINE SYSTEMS MONITOR section.

Fig. VIII-6 covers four major categories:

1. Monitors and controls that serve the purpose of warning the operator

2. Monitors and controls that cause the engine to unload and return to idle speed

3. Monitors and controls that cause a reduction of excitation and load to meet the unit's capabilities (system derated)

4. Monitors and controls that cause the engine to shut down.

One additional control (sanding) is included in Fig. VIII-6. An indication (status) light will be lit when manual sanding is activated by the operator.

All of the items shown on Fig. VIII-6 are covered, in part, elsewhere within this publication or, in detail, within the composite maintenance manual furnished with the locomotive.

ELECTRICAL

BASIC PROPULSION SYSTEM

The basic propulsion system, Fig. VIII-7, consists of the diesel engine, traction alternator, power rectifiers and traction motors.

Assuming all controls and switches are set-up correctly, when the operator pushes the ENGINE START push-button, Fig. VIII-7, current will flow from the battery to the cranking motor to start the diesel engine. After the engine is at idle speed and before the locomotive is to be operated, the ENGINE CONTROL switch must be moved to the RUN position to bring the engine up to speed. The locomotive is now ready for the operator to apply propulsion power by operating the Master Controller.

The diesel engine is mechanically coupled to the traction alternator. The traction alternator is a rotating machine which converts the mechanical energy from the diesel engine into electrical energy. This electrical energy consists of three-phase a-c which is rectified by three banks of power rectifiers; one bank for each phase. The resultant d-c is then applied to the traction motors. The function of the traction motors is to convert the d-c electrical energy into mechanical power for driving the locomotive wheels.

BASIC CONTROL SYSTEM

The basic control system, Fig. VIII-8, provides the means of controlling the propulsion system during the motoring operation. It should be noted that the braking system mode is not shown on Fig. VIII-8, but is covered elsewhere within this publication.

The major equipment for control consists of the Master Controller, CHEC Panel, exciter, CMR Wheelslip Detection Panel, current measuring reactors, axle alternator and the Speed Event Panel.

The Master Controller enables the operator to initiate operation of the propulsion equipment by operating the Throttle handle (also the Reverse handle). The Throttle handle notch signals are then applied to the CHEC Panel.

The CHEC Panel functions as an electronic control center for control signals and power requests. It analyzes numerous signals from equipment such as the Master Controller, CMR Wheelslip Detection Panel, current measuring reactors and the diesel engine. In addition, the CHEC Panel receives transition signals from the transition control circuit. This circuit senses locomotive speed from an axle-mounted alternator which develops a signal proportional to locomotive wheel speed. This speed signal is compared with a reference speed signal within the Speed Event Panel and the output of this comparison function then generates a transition control signal which is sent to the CHEC Panel to place the traction motors in either a series-parallel or parallel configuration. The CHEC Panel then utilizes the various signals to regulate the propulsion system to obtain maximum efficiency in applying propulsion power to the wheels. This is accomplished, basically, by supplying a regulated, variable current to the exciter's shunt field thereby controlling the excitation

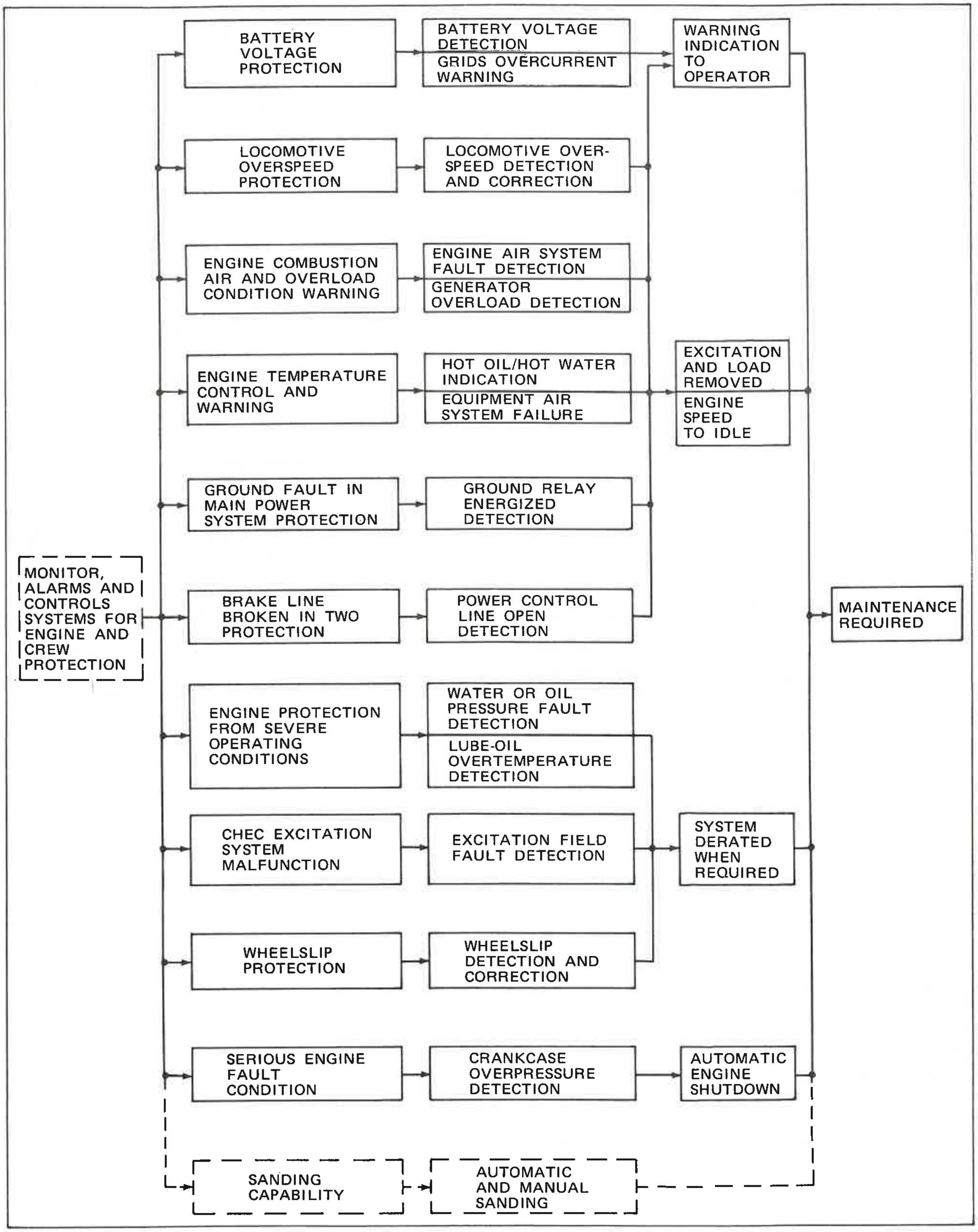


FIG. VIII-6. SYSTEMS MONITOR AND PROTECTION.

FIG. VIII-6, E-25262

VIII

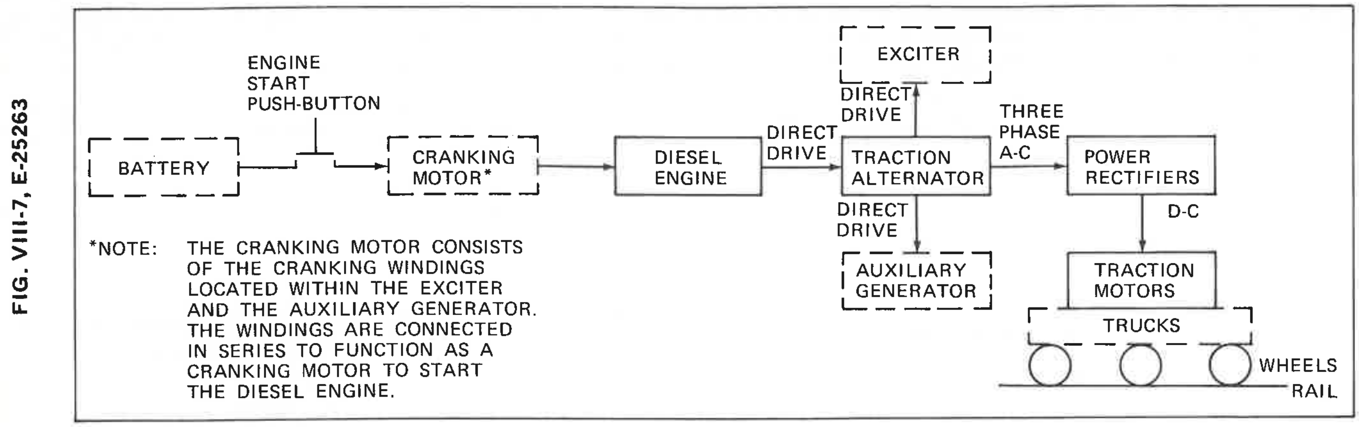


FIG. VIII-7. BASIC PROPULSION SYSTEM.

current to the field of the traction alternator. Thus, the traction alternator output to the traction motors is controlled during motoring (propulsion, transition and wheelslip).

BASIC BATTERY CHARGING SYSTEM

The basic battery charging system, Fig. VIII-9, consists of the battery, auxiliary generator and voltage regulator.

The battery is used to supply electric power for diesel engine starting and auxiliary electrical power for when the diesel engine is shutdown. After the battery has been used to start the diesel engine and the engine and traction alternator have reached running speed, the auxiliary generator which is driven by a gear box mounted on the traction alternator, will provide battery charging d-c voltage to the voltage regulator.

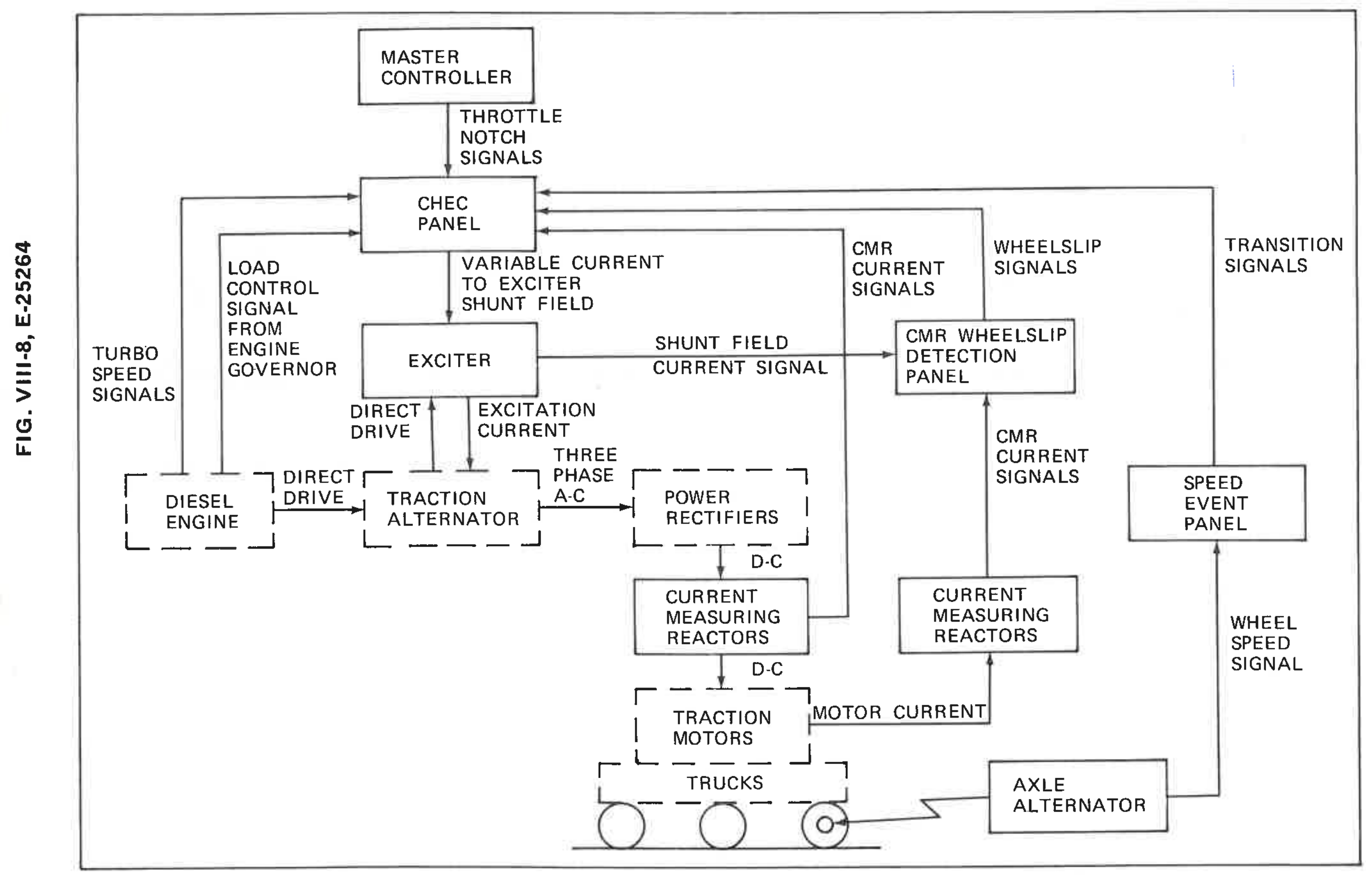


FIG. VIII-8. BASIC CONTROL SYSTEM.

VIII

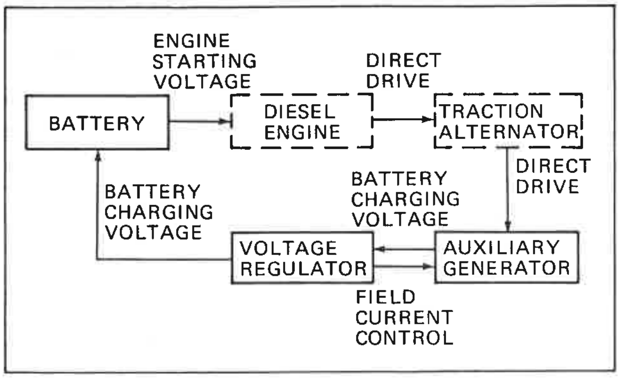


FIG. VIII-9. BASIC BATTERY CHARGING SYSTEM.

The voltage regulator controls the output from the auxiliary generator by sensing the generator output and adjusting the field current of the generator to maintain +74 vdc under various conditions of load and of diesel engine rpm. This 74 volts is then supplied to the battery as a charging voltage.

CHEC SYSTEM

The Constant Horsepower Excitation Control (CHEC) system is a method of electronic control of traction alternator excitation.

The FL138 Excitation Panel is the major component in the CHEC system. It sometimes is referred to as the CHEC Panel. The panel contains ten plug-in cards, nine of which contain electronic components primarily related to a specific CHEC function. The tenth card is a test card which contains no electronic apparatus but, when removed, allows a test kit (CHECKIT) to be inserted to test the CHEC system.

A simplified drawing of the CHEC Panel's input, output and feedback signals is shown on Fig. VIII-10. A simplified CHEC system block diagram is shown on Fig. VIII-11. Various signals are fed into the CHEC Panel. For example, a turbo speed signal generated by the turning of the turbo-rotor is fed into the CHEC Panel to limit the rate and the amount of engine loading. This minimizes the amount of acceleration smoke, and provides a simple and reliable altitude compensation and overspeed protection for the turbocharger.

A load control signal, sometimes referred to as reference voltage-supply signal, is fed from the engine governor to the CHEC Panel. As the first step in controlling locomotive performance for each Throttle notch, a reference voltage must be established and isolated from the battery so that any changes in the battery voltage will not affect the reference voltage. This reference-voltage signal and the

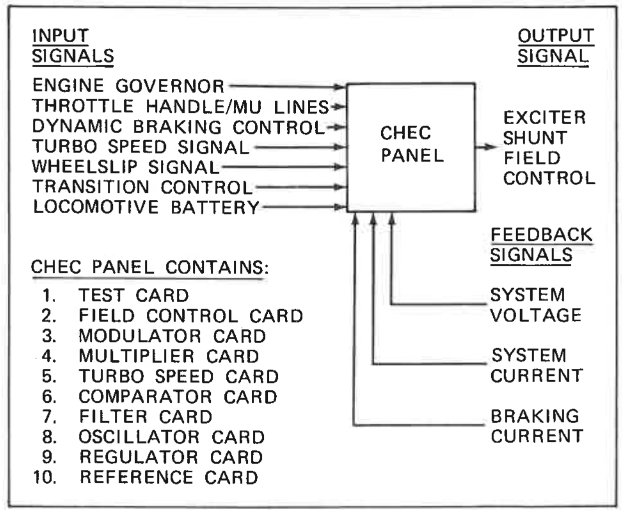


FIG. VIII-10. CHEC PANEL'S INPUT, OUTPUT AND FEEDBACK SIGNALS.

notching control signal from the Master Controller are fed to the CHEC Panel via the trainline circuits. Three reference-voltage signals are established for each notch.

1. Current limit
2. Power limit
3. Voltage limit.

The three-phase output from the traction alternator is fed to full wave power rectifier bridges for rectification and the resultant d-c output is supplied to the traction motor circuits. The d-c from the traction motors is passed thru an Alternator Current Control Reactor (ACCR), Fig. VIII-12, to provide an isolated low voltage current proportional to system current. This system-current signal is fed to the CHEC Panel where a proportional voltage is developed as one of the signals required for control of system current and power. The d-c output from the power rectifiers is also fed thru a Voltage Control Reactor (VCR) to provide an isolated low voltage, proportional to system voltage, to the CHEC Panel. This signal is used in the CHEC Panel's multiplier circuit for voltage control. The secondary use of the VCR signal is to initiate protective action by overriding the Braking-Current Control Reactor (BCCR) signal if the alternator voltage should rise above normal value.

The dynamic braking control signal from the Master Controller is fed to the CHEC Panel via trainline circuits. The braking grid current signal from BCCR also is fed back to the CHEC Panel. BCCR provides a signal proportional to the current flowing in the armature and braking grid circuit of one traction motor armature. The BCCR signal is one of three feedback signals used during dynamic braking. The other two are from ACCR and VCR. The traction-motor

FIG. VIII-9, E-25265

FIG. VIII-10, E-25266

VIII

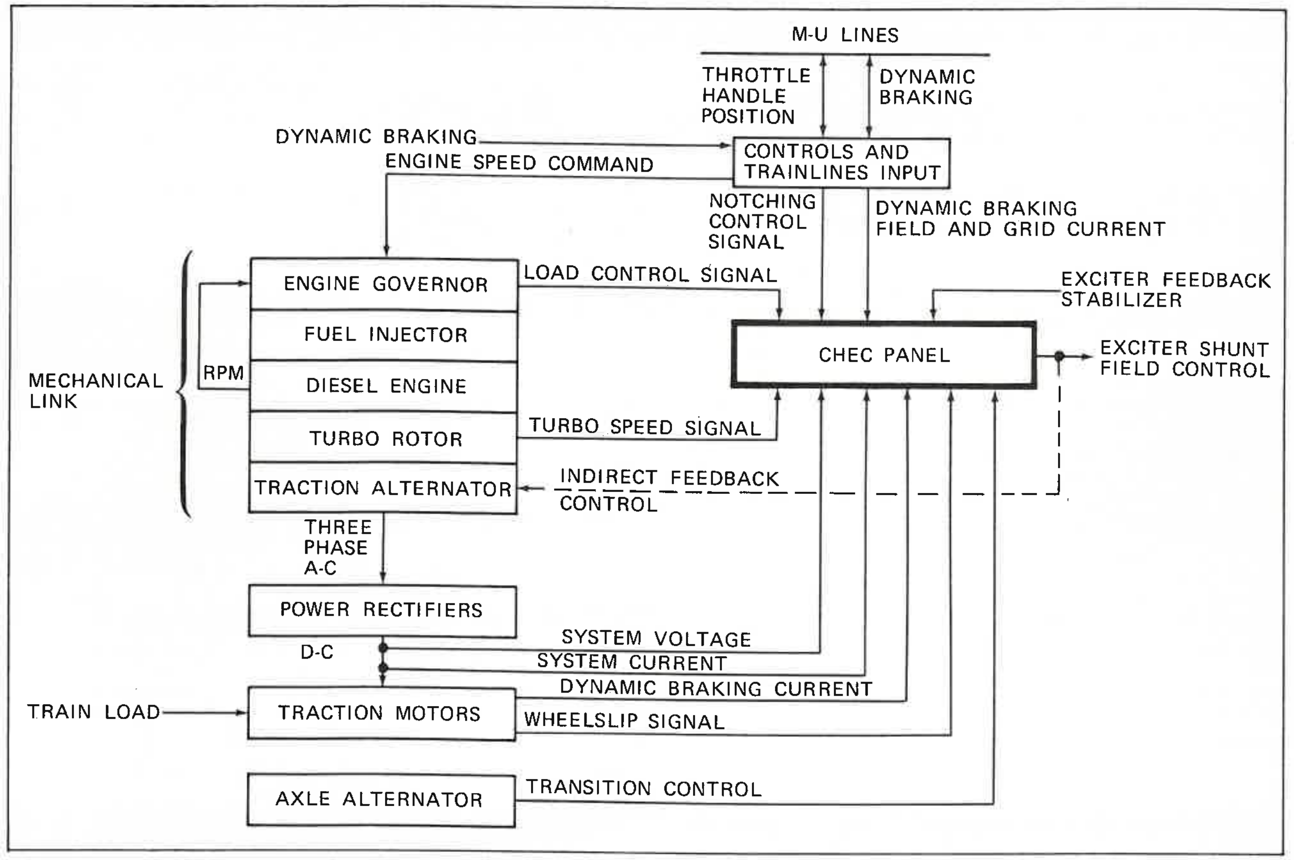


FIG. VIII-11. SIMPLIFIED CHEC SYSTEM BLOCK DIAGRAM.

FIG. VIII-11, E-25267

field windings are all connected in series, and are fed the rectified current from the alternator. This current is again measured by ACCR during dynamic braking just as it did during motoring (power) operations. The VCR remains connected during dynamic braking, but since the rectified voltage applied to the traction-motor field circuit is low, the VCR signal is too weak to be functional. If however, the traction-motor field circuit should become open-circuited, VCR will come into control of the traction-alternator voltage to provide a protective function.

The CHEC Panel receives the turbo-speed signal, system-current signal, dynamic braking signal, etc., and after considering all the circumstances it can sense, adjusts the amount of current supplied to the shunt field of the exciter. The exciter is mounted on the traction-alternator gear box and is used to control alternator field current. Thus, by controlling the exciter, maximum efficiency is obtained in applying the diesel-engine output to drive the locomotive's traction motors.

CMR WHEELSLIP DETECTION AND CORRECTION SYSTEM

The function of wheelslip control is to detect and correct for wheelslips in both motoring and dynamic braking modes of operation. Wheelslip is detected by measuring the current in each traction motor and detecting differences in level and rate to indicate that wheelslip is occurring. When wheelslip is detected, the excitation is reduced through the CHEC circuits to reduce power to the traction motors. Also, wheelslip relays are energized to provide automatic sanding and to open the exciter shunt-field circuit. A wheelslip warning light on the operator's control console will be lit to indicate that a wheelslip is occurring.

The function of the CMR wheelslip detection and correction system, Fig. VIII-13, is to provide the best possible adhesion for traction and to protect the traction equipment.

The wheelslip circuit detects and corrects for the following anomalies: During motoring it corrects for wheelslip, open or improper motor connection, locked axle and slipped pinion. During dynamic braking it corrects for wheelslip or open grid circuit.

Three types of corrections for wheelslip are provided. One for short and sudden wheelslip, one for a more lasting and severe wheelslip and a third one to guard against overspeed and simultaneous slip.

VIII

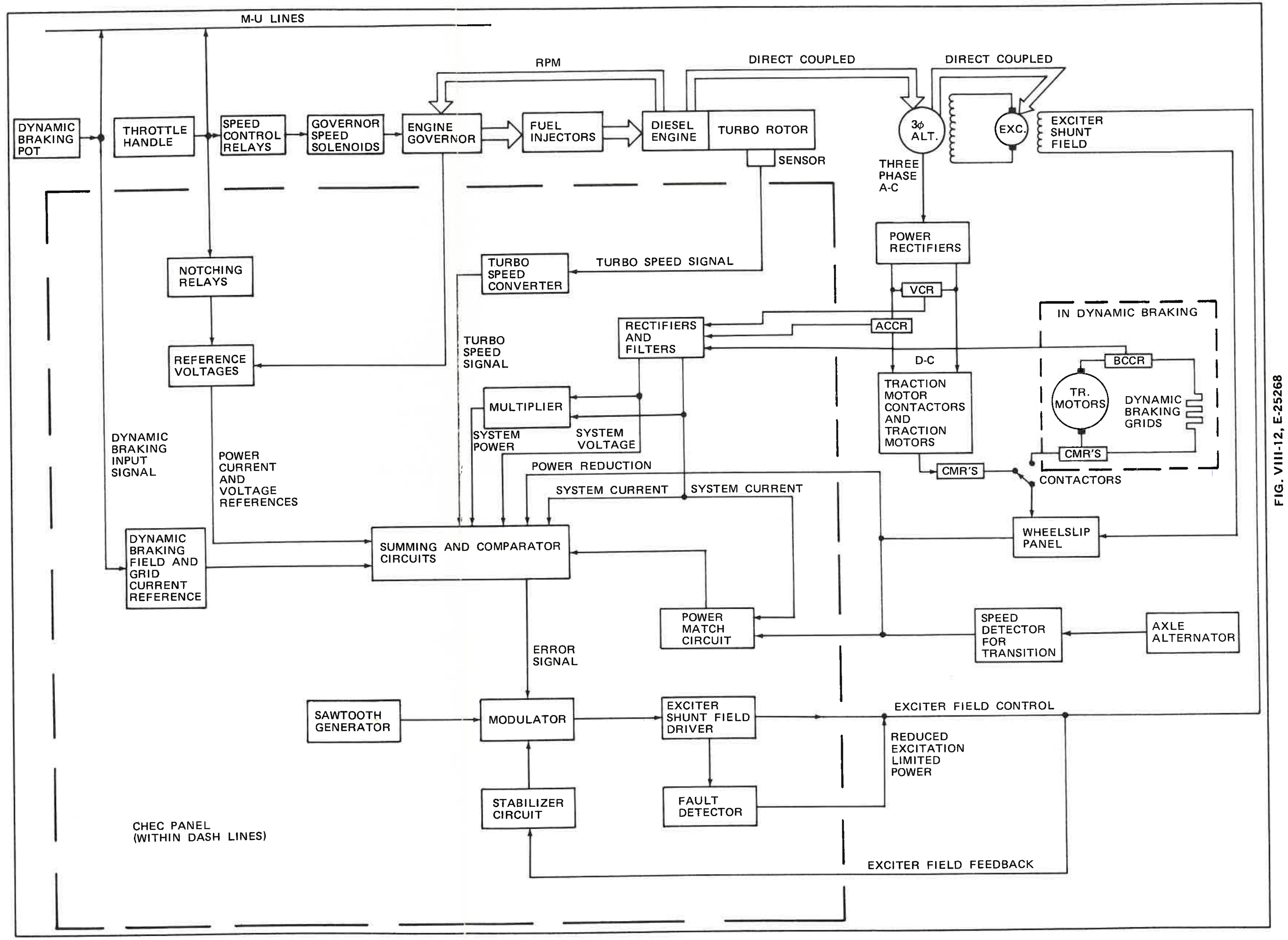


FIG. VIII-12. CHEC SYSTEM BLOCK DIAGRAM.

VIII

FIG. VIII-13, E-25269

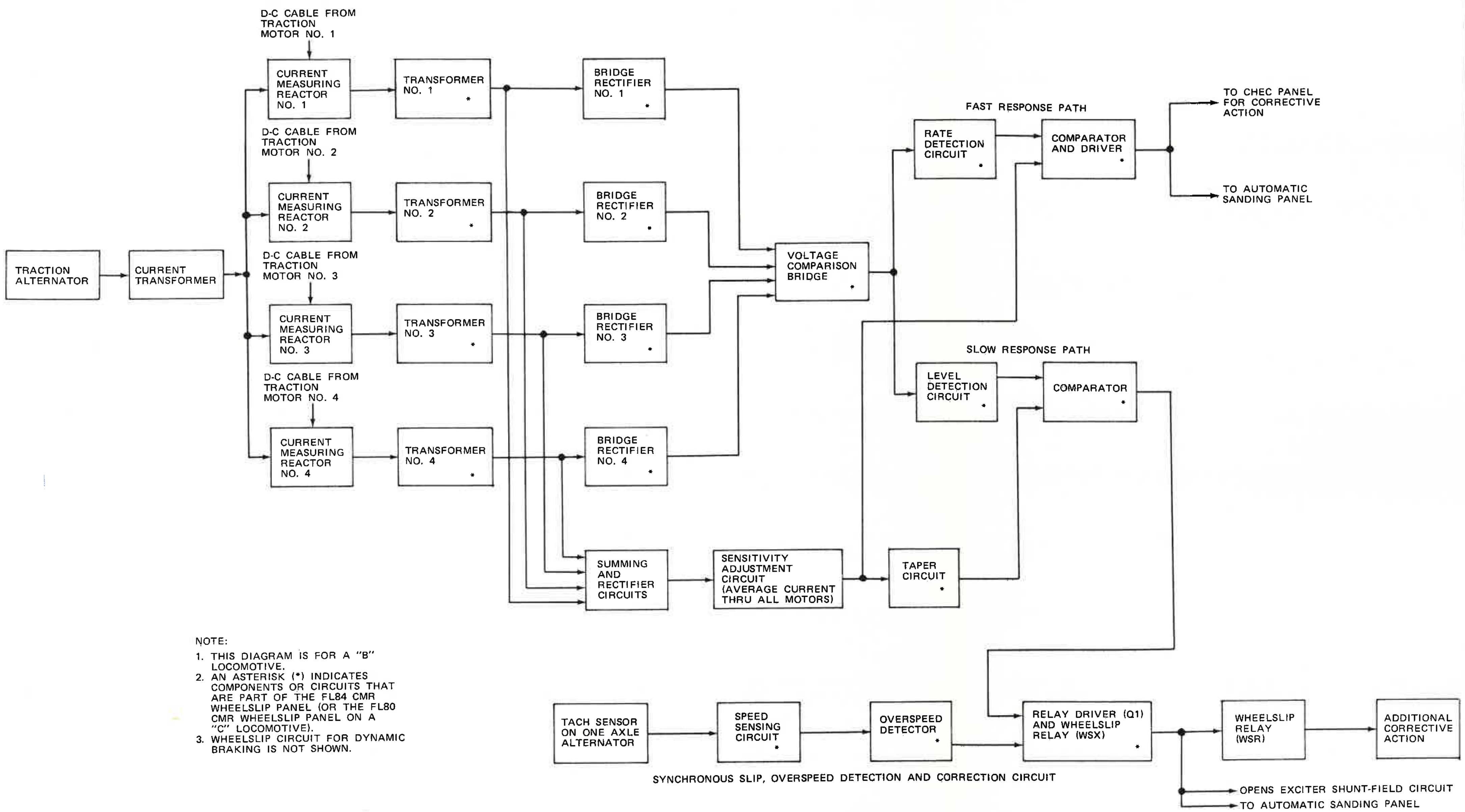


FIG. VIII-13. CMR WHEELSLIP DETECTION AND CORRECTION SYSTEM.

VIII

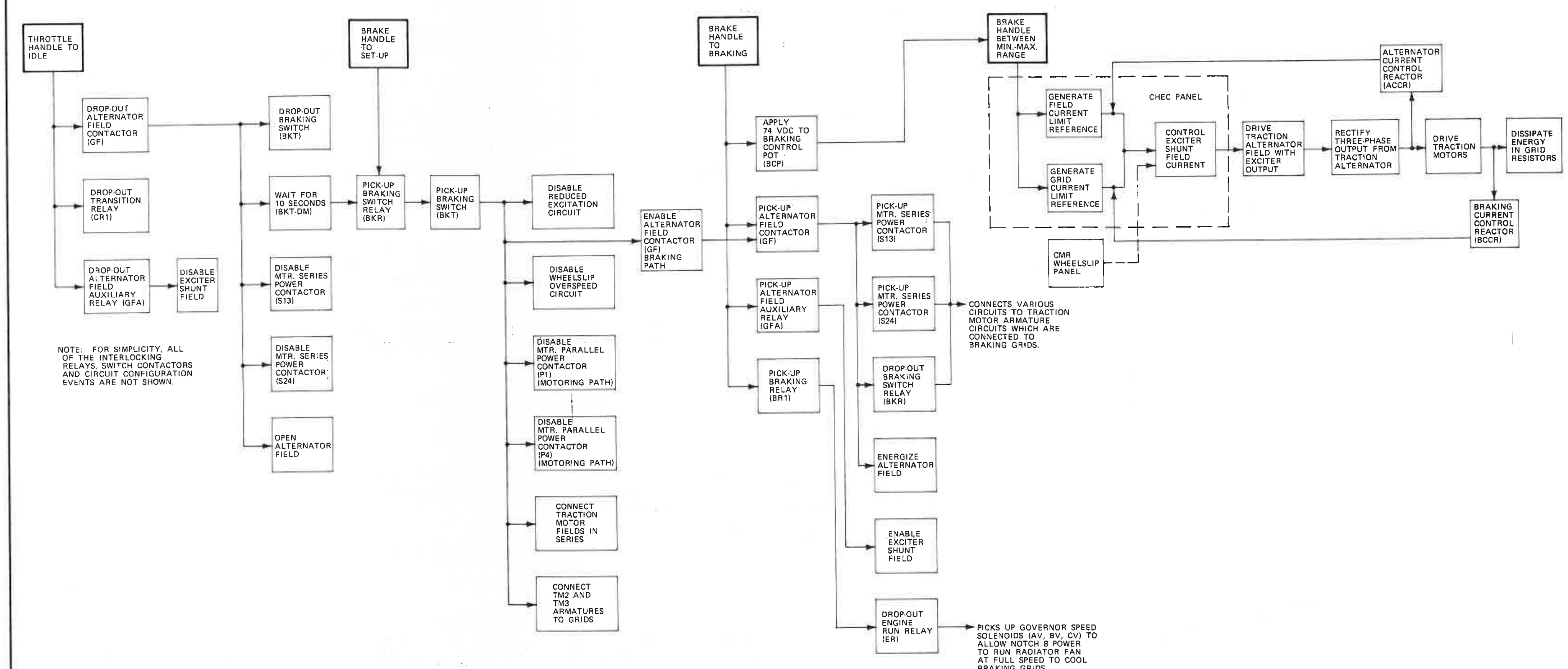


FIG. VIII-14, E-25270

FIG. VIII-14. DYNAMIC BRAKING SYSTEM BLOCK DIAGRAM OF EVENTS.

The first two types of wheelslip detection employ Current Measuring Reactors (CMR's) to monitor the current through each traction motor. Power for the CMR's is developed through a current transformer connected to one of the three phases of the traction alternator. The output of the current transformer is then fed to the CMR's.

A sensitivity adjustment circuit is necessary to compensate for differences in motor current between motoring and braking. Each CMR is connected to an isolation transformer and their output follows two paths. First, the outputs are all summed together to form an average current signal. This signal is rectified and filtered to obtain a d-c reference level to be used as a sensitivity control to make up for differences in traction motor current at high and low speeds. The second path is from the isolation transformers through bridge rectifiers and filters to obtain a d-c output proportional to each traction motor current. These d-c signals are then compared to a precision reference voltage in the voltage comparison bridge circuit.

Under normal operating conditions, the tractive effort of each axle is proportional to the individual motor current, so for closely matched traction effort (or braking effort) the motor currents are approximately the same.

The error signal detected by the voltage comparison bridge circuit can be a response to a sudden surge in current due to a rapid traction unbalance (wheelslip), in which case it is sensed by the rate detection circuit and fed to the comparator and driver circuit. This circuit compares the rate detection signal and the output from the sensitivity adjustment circuit to provide a correction signal to the CHEC Panel. Corrective action is in the form of an excitation pulse reduction signal. Also, if the signal from the rate detection circuit lasts more than three seconds, it enables the automatic sanding circuit.

When the wheelslip is of a more severe nature (greater and longer lasting unbalance), a level detection circuit is triggered by the voltage comparison bridge circuit. The level detection circuit senses the unbalance and feeds a signal to the comparator circuit which compares this signal and a taper circuit signal from the sensitivity adjustment and taper circuits. It then provides an energizing signal to a fast response Wheelslip Relay (WSX) to open the exciter shunt-field circuit. At the same time, the automatic sanding panel will provide sand to the rails. If the wheelslip lasts even longer, a slow response Wheelslip Relay (WSR) will be energized and additional corrective action will be taken to bleed additional current from the exciter shunt-field circuit. Also, a wheelslip indication light on the operator's control console will be lit.

To guard against simultaneous wheelslips and to protect against an overspeed condition, a third correction path is available. In this circuit a tachometer is located on one of the axles to monitor the speed. The speed sensing circuit will sense the speed and feed the speed signal to an overspeed detector circuit. If an overspeed condition exists, the detector will energize the WSX circuit and, if necessary, will energize the WSR circuit to remove excitation, provide sanding and activate the wheelslip light.

DYNAMIC BRAKING SYSTEM

The dynamic braking system is explained in the "Dynamic Braking" part of the Braking Systems section in this publication.

The sequence of events that occur as the Throttle handle is moved to IDLE and the Braking handle is positioned is shown in Fig. VIII-14. This figure is divided into four operating conditions:

1. Throttle handle to IDLE.
2. Brake handle to SET-UP.
3. Brake handle to braking.
4. Brake handle between the minimum-maximum positions.

It should be noted that the events that occur as the handles are positioned occur at a fast rate and many events occur simultaneously. Also, for simplicity, all of the circuit configuration events are not shown.

ENGINE SYSTEMS MONITOR

DESCRIPTION

The Engine Systems Monitor (ESM) is a protective system that electrically, mechanically and automatically identifies improper locomotive conditions. Its function is to provide over-the-road reliability, avoid unnecessary shutdowns and reduce secondary failures. These objectives are accomplished by indicating when and what kind of maintenance work is required before the faulty condition causes a shutdown or road failure. Under most conditions, ESM will keep the diesel engine running, although load and speed may be reduced to match the unit's capabilities.

When a problem occurs, malfunction indicating lights on the Engine Control (EC) Panel in the operator's cab will be lit, either singly or in combination, to advise the crew and maintenance personnel that a problem has developed. Also, malfunction indicating lights on an Annunciator Panel located within the control compartment will be lit. By observing the indicating lights, comparing their pattern shown on an ESM Diagnostic Chart and checking the most probable cause, maintenance personnel can quickly analyze and correct the problem.

ESM DIAGNOSTIC CHART

The ESM Diagnostic Chart, Fig. VIII-15, presents a listing of indicating lights and system conditions including the most probable cause(s) of the problem.

When one or more ESM indicating lights on the EC Panel are lit, one or more indicating lights on the Annunciator Panel also will be lit. By comparing those illuminated with the chart, maintenance personnel can identify which line of the chart applies to the problem.

For example: if the NO BATTERY CHARGE, ANNUNCIATOR PANEL and CRANKCASE OVERPRESSURE lights are lit, Line No. 1 applies. Note that the EC PANEL LIGHTS column for Line No. 1 is divided into two sections. The top section lists the lights that are lit for a specific problem and alerts the train crew that some action may have to be taken. The bottom section lists the ANNUNCIATOR PANEL light which alerts maintenance personnel that a problem had occurred and further investigation is warranted. In this case, the action to be taken by the train crew is to reset the Crankcase Overpressure (COP) switch, (see ENGINE CONDITION column), in accordance with recommended railroad procedures.

The CRANKCASE OVERPRESSURE light on the Annunciator Panel (see ANNUNCIATOR PANEL column) will remain lit after COP is reset to indicate that the locomotive experienced a crankcase overpressure problem. After maintenance personnel have resolved the overpressure problem, the light on the Annunciator Panel can be turned-off by lifting-up the spring-loaded, RESET Toggle switch on the Annunciator Panel. This switch may be sealed with lockwire.

The ENGINE CONDITION column lists the various possible engine modes such as shutdown, idling or running.

The MOST PROBABLE CAUSE column lists the causes in descending order of probability. Thus, too high oil level in the crankcase would be considered the most probable cause; a plugged crankcase breather screen would be the least likely cause.

It should be noted that order of severity generally increases from Line No. 1 through Line No. 10. If an indication on one of the upper lines is ignored, expect progression to one of the lower.

The ESM Diagnostic Chart also has a column titled HOLD RELAY. This column lists the Engine Temperature Holding Relay (ETHR) and the Governor Shut Down Holding Relay (GSDHR). The ETHR relay will pick-up if the engine experiences an engine overtemperature condition. This condition is usually caused by high lube-oil temperature, or low water pressure which causes the water temperature to increase above normal operating temperature. The GSDHR relay will pick-up if the engine experiences a very low oil pressure and/or very low water pressure condition, and the governor will then shut down the engine.

EQUIPMENT

Holding Relays

The ETHR and GSDHR relays, Fig. VIII-16, are located within the control compartment near the Annunciator Panel. When the coil of either relay is energized, even momentarily, the relay mechanically latches in the closed (picked-up) position and a red light on its face is lit.

Even if the locomotive is shut down on the road and the battery switch is opened, the relay(s) will remain latched until manually reset. After the problem has been resolved, reset the relay by pushing the red tab on the relay labeled PUSH/RESET.

NOTE: *Other holding relays and their applicable circuitry are available as optional equipment.*

Engine Control Panel

The Engine Control Panel, Figs. VIII-17 and VIII-18, in the operator's cab contains ten malfunction indicating lights to warn the train crew and maintenance personnel that a problem has developed. When a problem occurs, the following ten lights will be lit either singly or in combination:

1. GROUND RELAY TRIPPED
2. OVERLOAD RELAY TRIPPED
3. NO BATTERY CHARGE
4. ENGINE OVERTEMPERATURE
5. ANNUNCIATOR PANEL
6. GOVERNOR SHUT DOWN
7. REDUCED EXCITATION
8. CRANKCASE OVERPRESSURE
9. ENGINE AIR FILTER
10. HOT DIODES.

NOTE: *The Engine Control Panel can accommodate two, additional malfunction indicating lights as a customer option.*

ENGINE SYSTEMS MONITOR DIAGNOSTIC CHART

LINE NO.	EC PANEL LIGHTS (Throttle at IDLE)	CONTROL COMP. LIGHTS: ANNUNC. PANEL	CONTROL COMP. LIGHTS: HOLD REL.	ENGINE CONDITION (Unless Manually Shut Down)	CHECK EQUIPMENT LISTED FOR MOST PROBABLE CAUSE
1	NO BATT. CHARGE ANNUNC. PANEL CR'CASE OVER PR. ANNUNC. PANEL	CRANKCASE OVERPRESS.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**SHUTDOWN:** will not crank until COP is reset. Indicates engine had excess crankcase pressure. **RUNNING:** indicates COP switch has tripped and been reset.	Too high oil level in crankcase, piston blow-by, plugged crankcase breather screen.
2	ANNUNC. PANEL ENGINE AIR FILTER ANNUNC. PANEL	ENGINE PAPER FILTER	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**IDLING:** will not load. Indicates engine paper air filters excessively dirty. **RUNNING:** may take full load. Indicates Engine Paper Filter Switch and Relay has tripped and been reset.	Dirty engine paper air filters, blockage in primary air cleaners, debris obstructing engine air intake screens.
3	ANNUNC. PANEL	LOW OIL PRESS.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low oil pressure.	Low oil level, dirty oil filter, open filter tank drain-back valve (C), dirty lube oil cooler – oil side, dirt in crankcase oil strainer, faulty lube oil relief valve, dirty fuel filter or strainer, failed (slipping) bonded pump drive, electrical bogging or overloading governor.
4	ANNUNC. PANEL	LOW OIL PRESS. O LUBE OIL TEMP.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low oil pressure and high oil temperature.	Very dirty, almost plugged lube oil cooler – oil side. Also check all equipment listed on Lines 3 and 9. A more severe condition likely exists.
5	NO BATT. CHARGE ANNUNC. PANEL GOV. SHUTDOWN	LOW OIL PRESS.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**SHUTDOWN:** will not crank until reset. Indicates engine experienced very low oil pressure.	All equipment listed on Line 3. A more severe condition likely exists. Also investigate engine for failed lube oil pump.
6	ANNUNC. PANEL	LOW WATER PRESS.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low water pressure.	Low water level, cooling system not pressurized, dirty lube oil cooler – water side, water tank or lube oil cooler inlet screen plugged, dirty fuel filter or strainer, failed (slipping) bonded pump drive, governor.
7	ANNUNC. PANEL	LOW WATER PRESS. LUBE OIL TEMP.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced low water pressure and high oil temperature.	Very dirty, almost plugged lube oil cooler – water side. Also check all equipment listed on Line 6 and 9. A more severe condition likely exists.
8	NO BATT. CHARGE ANNUNC. PANEL GOV. SHUTDOWN	LOW WATER PRESS.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**SHUTDOWN:** will not crank until reset. Indicates engine experienced very low water pressure.	All equipment listed on Line 6. A more severe condition likely exists. Also investigate engine for failed water pump.
9	ANNUNC. PANEL	LUBE OIL TEMP.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**RUNNING:** may take full load. Indicates engine experienced high oil temperature.	Dirty radiators, plugged air inlet screens, excessive braking current, faulty control of water temperature, dirty lube oil cooler – either side, excess horsepower output. *(May also be caused by very high ambient temperature or by tunnel operation.)*
10	ENGINE OVERTEMP. ANNUNC. PANEL		ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**IDLING:** will not load. Indicates engine experienced very high water temperature.	Severe cooling system-related problem. If the system checks OK, test LOT switch. It may not be indicating that a high lube oil temperature has occurred. If LOT switch is found faulty, proceed to Line 11.
11	ENGINE OVERTEMP. ANNUNC. PANEL	LUBE OIL TEMP.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**IDLING:** will not load. Indicates engine experienced very high oil or oil and water temperature.	All equipment listed on Line 9. A more severe condition likely exists. Also inspect for failed fan drive.
12	ENGINE OVERTEMP. ANNUNC. PANEL	LOW WATER PRESS.	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**IDLING:** will not load. Indicates engine experienced low water pressure and very high water temperature.	Low water level.
13	OVERLOAD RELAY TRIPPED ANNUNC. PANEL ANNUNC. PANEL	GENERATOR OVERLOAD	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**IDLING:** will not load. Indicates main alternator experienced a surge of current. Reset GOLR to make unit operable. **RUNNING:** may take full load. Indicates GOLR has tripped and been reset.	Traction motors for signs of flashover; motors for shorted fields, busbars, or leads; bus bars and cables at main alternator and rectifier panels for loose connections; current limit adjustment in excitation panel; failure of ACCR; single-phasing of alternator; GOLR for defects; alternator field connections and busbars for a short circuit.
14	GROUND RELAY TRIPPED ANNUNC. PANEL ANNUNC. PANEL	GROUND RELAY	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**IDLING:** will not load. Indicates power circuits have experienced a ground. **RUNNING:** may take full load. Indicates GR has tripped and been reset.	Electrical power equipment for evidence of a flashover, intermittent ground, or continuing ground.
15	ANNUNC. PANEL HOT DIODES ANNUNC. PANEL	HOT DIODES	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**IDLING:** will not load. Indicates one or more rectifier panels have experienced excessive temperature. **RUNNING:** may take full load. Indicates one or more hot diode detectors have tripped and relay has been reset.	Main alternator for loose or missing covers, accumulation of debris on blower intake screens, inoperative blower, failed diodes in rectifier panels, single-phased alternator.
16	REDUCED EXCIT. ANNUNC. PANEL ANNUNC. PANEL	REDUCED EXCITATION	ETHR 6SDHR HOT ENG. GOV. SH'DOWN	**RUNNING:** will not take full load. Indicates problem in Excitation Panel causing operation in Reduced Excitation mode. **RUNNING:** will take full load. Indicates some period of operation in Reduced Excitation mode, and switch on MD card has been reset.	Excitation panel for proper cards in correct locations. Each card for dirty, bent, or broken contact pins. Faulty card. Allied circuits for loose or broken wires or components, including feedback connections from rectifier panels and ACCR to excitation panel. Make sure alternator is not single-phased. Make sure governor plug connection and wiring is correct.

FIG. VIII-15. ENGINE SYSTEMS MONITOR DIAGNOSTIC CHART.

FIG. VIII-15, E-25038

VIII

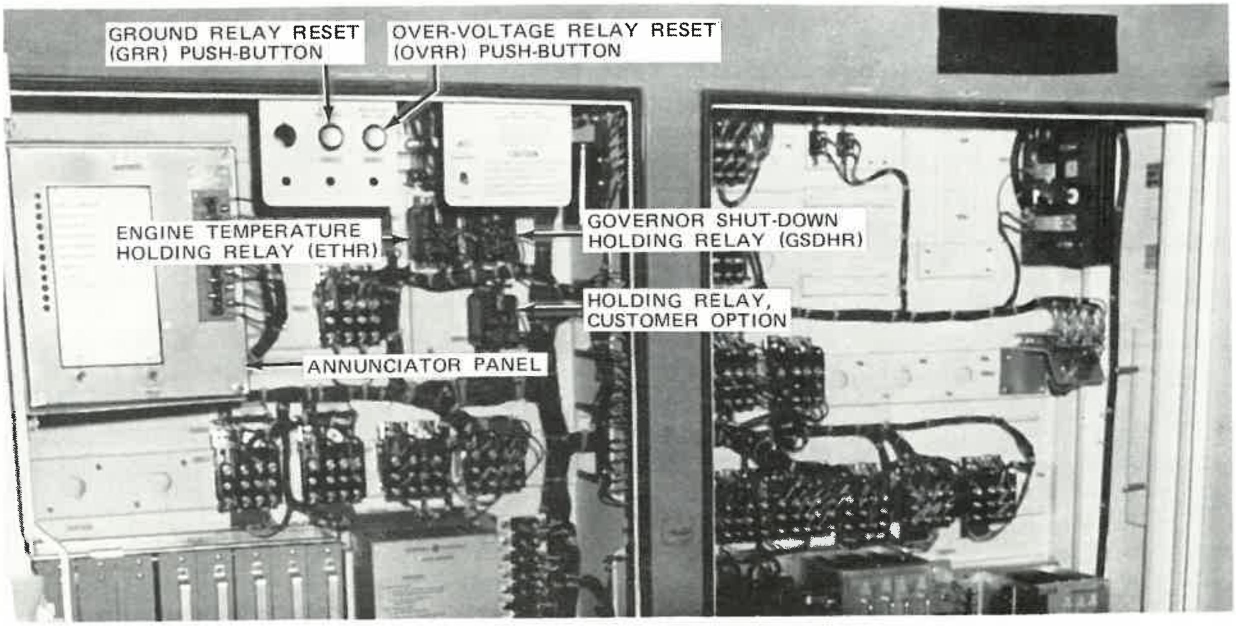


FIG. VIII-16, E-25039

FIG. VIII-16. HOLDING RELAYS (SHOWN WITHIN THE CONTROL COMPARTMENT).

Annunciator Panel

The Annunciator Panel, Fig. VIII-19, located within the control compartment contains nine malfunction lights, a LAMP TEST push-button switch and a spring-loaded RESET Toggle switch. The panel is electrically connected directly to the locomotive battery so that if the locomotive is shut down and the battery switch is opened, the applicable malfunction light(s) will remain lit to alert maintenance personnel that a problem has occurred. The nine lights are:

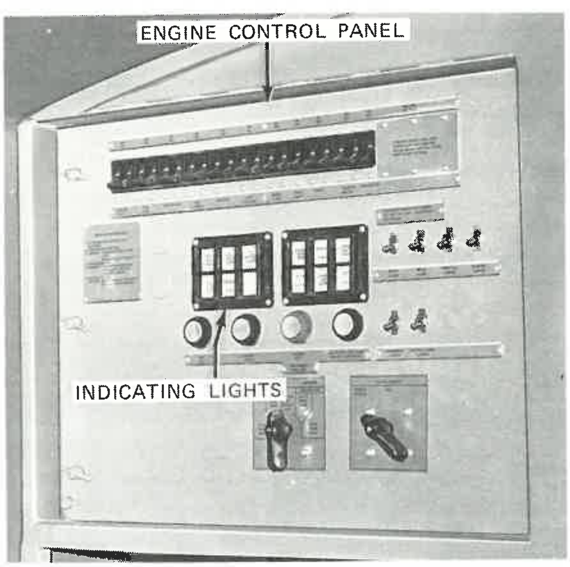


FIG. VIII-17, E-25040

FIG. VIII-17. ENGINE CONTROL PANEL.

1. CRANKCASE OVERPRESSURE
2. ENGINE PAPER FILTER
3. LOW OIL PRESSURE
4. LOW WATER PRESSURE
5. LUBE OIL TEMPERATURE
6. GENERATOR OVERLOAD
7. GROUND RELAY
8. HOT DIODES
9. REDUCED EXCITATION.

A LAMP TEST push-button switch is provided to test the lamps. A RESET Toggle switch provides the means to turn-off the malfunction light(s) after the problem has been resolved. This switch may be sealed with lockwire.

NOTE: *The Annunciator Panel can accommodate three, additional malfunction indicating lights as a customer option.*

Modulating Control Governor

The major component in the Engine Systems Monitor is a modified control governor, Fig. VIII-20. The control governor is an electro-hydraulic device used to regulate speed and horsepower output of the diesel engine. It also includes a number of auxiliary devices to protect and provide the power plant with characteristics desirable for railway locomotive service.

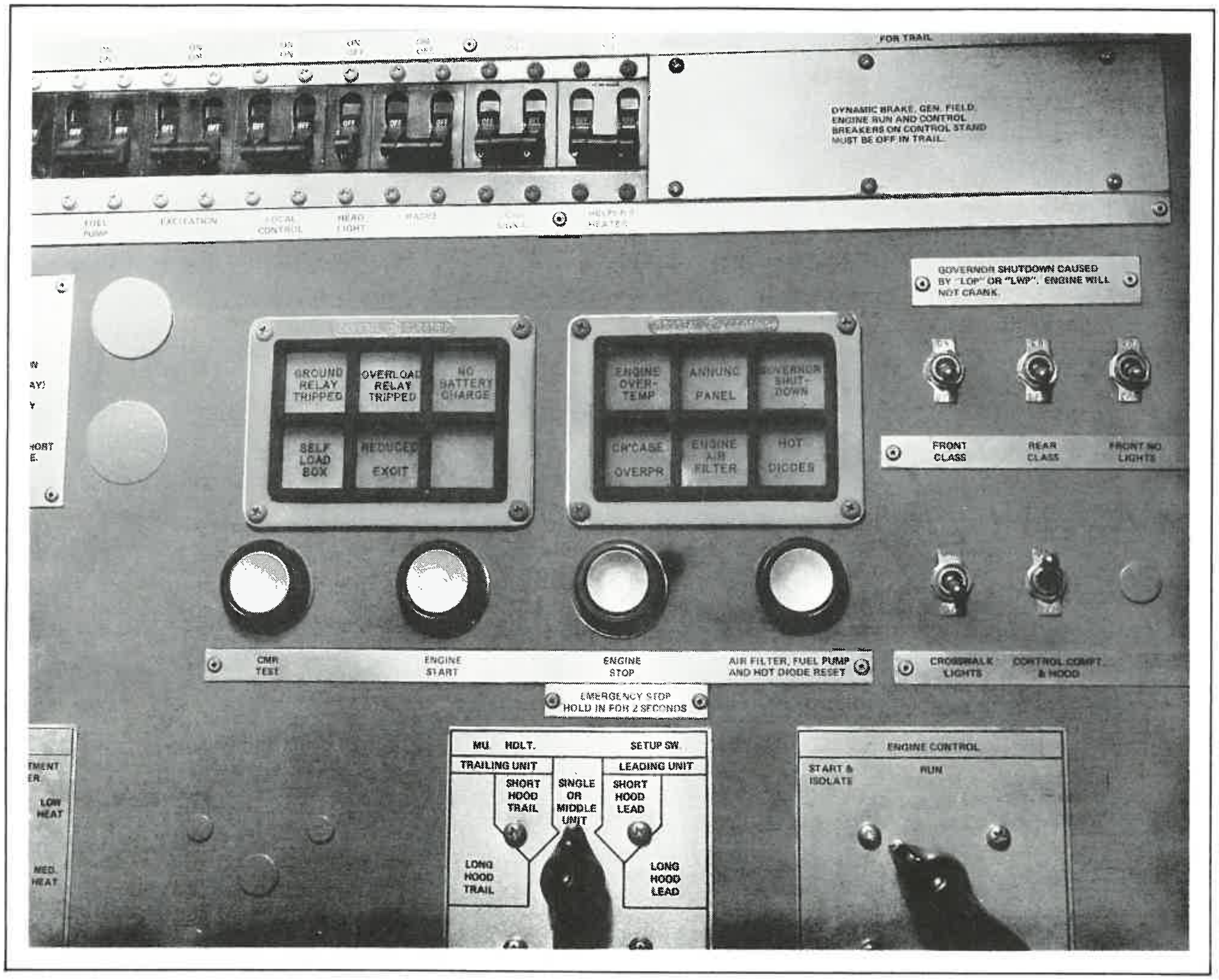


FIG. VIII-18, E-25041

FIG. VIII-18. ENGINE CONTROL PANEL INDICATING LIGHTS.

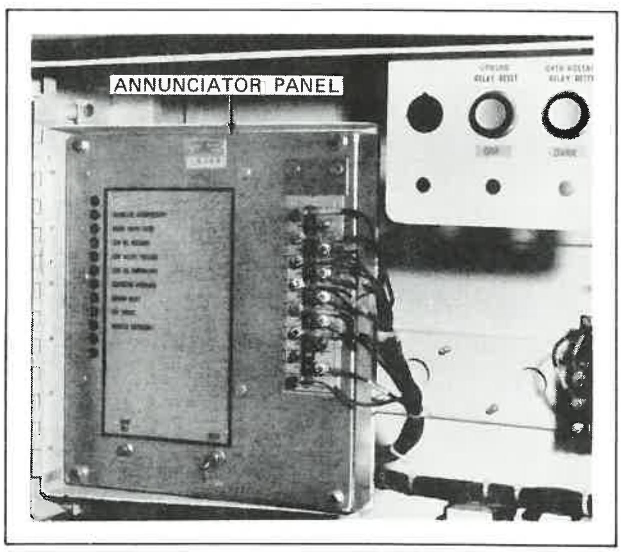


FIG. VIII-19, E-25042

FIG. VIII-19. ANNUNCIATOR PANEL.

The governor is a self-contained unit which is mounted on and driven by the diesel engine. It is equipped with its own oil supply and oil pressure pump and is remotely controlled by the locomotive throttle.

During operation the governor performs two basic functions. Primarily, it controls the speed of the diesel engine by regulating the amount of fuel supplied to the engine cylinders. At any speed setting of the governor, speed control is isochronous; that is, the governor maintains constant engine speed regardless of changing conditions of load. The secondary function of the governor is to maintain a constant predetermined horsepower output of the engine for each specific speed setting by accurately controlling the engine load. Control of the engine load is accomplished by adjusting the strength of the generator field to compensate for electrical load changes on the generator, and those resulting from variable auxiliary loads such as the air compressor, battery charging generator, etc.

VIII

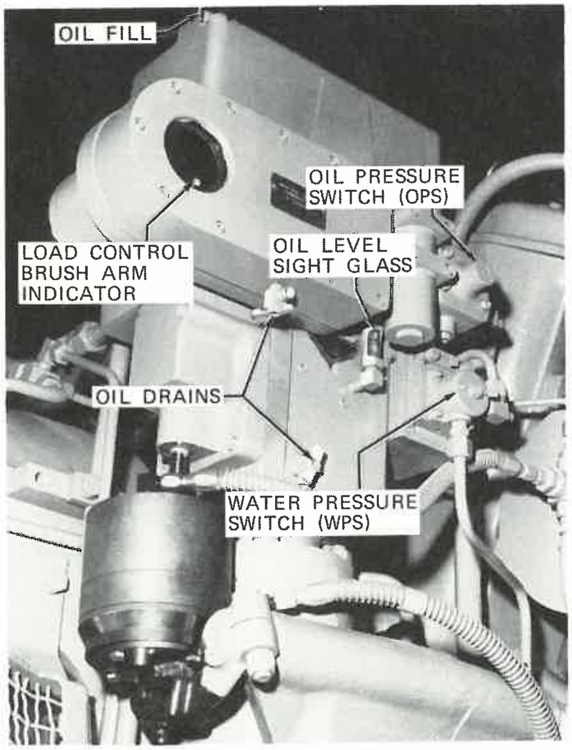


FIG. VIII-20. MODULATING CONTROL GOVERNOR.

Thus, while the primary function of the governor is to maintain speed of the engine by controlling both speed and load, a condition of balance can be established which results in a constant, single horsepower output for each speed setting of the engine.

The governor also has the following auxiliary functions:

1. Remote, electrical throttle control for eight notch speeds plus a SHUTDOWN position.
2. Overriding of the normal load control operation to aid in controlling wheelslip and, in some applications, dynamic braking functions.
3. Automatic shutdown of the diesel engine in the event of failure of the lubricating oil pressure or failure of the cooling water pressure. At idle speed a time delay is provided on these safety devices to permit starting the engine while still providing shutdown protection if the pressures fail to develop within the allotted time.
4. Limiting of fuel supplied to the engine during starting to provide improved starting characteristics.

Thus, the governor automatically reduces engine load and speed to match temporarily lower than normal lubricating oil or water pressure. When the temporary fault condition returns to normal, the governor automatically permits reapplication of full load and speed. In motoring, no action by the operator is required.

In dynamic braking, all braking excitation is dropped and the diesel engine goes to IDLE when either lubricating oil or water pressure is low. After the temporary fault has been cleared, the operator can restore braking by moving the Braking handle to OFF and again advancing it in the braking mode.

If either oil or water pressure falls to the point that continued operation would be dangerous, the governor will shut down the engine.

Both derating and shutdown action is controlled by a bleed-off of speed-setting oil pressure within the governor. This bleed-off is actuated by engine lube oil and water pressure acting on their respective diaphragms. The diaphragms move plungers to regulate the bleed-off and operate the low Oil Pressure (OPS) and low Water Pressure Switches (WPS).

FIG. VIII-20, E-25043

Temperature Switches

There are three temperature switches. Two switches, Fig. VIII-21, measure lube oil temperature out of the engine crankcase and are located externally near the outlet of the oil pump. The third measures water temperature, Fig. VIII-22, and is located on top of the water tank where water discharged by the diesel engine enters the temperature control equipment.

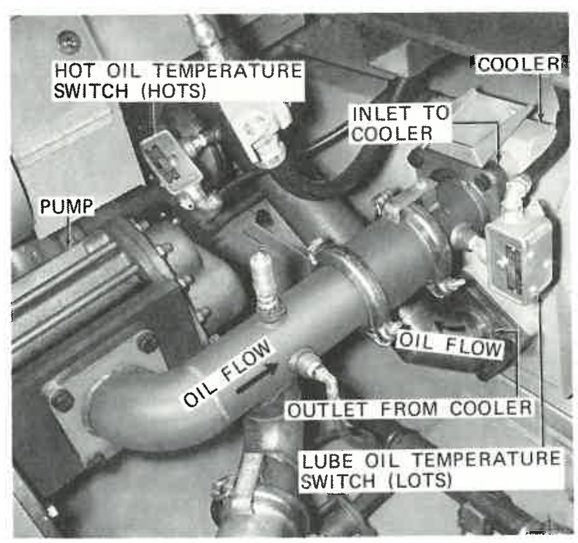
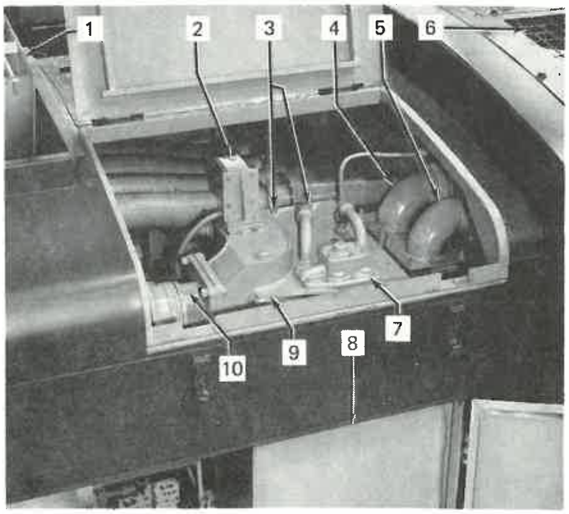


FIG. VIII-21. LOTS AND HOTS TEMPERATURE SWITCHES.

FIG. VIII-21, E-25044

FIG. VIII-22, E-19692
FIG. VIII-23, E-21624



REF.	DESCRIPTION
1	ENGINE EXHAUST STACK
2	ENGINE TEMPERATURE SWITCH
3	PILOT VALVE ORIFICE INSPECTION PLUGS
4	WATER OUTLET, TO LEFT-BANK RADIATORS
5	WATER OUTLET, TO RIGHT-BANK RADIATORS
6	RADIATORS
7	THERMOSTATIC PILOT VALVE
8	WATER STORAGE TANK
9	FLUID-AMPLIFIER FLOW-CONTROL VALVE
10	WATER INLET TO FLOW-CONTROL VALVE

FIG. VIII-22. HOT WATER (ENGINE) TEMPERATURE SWITCH (HWTS) AND NEARBY COMPONENTS.

The Lube Oil Temperature Switch (LOTS) picks-up at 235 F. This switch is mounted in the oil inlet piping to the cooler. When it closes, the engine continues to run at designated speed. However, load (or dynamic braking) will be reduced to about two-thirds of normal for that Throttle notch. If lube oil temperature cools to 228 F, the switch drops-out and full load (or dynamic braking) is restored.

The Hot Oil Temperature Switch (HOTS) closes at 235 F. This switch is mounted in the cooler outlet piping. When it closes, all load is dropped, the alarm bell rings, and the engine speed returns to IDLE after 30 seconds. The alarm bell is then silenced.

The latching feature on the Engine Temperature Holding Relay (ETHR) maintains the no-load and IDLE speed condition until manually reset. This resetting should be performed after the cause of the problem has been resolved.

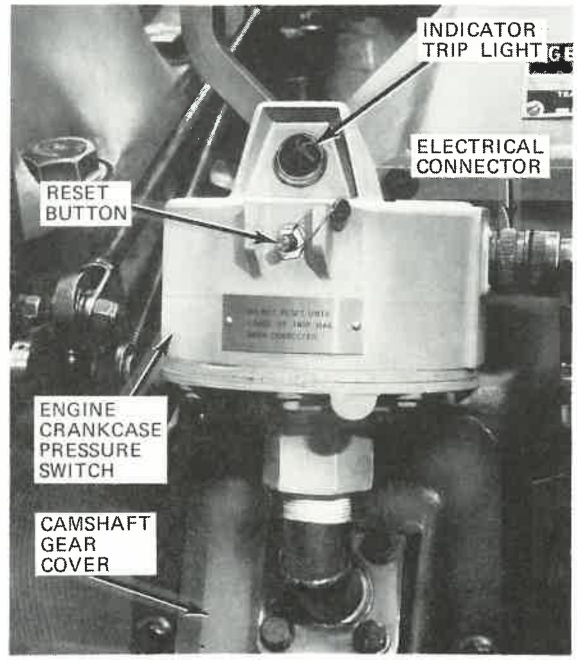


FIG. VIII-23. CRANKCASE OVERPRESSURE (COP) SWITCH.

The Hot Water Temperature Switch (HWTS) is set to pick-up at 235 F. Performance of HWTS is similar to HOTS; all load is dropped and engine speed returns to IDLE after 30 seconds. The alarm bell rings during this 30 second period.

VIII

Pressure Switches

The pressure switches consist of a Crankcase Overpressure (COP) switch, a low Oil Pressure Switch (OPS), a low Water Pressure Switch (WPS) and an Engine Filter Pressure Switch (EFPS).

The COP, Fig. VIII-23, is located on the left side of the diesel engine near the alternator. This switch protects the engine in case of excessive crankcase pressure. In normal operation, there is a slight vacuum in the engine crankcase. If a pressure of approximately 2 in. of water builds-up in the crankcase, the switch will trip and shut down the engine. A red indicating light is provided on the device (also on the EC Panel) to alert the operator when the switch is tripped. The switch can be reset by pushing the manual reset push-button located beneath the indicating light on the device after the cause of the trip is understood and corrected.

The OPS and WPS are located within the modulating governor, Fig. VIII-20. Their action will automatically

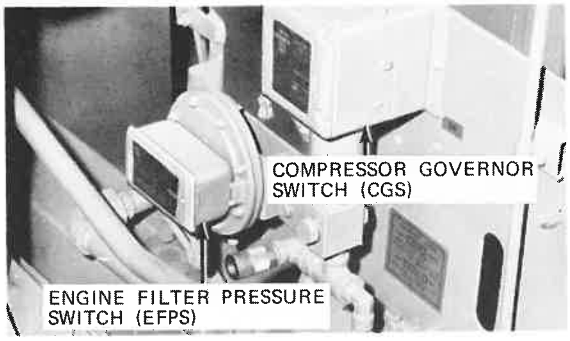


FIG. VIII-24. ENGINE FILTER PRESSURE SWITCH (EFPS).

reduce engine load and speed to match the low oil and/or water pressure. When the fault condition returns to normal, the switch(es) will automatically restore the locomotive to full load and speed.

The EFPS, Fig. VIII-24, is located on the right side of the locomotive in the air compressor compartment. This switch operates in conjunction with a service indicator, Fig. VIII-25. These two devices operate from the vacuum in the cleaned-air plenum. Dirt accumulation on the secondary air filter or primary air cleaner, Fig. VIII-26, will gradually cause the vacuum in the cleaned-air plenum to increase. It should be understood that the filters alone do not create a vacuum.

The vacuum is created by the suction of the turbo pulling clean air out of the cleaned-air plenum. As the paper filters become increasingly dirty, less outside air can enter the cleaned-air plenum to replace the air being pulled-out by the turbo, thereby, causing the vacuum pressure within the plenum to increase.

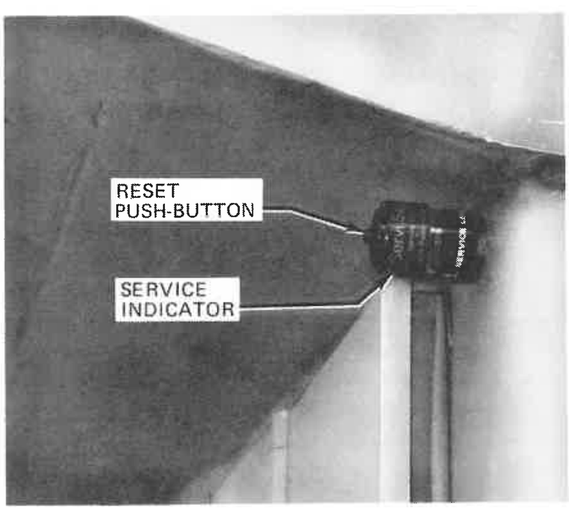


FIG. VIII-25. SERVICE INDICATOR.

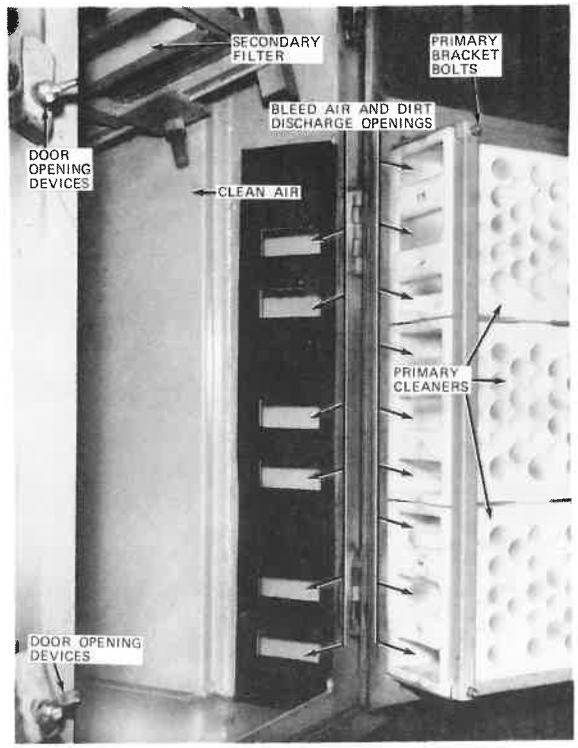


FIG. VIII-26. ENGINE-AIR FILTER ARRANGEMENT.

The service indicator, located high on the right-side of the locomotive, has a red band that gradually rises in the service-indicator window as the air filters start to get dirty, causing the vacuum to increase at full load on the engine. When the pressure reaches minus 12 in. water vacuum, the red band will lock in place and no longer drop when the engine is at idle. The red band movement is visible when the air filter is starting to get dirty and the engine is running at full load. After confirmation of this condition with a manometer, the filter elements should be changed. To reset the service indicator, push the reset button located on the service indicator.

If the filter elements are not changed, the vacuum in the cleaned-air plenum will increase at an accelerated rate. At minus 14 in. water vacuum, the Engine Filter Pressure Switch (EFPS) (sometimes referred to as the vacuum switch) will trip, the Engine Paper Filter Relay (EPFR) will be energized, and the engine will return to IDLE. Also, the ENGINE AIR FILTER light on the EC Panel will be lit and a trainline alarm will ring for 30 seconds. After the paper filters have been replaced and/or the air blocking debris has been removed, the EPFR relay can be reset by pushing the AIR FILTER, FUEL PUMP AND HOT DIODE RESET push-button on the EC Panel, Fig. VIII-18.

FIG. VIII-24, E-25045

FIG. VIII-25, E-22356A

FIG. VIII-26, E-15051

VIII

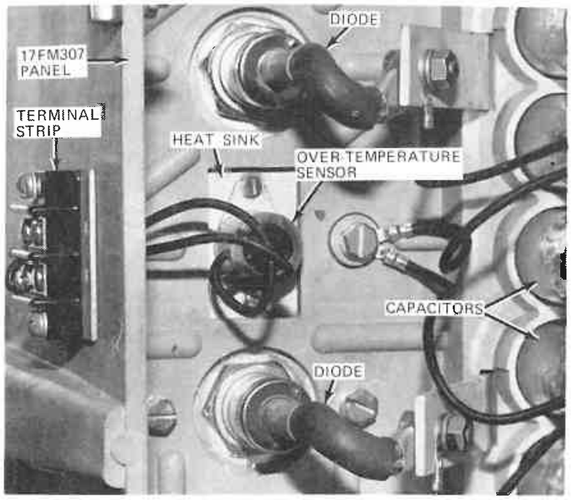


FIG. VIII-27. HOT DIODES SENSOR SHOWN IN A POWER RECTIFIER PANEL (TYPICAL).

Hot Diodes Sensor

Three hot diodes sensors, sometimes referred to as the rectifier Over Temperature Sensors (OTS), are mounted, one in each of the three power rectifier panels, Fig. VIII-27. These sensors react to a rise in temperature usually caused by a lack of cooling air from the equipment blower or from an impending failure of a rectifier panel.

Activation of any of the three sensors will cause:

1. The Rectifier Over Temperature Relay (ROR) to be energized
2. The alternator to unload
3. The engine to return to idle speed after 30 seconds
4. The HOT DIODES light on the EC Panel to light
5. The trainline alarm bell to ring for 30 seconds.

After the problem has been resolved, the ROR relay can be reset by pushing the AIR FILTER, FUEL PUMP AND HOT DIODE RESET push-button on the EC Panel.

MONITOR CIRCUITS AND INDICATORS

The monitor circuits and indicators are shown on Fig. VIII-28. This figure lists the indicators (lights and alarms) located on the Engine Control Panel, Annunciator Panel and the operator's control console. It also defines the applicable monitor circuit for each indicator and the action that will result should the circuit be activated. As stated before, variations will exist between different models of locomotives and between railroad customers.

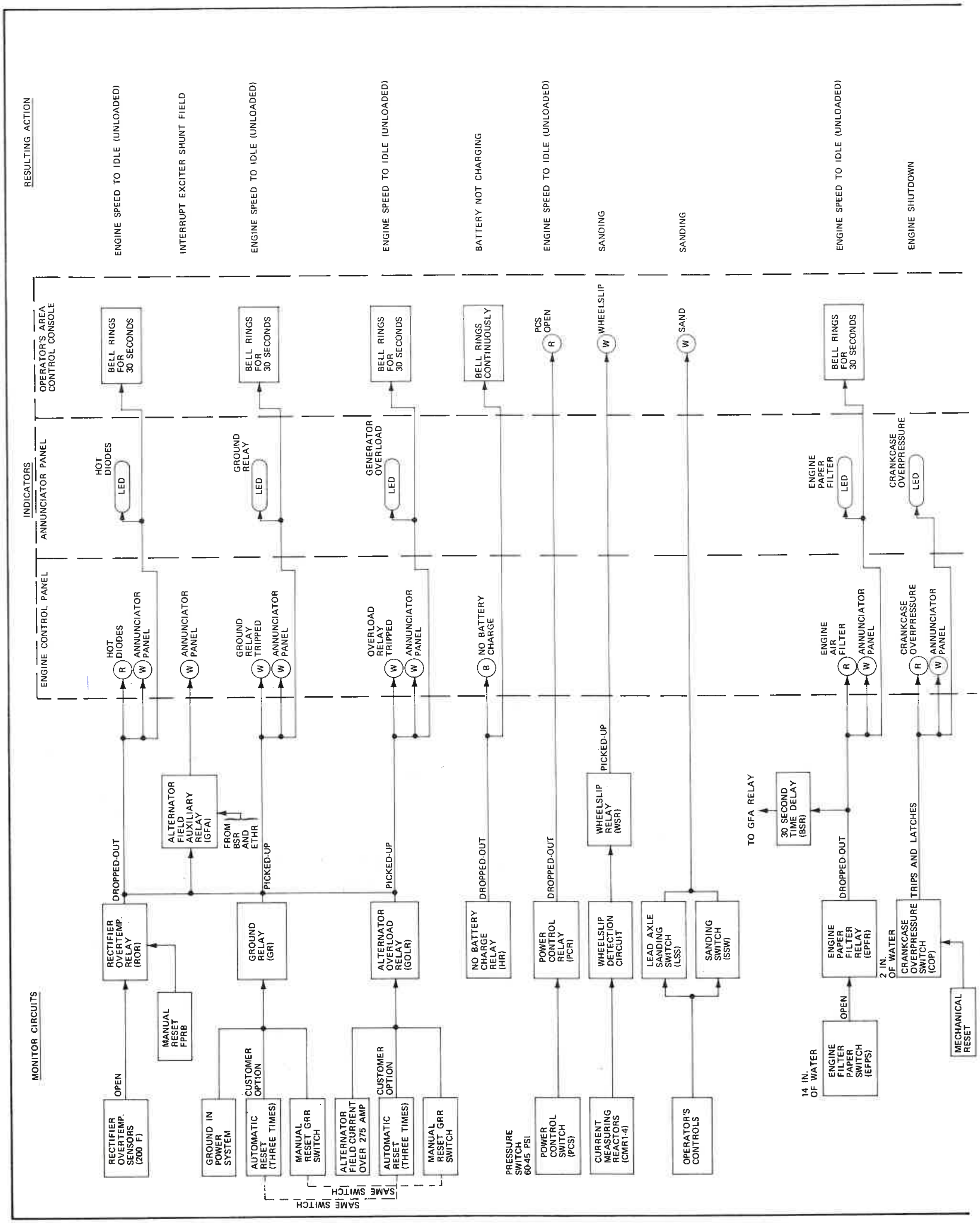


FIG. VIII-28, E-25271

VIII

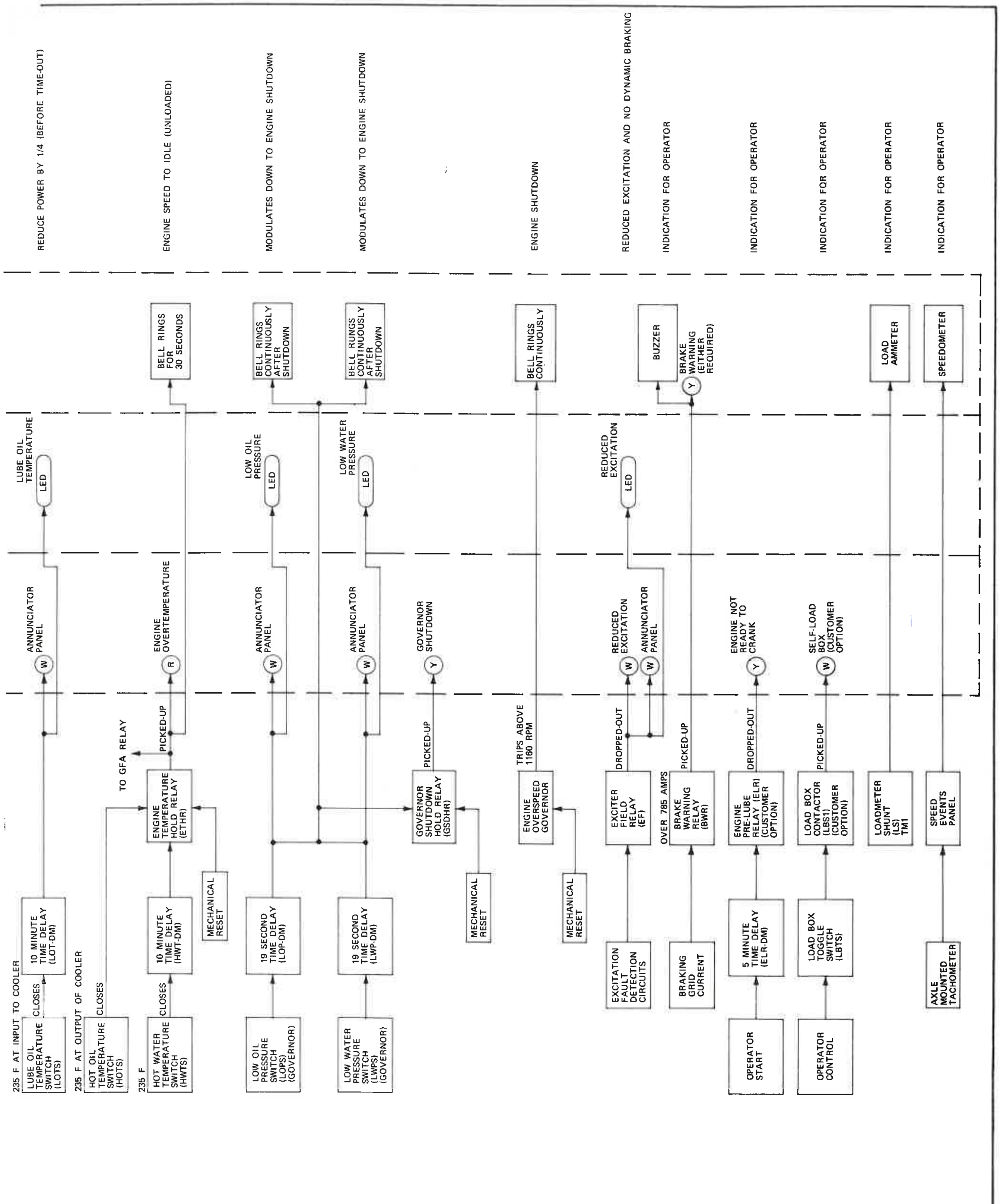


FIG. VIII-28. MONITOR CIRCUITS AND INDICATORS.

TRANSPORTATION SYSTEMS BUSINESS DIVISION

ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

DIESEL ENGINE

CONTENTS

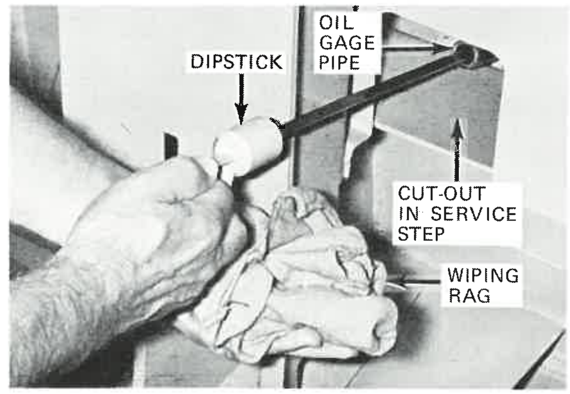


FIG. IX-1. CHECKING LUBE-OIL LEVEL.

FIG. IX-1, E-25551

CONTENTS (Cont'd.)

IX

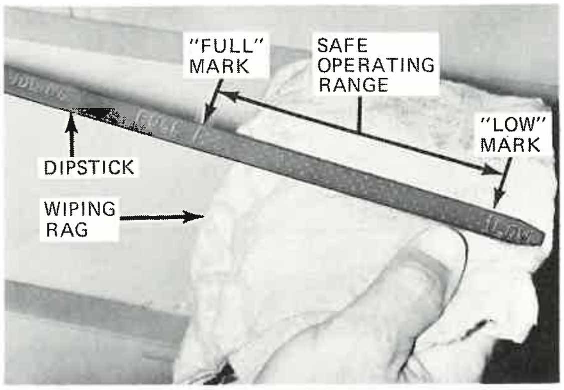


FIG. IX-2. CRANKCASE DIPSTICK.

INTRODUCTION

This section covers the procedures required to service the diesel engine at periodic inspections. It also covers replacement procedures that may be required following the performance of the necessary checks and adjustments of the engine systems and components.

CHECKS

CRANKCASE OIL LEVEL

With the engine running at IDLE speed, remove the dipstick, Fig. IX-1, and wipe it clean. Install the dipstick to its full depth and quickly remove and read the indication which should be between the FULL and LOW marks on the dipstick, Fig. IX-2.

IX

If oil level is low, add oil at fill pipe, Fig. IX-3, until level is at, or near, the FULL mark on the dipstick. Replace and secure the fill cap.

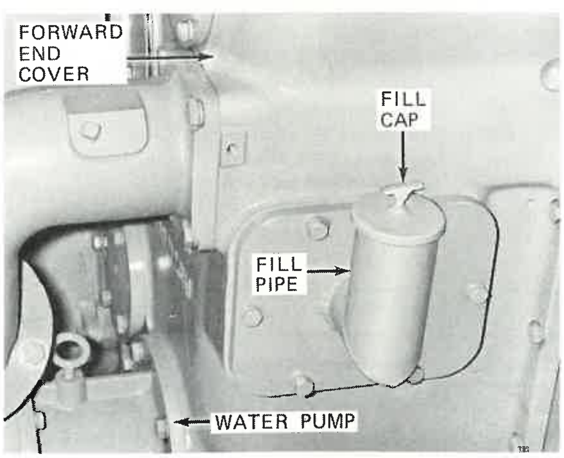


FIG. IX-3. LUBE-OIL FILL.

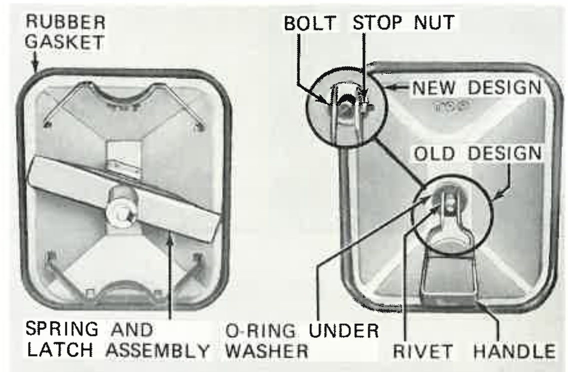


FIG. IX-4. CRANKCASE INSPECTION COVER.

CAUTION: *Do not fill above the FULL mark. This may cause a false Crankcase Overpressure (COP) switch operation.*

CRANKCASE INSPECTION COVERS

After engine has run for a long time period and before any crankcase covers, Fig. IX-4, have been removed, check both sides of the engine main frame. At each cover location, check for lube-oil leakage in the following areas:

1. Past the gasket which seals the cover to the face of the main frame
2. Around the latch shaft where it passes outward through the cover.

Leakage at either area should be corrected immediately by renewing defective gaskets and O-rings.

CRANKCASE STRAINER

With engine shut down, remove appropriate crankcase inspection covers. Work thru convenient openings and remove the strainer cover, Fig. IX-5 and Fig. IX-6, which is identical to the covers on the sides of the main frame. Lift out the strainer basket and examine the inside of the basket. Analyze any debris collected in the basket.

Clean the basket before reinstalling. Check the cover gasket and O-ring around the latch shaft; if not in good condition, renew.

NOTE: *Leakage at either the gasket or the O-ring together with a low lube-oil level will cause a low-oil shutdown.*

FIG. IX-2, E-25552

FIG. IX-3, E-25553

FIG. IX-4, E-9977B

FIG. IX-5, E-18304

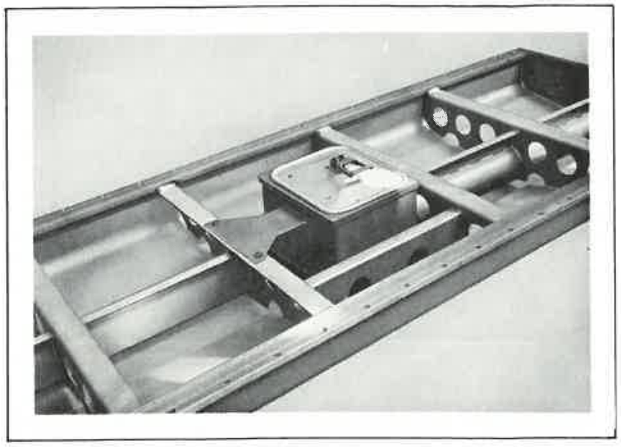


FIG. IX-5. ENGINE OIL PAN WITH STRAINER COMPLETELY ASSEMBLED.

ENGINE GOVERNOR OIL LEVEL

With the engine running at IDLE speed, check the oil level in the sight glass, Fig. IX-7. Correct level is at, or slightly below, the line in the sight glass; if level is above the line, the excess oil will spill out thru the vent in the top of the sight glass when the engine is shut down.

If oil level is low, add clean SAE 10W-30 governor oil thru the fill cap on the top of the governor cover. Fill with the engine running at IDLE speed until oil level in sight glass is at the line in the sight glass.

COOLING WATER LEVEL

Check the cooling water level after the engine has been idling for at least ten minutes. This will assure all water has drained from the radiator back to the storage tank. Correct water level is between the FULL AT IDLE and LOW AT IDLE marks in the sight glass, Figs. IX-8 and IX-9.

FIG. IX-6, E-18305

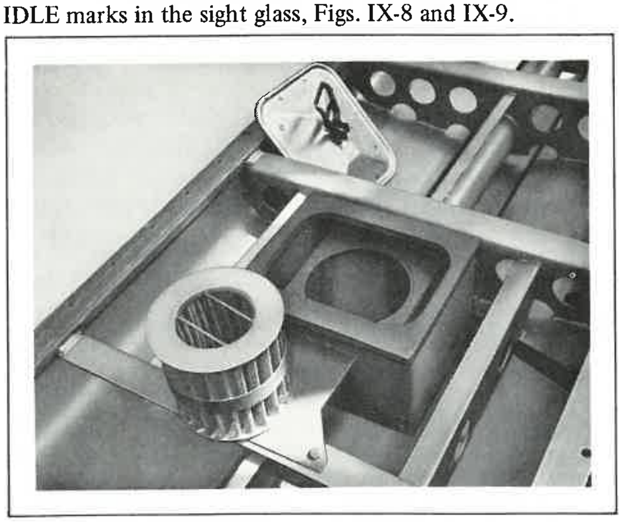


FIG. IX-6. STRAINER WITH BASKET REMOVED.

FIG. IX-7, E-25085

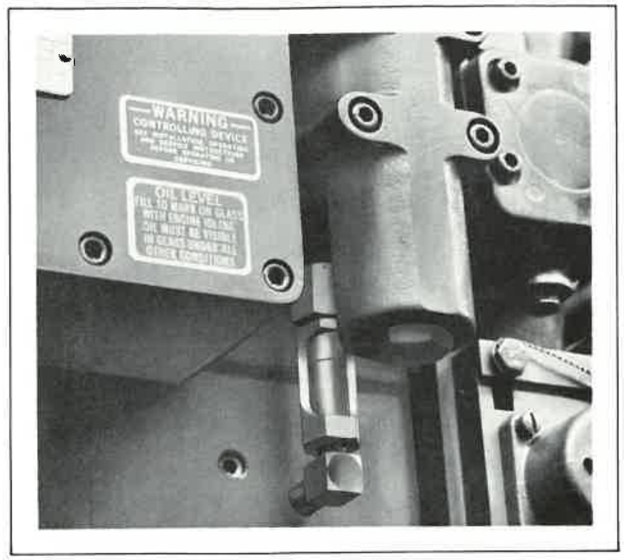


FIG. IX-7. GOVERNOR-OIL SIGHT GLASS.

If cooling water is below the LOW AT IDLE mark, add water to the correct level by one of the following methods:

Thru the Water Fill Pipe, Fig. IX-9 –

1. Attach the hose on the end of the water supply to the fill pipe connection
2. Turn on the water supply
3. Pull down the spring-loaded handle on the water fill valve
4. Hold handle down until water level is at the FULL AT IDLE mark
5. Slowly raise the spring-loaded handle to its normal vertical position

FIG. IX-8, E-25554

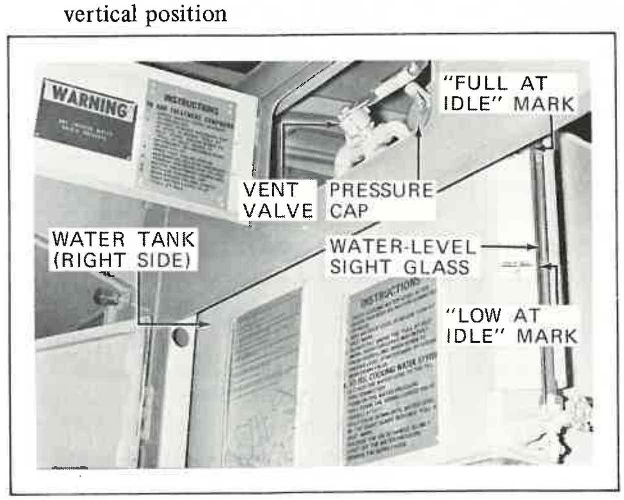


FIG. IX-8. COOLING WATER-LEVEL GAGE.

IX

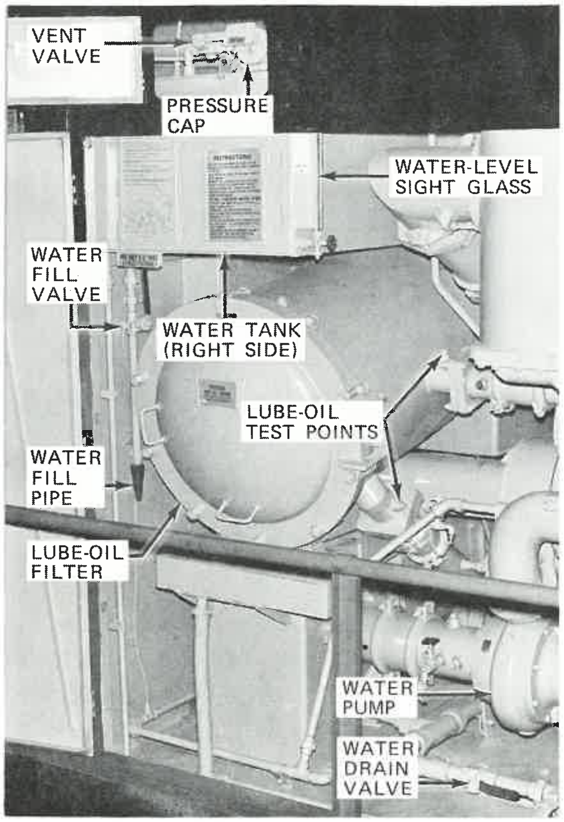


FIG. IX-9. COOLING WATER FILLS AND DRAIN.

6. Shut off the water supply

7. Remove the water supply hose from the connection.

Thru the Fill Pipe Covered by the Pressure Cap, Figs. IX-8 and IX-9 –

1. Pull the vent-valve handle downward and hold for 60 seconds to vent pressure from the system

2. With the vent-valve handle still held downward, remove the pressure cap

3. Add water thru the fill pipe until water level is at the FULL AT IDLE mark

4. Replace the pressure cap and allow the vent-valve handle to return to its normal horizontal position.

COOLING WATER ANALYSIS

Take sample of cooling water from the sampling valve, Fig. IX-10. Have sample anlayzed by laboratory and take appropriate action based on the analysis. That is, change cooling water, add treatment, find and correct exhaust leak, etc. If treatment compound is required, add it thru the fill pipe covered by the pressure cap, Figs. IX-8 and IX-9, in the following manner:

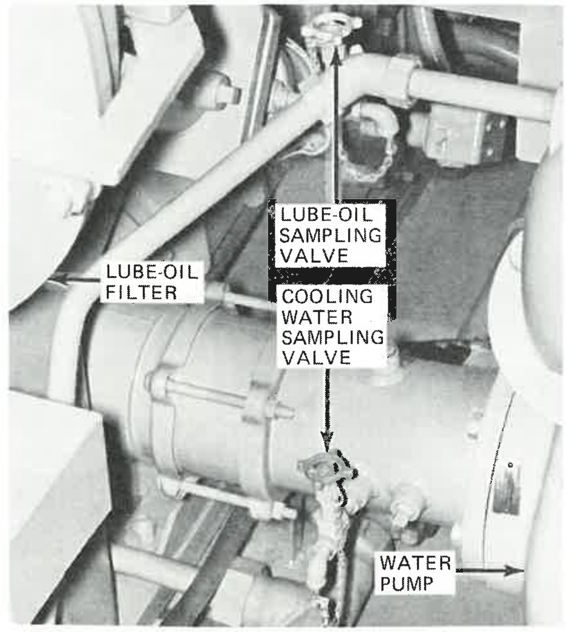


FIG. IX-10. SAMPLING VALVES.

1. Check the water level in the sight glass with the engine idling.

2. Do not remove the pressure cap if level is above FULL AT IDLE mark. Drain down till level is at FULL AT IDLE mark.

3. Pull the vent-valve handle downward and hold for 60 seconds to vent pressure from the system.

4. Remove the pressure cap and add the required amount of treatment compound.

5. Replace the pressure cap.

6. With engine idling, check water level is at FULL AT IDLE mark.

LUBE-OIL ANALYSIS

Take sample of lube oil from the sampling valve, Fig. IX-10. Have sample analyzed by laboratory and take appropriate action based on the analysis. That is, change lube oil, find and correct cause of dilution by fuel oil or water, find and correct cause of increase of such metals as copper, iron, chromium, aluminum, etc.

FIG. IX-9, E-25555

FIG. IX-10, E-25556

IX

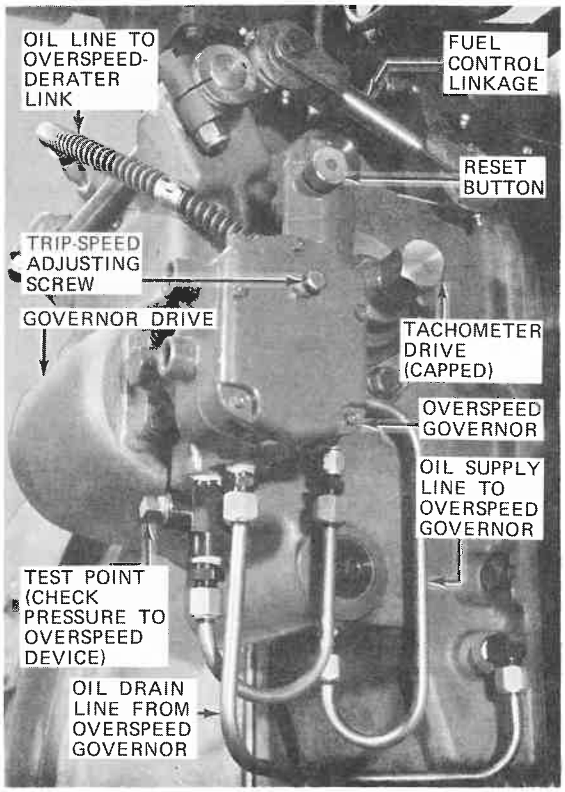


FIG. IX-11. TYPICAL OVERSPEED GOVERNOR ARRANGEMENT.

FIG. IX-11, E-25557

OVERSPEED GOVERNOR OUTPUT OIL PRESSURE

With the engine shut down, remove the pipe plug and install a 0-300 psi pressure gage in the test point below the overspeed governor, Fig. IX-11. While cranking the engine, crack a fitting in the oil line to the overspeed-derater link to bleed all air from this line. Tighten the cracked fitting and while cranking the engine, note the output oil pressure on the test gage. A pressure of 95 to 175 psi should quickly develop and completely compress the overspeed-derater link. After the engine is running, the output oil pressure should be 180-220 psi.

Low output oil pressure can be caused by a dirty or stuck regulating valve located in the oil inlet portion of the overspeed governor or by excessively worn gears in the pump portion of the overspeed governor. Remove, clean the regulating valve and reinstall it in the governor. If this does not correct the low output oil pressure condition, replace the overspeed governor with a new or rebuilt unit.

OVERSPEED GOVERNOR TRIP SPEED

The trip speed is best checked with the overspeed governor set up on a governor test stand. When this is not possible, the overspeed governor can be checked when mounted on the diesel engine. The trip speed is checked in the locomotive in the following manner:

1. Install a direct-reading, accurately-calibrated tachometer. Attach it to the standard SAE tachometer drive located on the forward side of the governor drive, Fig. IX-11.
2. With engine running at Notch 8, no load speed, apply a pry bar to the overspeed link to override the governor and increase engine speed. Pivot the pry bar on the head of the clamp bolt which secures the fuel-linkage lever attached to the bottom of the link, and allow the pry bar to apply an upward force to the bottom of the oil inlet boss. DO NOT APPLY FORCE AGAINST OIL FITTING OR HOSE. A downward pressure on the outer end of the pry bar will thus raise the overspeed link and the governor power piston, and will cause the fuel pump racks to extend and increase engine speed. At the same time, the overspeed link is free to extend itself when the overspeed governor trips.
3. Slowly and cautiously, raise the engine speed to 1155 ± 10 crankshaft rpm (1738 ± 15 tachometer drive rpm).
4. If the overspeed governor does not trip at speeds specified in Step 3:
   a. Remove the pry bar.
   b. With the engine still in Notch 8, no load speed, back out (turn counterclockwise) the overspeed governor trip-speed adjusting screw until the governor trips.
5. Return Throttle handle to IDLE and restart the engine.
6. Apply the pry bar, as outlined in Step 2, and slowly raise the engine speed. At the same time slowly turn the trip-speed adjusting screw inward (clockwise). Alternate turning the adjusting screw and increasing the speed until correct trip speed is achieved.

   By keeping a close observation and promptly depressing (at about IDLE speed) the overspeed governor reset button after tripping, the engine will ordinarily recover and continue operating without the need for additional cranking.

CAUTION: *While checking the overspeed governor trip speed, never exceed 1200 crankshaft rpm (1783 tachometer drive rpm). Exceeding this speed may cause serious damage to the engine and to the auxiliary equipment mechanically driven by the engine.*

IX

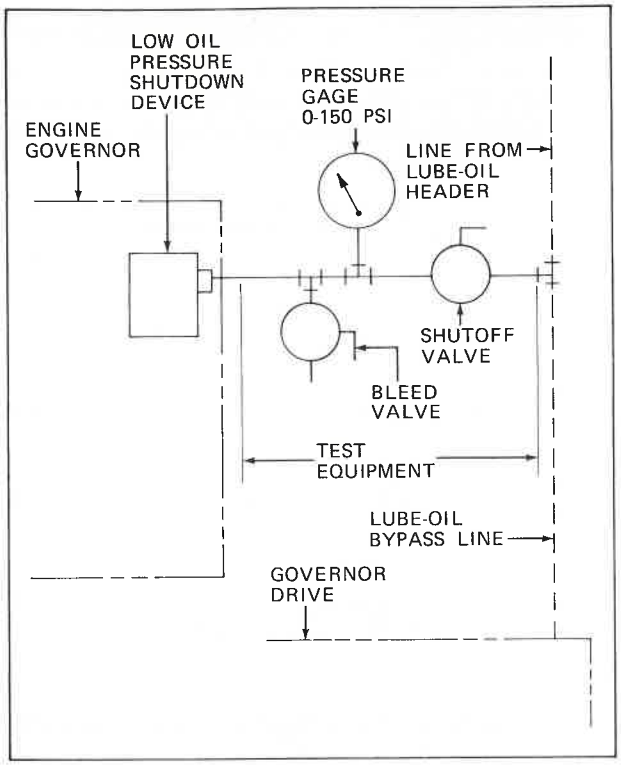


FIG. IX-12. SCHEMATIC DIAGRAM SHOWING TEST EQUIPMENT FOR CHECKING LOW OIL PRESSURE SHUTDOWN DEVICE.

OVERSPEED-DERATER LINK

Check to ensure that air and oil supply connections are tight, and hoses are free of leaks.

Check to ensure that link moves freely from its fully-opened to its fully-closed position, and from its fully-closed to its fully-opened position. This is accomplished by starting and running the engine, and then shutting the engine down. While running the engine note that link is fully closed by observing the top edge of the indicator aligned with the lower groove on the outer casing, Fig. IX-34.

ENGINE GOVERNOR LUBE-OIL TRIP PRESSURE

While the governor is best checked on a governor test stand, it can be checked on the locomotive in the following manner:

NOTE: *The engine speed may hunt during the following test. Hunting is not a reason for disqualifying an engine governor.*

1. Install a test shutoff valve, a 0-150 psi pressure gage and a pressure bleed valve in the engine oil supply line where it connects to the low-oil pressure device on the governor, Fig. IX-12. The pressure bleed valve and gage must be connected in the line between the shutoff valve and the governor with one side of the bleed valve open to atmosphere.

2. Open the test shutoff valve and close the bleed valve.

3. Start the engine and allow it to operate at IDLE speed until normal operating temperature has been reached.

4. Run the engine at Notch 8 speed. Then close the test shutoff valve and slowly open the bleed valve. When the oil pressure drops to the trip pressure of 45.5-46.5 psi:

   a. The Engine Governor Relay (EGR) should pick-up

   b. After 19 seconds the LOW OIL PRESSURE light on the annunciator panel will come on.

   When the oil pressure is reduced about 2 to 3 psi below the trip setting, the engine should start to reduce speed.

   When the bleed valve is opened to further reduce the oil pressure, the engine should further reduce speed.

   When the oil pressure is reduced to about 4 psi, the engine should shut down, and the Governor Shutdown Hold Relay (GSDHR) should pick-up. This will cause a light on the relay and a light on the engine control panel to come on.

5. Close the bleed valve and open the shutoff valve.

6. After three minutes, reset the Governor Shutdown Hold Relay (GSDHR).

NOTE: *The lights on the engine control panel and the relay should go off. If they do not go off, it indicates that the governor has not yet reset. Wait four minutes and again reset the governor shutdown hold relay. If lights do not go off, and stay off, change out the governor.*

7. Operate the reset switch on the annunciator panel to cause the annunciator panel light to go off.

8. Restart the engine and operate at IDLE speed. Then close the test shutoff valve and slowly open the bleed valve. When the trip pressure of 7-14 psi is reached, and after 45 seconds time delay, the engine speed should decrease. When the pressure is further reduced to about 4 psi, the engine should shut down and the lights on the engine control panel and the Governor Shutdown Hold Relay (GSDHR) should come on.

FIG. IX-12, E-25601

IX

FIG. IX-13, E-21436

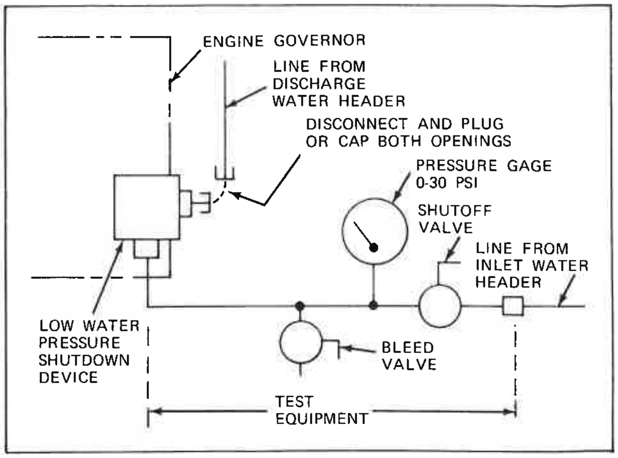


FIG. IX-13. SCHEMATIC DIAGRAM SHOWING TEST EQUIPMENT FOR CHECKING LOW WATER PRESSURE SHUTDOWN DEVICE.

9. Repeat Steps 5, 6 and 7, remove the test equipment and restore the original piping.

ENGINE GOVERNOR WATER TRIP PRESSURE

While the governor is best checked on a governor test stand, it can be checked on the locomotive in the following manner:

NOTE: *The engine speed may hunt during the following test. Hunting is not a reason for disqualifying an engine governor.*

1. Install a test shutoff valve, a 0-30 psi pressure gage (or a mercury manometer) and a pressure bleed valve in the engine water pressure line where it connects to the low water pressure device on the governor, Fig. IX-13. Also disconnect the line from the water discharge header to the low-water pressure device on the governor, at the device. Plug or cap each side of this break.
2. Follow the same procedure outlined in the Engine Governor Lube-Oil Trip Pressure section except use the following values of water pressure:

   At Notch 8 Speed –

   Governor trips, Engine Governor Relay (EGR) picks-up, speed starts to drop and, after 19 seconds, the LOW WATER PRESSURE light on the annunciator panel will come on at 22-29 in. of mercury (in. Hg) which is equal to 11-15 psi.

   Governor must shut engine down, the Governor Shutdown Hold Relay (GSDHR) should pick-up, the lights on the relay and the engine control panel come on at 2 in. Hg which is equal to 1 psi.

   At IDLE Speed –

   Governor trips and, after 45 seconds time delay, the speed drops, and after another 19 seconds time delay, the light on the annunciator panel will come on at 3.5-4.5 in. Hg which is equal to 2 psi.

   Governor must shut engine down, the Governor Shutdown Hold Relay (GSDHR) should pick-up and the lights on the relay and the engine control panel come on at 2 in. Hg which is equal to 1 psi.

ENGINE SPEEDS

The engine speeds are controlled by the engine control governor and it is preferable to check and set the speeds with the governor on a test stand. When this is not possible, the control governor can be checked when mounted on the diesel engine. The speeds are checked, in the locomotive, in the following manner:

1. Install a direct-reading, accurately-calibrated tachometer. Attach it to the standard SAE tachometer drive located on the forward side of the governor drive, Fig. IX-11.
2. With the engine running at normal operating temperature and at no load, advance the throttle thru all notches. Dwell in each notch long enough for the engine speed to stabilize, then read the speed on the tachometer.

NOTE: *If locomotive has a standard speed schedule, refer to Table IX-I for correct values for engine crankshaft speeds. This table also gives equivalent tachometer drive speeds for each throttle notch. Many locomotives have a special speed schedule which is identified by comparing the values given in Table IX-I with those found on the locomotive electrical schematic diagram. When a special speed schedule is used, use the speed values given on the schematic diagram and not those given in Table IX-I. Be certain that the schematic diagram applies to the locomotive being checked.*

TABLE IX-I
STANDARD SPEED SCHEDULE

Throttle Position	Engine Crankshaft rpm	Tachometer Drive rpm
Idle	444-453	660-673
1	444-453	660-673
2	519-549	771-816
3	606-636	900-945
4	702-710	1043-1055
5	778-808	1156-1201
6	874-882	1299-1310
7	960-968	1426-1438
8	1045-1055	1553-1568

IX

DIFFERENTIAL PRESSURE – ACROSS LUBE-OIL FILTER

With the engine shut down, install 0-150 psi pressure gages in the test points (Fig. X-2 and Fig. IX-9) in the pipes into, and out of, the filter.

With the engine running in Notch 8 speed and the lube oil at normal operating temperature of 200-210 F, read pressures on both gages. Subtract the lower pressure from the higher pressure to get the differential pressure, or drop in pressure, across the filter. With new filter elements in the filter, the differential pressure should be 5-9 psi; filter elements should be changed when the differential pressure exceeds 25 psi.

DIFFERENTIAL PRESSURE – ACROSS LUBE-OIL COOLER

With engine shut down, install 0-150 psi pressure gages in the test points (Fig. X-2) in the pipes into, and out of, the oil cooler.

With the engine running in Notch 8 speed and the lube oil at normal operating temperature of 200-210 F, read pressures on both gages. Subtract the lower pressure from the higher pressure to get the differential pressure, or drop in pressure, across the cooler. With a clean cooler, the differential pressure should be 15-21 psi.

While an increase in the differential pressure will be indicative of dirt (sludge) accumulating in the cooler, the preferred method of determining when a cooler should be cleaned is to measure the performance of the cooler. See Determining Lube-Oil Cooler Condition section.

IX

DETERMINING LUBE-OIL COOLER CONDITION

To determine if the lube-oil cooler requires cleaning, the maximum stable temperature of the lube oil leaving the engine and the cooling water entering the cooler must be accurately measured and plotted on the graph, Fig. IX-14. Measurements plotted should fall between the two curves; clean the cooler if the plotted measurements fall above the upper, condemning limit curve.

To obtain maximum stable temperatures in the systems, during the cooler test, the engine must be operated for a sufficient length of time at its full horsepower rating. At no time during the test should the temperature of the lube oil leaving the engine be permitted to exceed 220 F.

To perform the test, install two accurate 250 F temperature gages, one at each of the following points:

1. In the lube-oil pump discharge pipe (Fig. X-2).

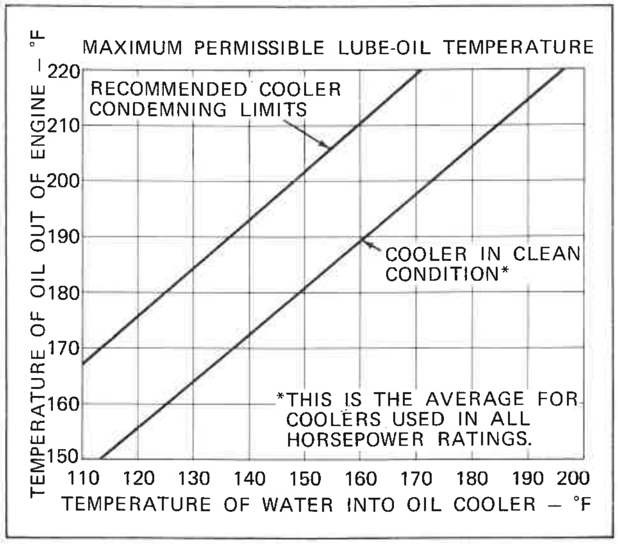


FIG. IX-14. LUBE-OIL COOLER PERFORMANCE GRAPH.

FIG. IX-14, E-13524A

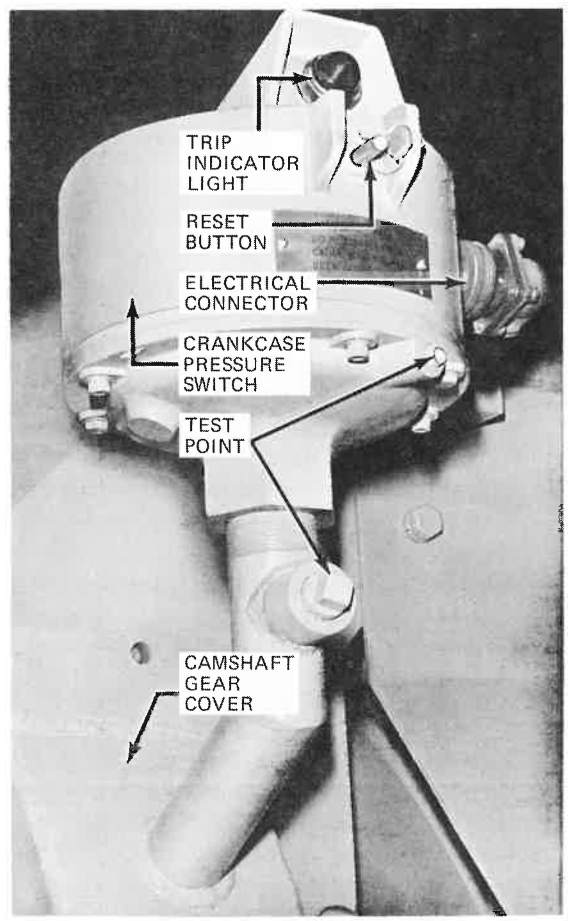
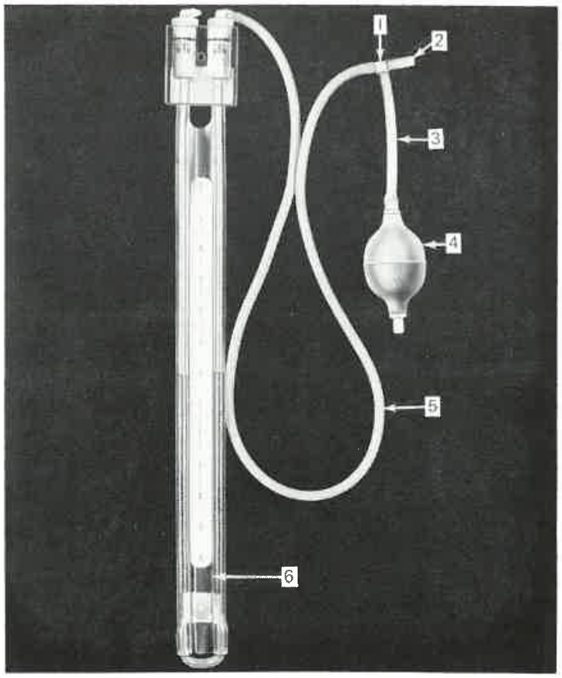


FIG. IX-15. ENGINE CRANKCASE PRESSURE SWITCH SHOWING CRANKCASE PRESSURE TEST POINTS.

FIG. IX-15, E-25558

FIG. IX-16, E-14841

FIG. IX-17, E-21627



REF.	DESCRIPTION
1	PLASTIC TEE
2	RUBBER TUBING, 3/16 IN. I.D., 1/2 IN. LONG
3	RUBBER TUBING, 3/16 IN. I.D., 5 IN. LONG
4	RUBBER BULB (DOUBLE ACTING)
5	RUBBER TUBING, 3/16 IN. I.D., 18 IN. LONG
6	MANOMETER 12 IN.

FIG. IX-16. SLACK TUBE MANOMETER TEST KIT, PART 147X1475.

2. In the lower right corner of the left-side water tank where the standard temperature gage is normally installed (Fig. X-4).

CRANKCASE PRESSURE

Connect one side of a slack tube manometer, Part 147X1475, to the crankcase. Two convenient connection points are shown in Fig. IX-15. Engines will have one connection point or the other while some will have both points.

With the engine running, measure the difference in water levels in the two vertical legs of the manometer, Fig. IX-16. This difference in levels, expressed as "inches of water" or as "in. H_2O" is the crankcase pressure. Normal crankcase pressure is slightly negative in. H_2O to very slightly positive in. H_2O.

NOTE: *When the crankcase pressure exceeds plus 1.9 to 2.1 in. H_2O, the Crankcase Overpressure switch (COP) should trip and shut down the engine.*

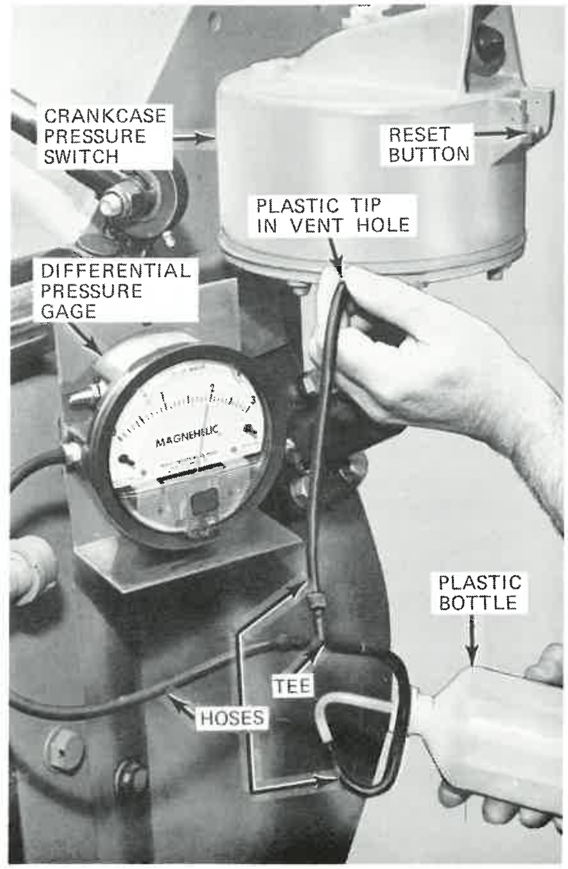


FIG. IX-17. CHECKING CRANKCASE PRESSURE SWITCH WITH TEST KIT, PART 147X1995.

IX

CRANKCASE PRESSURE SWITCH

Mechanical Check

Using the test kit shown in Fig. IX-16 or Fig. IX-17, check the tripping pressure of the switch. This should be plus 1.9 to 2.1 in. of water.

1. With the engine shut down, hang the manometer or the differential pressure gage in a convenient place close to the pressure switch.

2. Firmly push in on the reset button to be sure the switch is in the RESET, or normal-operating, position.

3. When using test kit, Part 147X1475, hold the short piece of rubber tubing tightly against the vent hole in the control plate, Fig. IX-15. Then slowly work the rubber bulb to draw air from the upper side of the diaphragm.

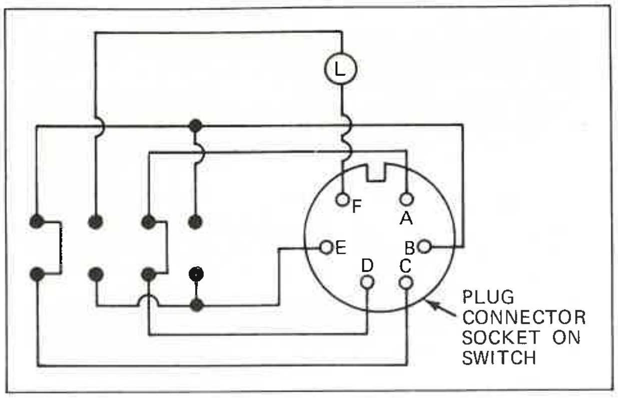


FIG. IX-18. INTERNAL WIRING DIAGRAM OF SWITCH — SHOWN IN RESET POSITION.

FIG. IX-18, E-21628

4. When using test kit, Part 147X1995, squeeze the plastic bottle to expel most of the air from within the bottle, then insert the plastic tip into the vent hole in the control plate, Fig. IX-17. Then allow the plastic bottle to expand and, in so doing, draw air from the upper side of the diaphragm.
5. Observe the indication on the manometer or the differential pressure gage when the switch begins to trip.
6. If indication is outside the correct tripping limits, replace the switch with a new or rebuilt switch.

Electrical Check

Disconnect the receptacle from the plug connector at the switch, so the pins in the plug connector are made accessible. Position the switch in both the RESET, or normal-operating, and TRIPPED positions. Using a test light or ohmmeter, check the internal circuitry of the switch. Refer to Figs. IX-18, IX-19 and Table IX-II. The switch can be tripped by drawing a slight vacuum at the vent hole (Fig. IX-15); it is reset by firmly depressing the reset button (Fig. IX-15).

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TABLE IX-II, CONTINUITY CHECK

Pins	Circuit Condition With Switch In Position: RESET	Circuit Condition With Switch In Position: TRIPPED
D-A	Closed	Open
B-E	Open	Closed
B-F	Open	Closed*

*If open check pilot light bulb on the switch.

CYLINDER INLET PORTS

Remove clamp rings, manifold tubes, manifold bodies and heads, Fig. IX-20, to expose the cylinder inlet ports, Fig. IX-21. Note the degree of carbon build-up on all visible

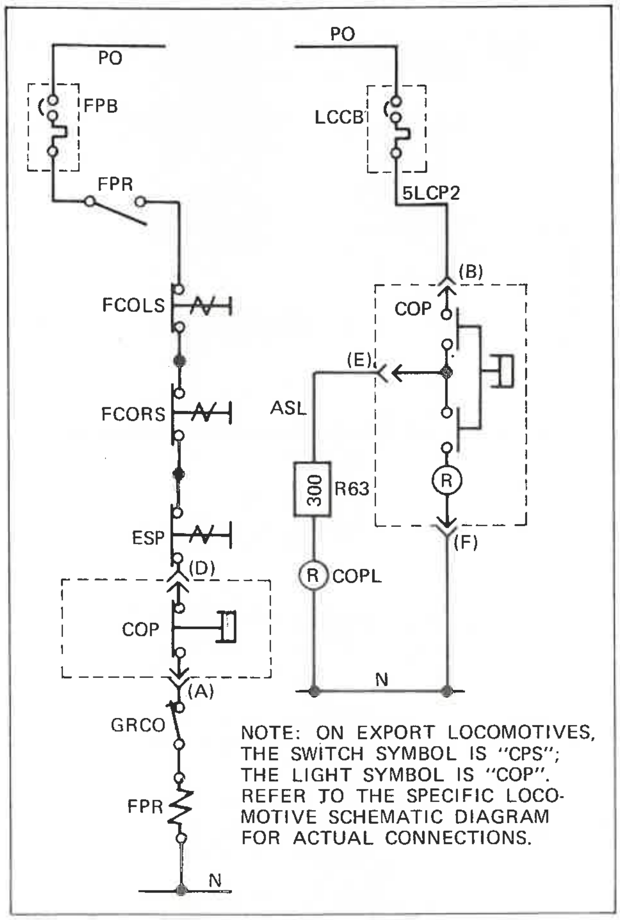

FIG. IX-19. TYPICAL LOCOMOTIVE SCHEMATIC DIAGRAM (PARTIAL) SHOWING CRANKCASE PRESSURE SWITCH CONNECTIONS.

FIG. IX-19, E-21629

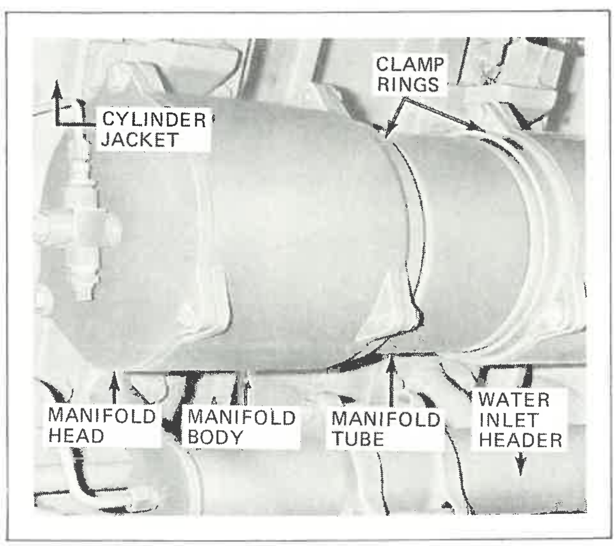

FIG. IX-20. ENGINE AIR INTAKE MANIFOLD.

FIG. IX-20, E-25559

FIG. IX-21, E-25560

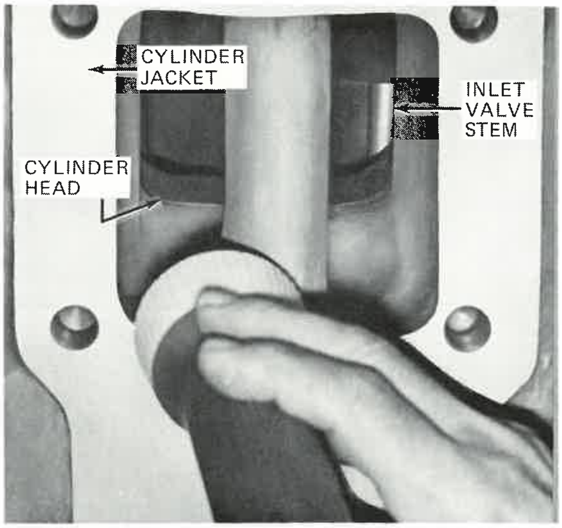

FIG. IX-21. CYLINDER INLET PORT.

surfaces of cylinder jacket, cylinder head and inlet valves. If carbon build-up exceeds 1/8 in. on any surface, clean the inlet ports of all cylinders in the engine using the walnut-shell cleaner, Part 147X1589.

CRANKSHAFT END-PLAY

With the engine shut down and crankcase inspection cover(s) removed, set up a magnetic base dial indicator, Part 147X1229. Attach the magnetic base to the main frame and position the indicator needle against the face of one of the counterweights. With a pry bar, move the crankshaft to its extreme forward and rear positions. Note the total movement of the dial indicator which is the crankshaft end-play or thrust clearance. If total clearance exceeds 0.030 in., renew thrust collars.

NOTE: *Crankshaft end-play is most easily done immediately after shutting the engine down.*

GEAR TRAINS

Front

Remove the lube-oil fill (Fig. IX-3) from the left side of the forward-end cover. Thru the opening in the cover, Fig. IX-23, and while barring-over the engine, visually inspect all gear teeth for excessive wear, broken teeth and overheating (discoloration).

NOTE: *While lube-oil fill is removed, check the pump drive gear rubber-bonded coupling. See Pump Drive Gear Coupling section.*

FIG. IX-22, E-25561

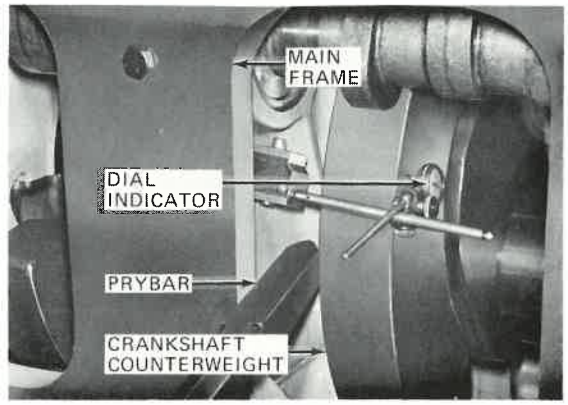

FIG. IX-22. CHECKING CRANKSHAFT END-PLAY.

Rear

Remove the camshaft gear cover (Fig. IX-15) from the rear left side of the main frame. Thru the opening in the main frame, Fig. IX-24, and while barring-over the engine, visually inspect all gear teeth for excessive wear, broken teeth and overheating (discoloration).

PUMP DRIVE GEAR COUPLING

Remove the lube-oil fill (Fig. IX-3) from the left side of the forward-end cover. Thru the opening in the cover, Fig. IX-25, apply a pry bar and gently rotate the gear on its hub 1/32 to 1/16 in. When the force on the pry bar is removed, the gear will quickly return to its original position if the rubber-bonded coupling is intact. A second, and better check, requires a flashlight and mirror. Work thru the opening, Fig. IX-26, in the forward-end cover and view the

FIG. IX-23, E-25562

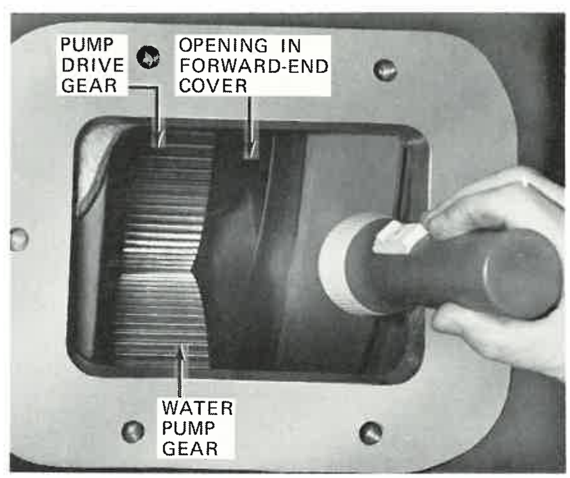

FIG. IX-23. CHECKING FRONT GEAR TRAIN.

IX

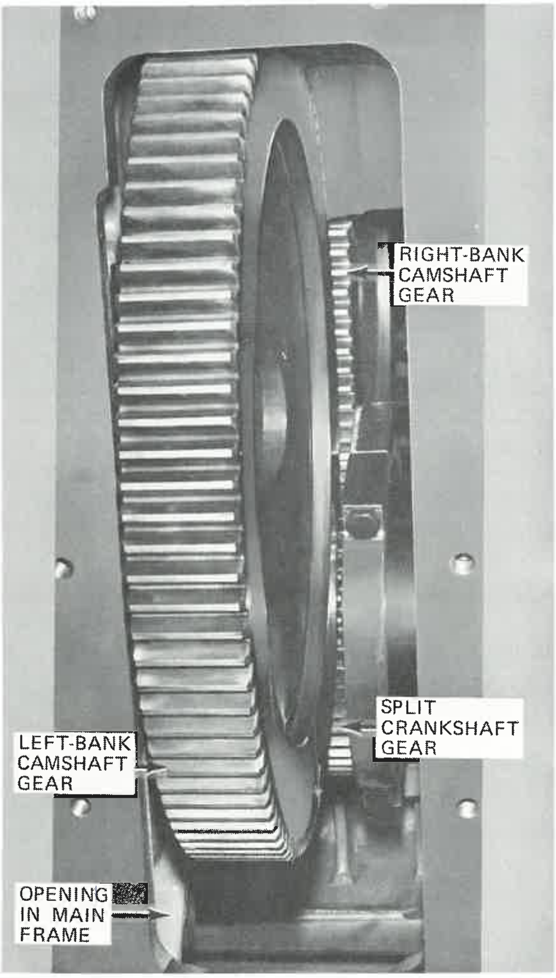

FIG. IX-24. CHECKING REAR GEAR TRAIN.

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rear surfaces of the gear and hub, Fig. IX-27. If rubber-bonded coupling is intact (has not sheared), at least one set of match-mark numbers, Fig. IX-28, will be aligned. Misaligned numbers indicate a sheared coupling which must be replaced.

FUEL INJECTION EQUIPMENT

With the engine idling, "pop" test each injector nozzle by pulling out the fuel linkage shaft, Fig. IX-29, so as to increase the injection-pump rack setting 2 or 3 mm, Fig. IX-30. The resulting "high-pitch" explosion qualifies the pump and nozzle as satisfactory; a "low-pitch" explosion indicates a faulty pump and/or nozzle. This test also quickly identifies "stuck" pumps.

FUEL LINKAGE

With the engine shut down, remove the clevis pin that connects the bottom of the overspeed-derater link to the

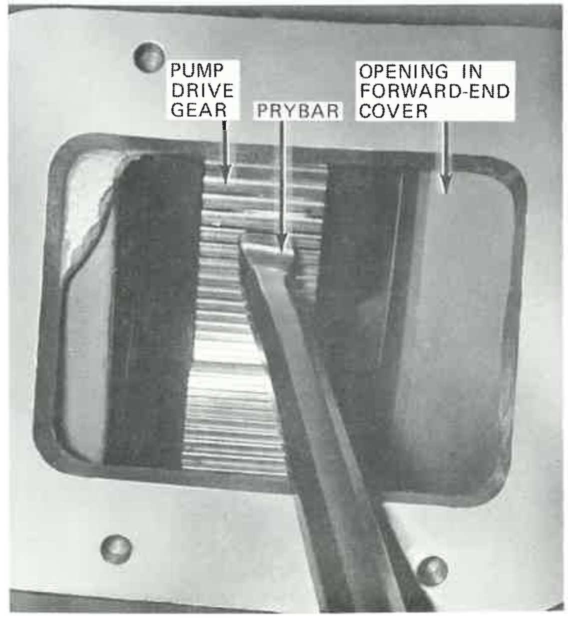


FIG. IX-25. CHECKING INTEGRITY OF RUBBER-BONDED COUPLING WITH A PRY BAR.

fuel linkage lever. With hand pressure applied to the fuel linkage lever, Fig. IX-31, rotate the short lay shaft which will operate the fuel linkage to all fuel injection pumps. Rotate lay shaft until full rack travel is achieved, then reverse the rotation until rack stop pins contact the faces of the calibration screws.

If fuel linkage cannot be moved thru its complete travel as outlined above, disconnect parts of the linkage, as required, until the source of the bindage is found and corrected.

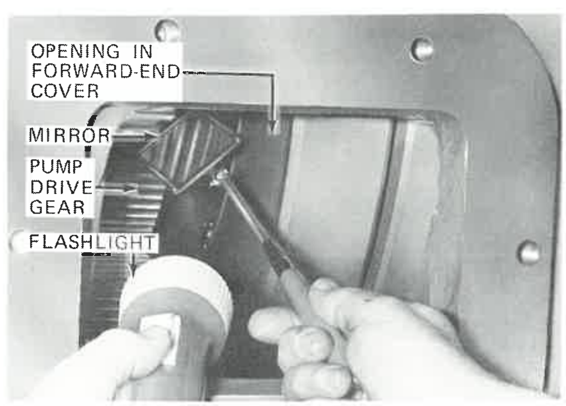


FIG. IX-26. CHECKING PUMP DRIVE GEAR MATCH MARK NUMBERS.

FIG. IX-24, E-25563

FIG. IX-25, E-25564

FIG. IX-26, E-25565

FIG. IX-27, E-25566
FIG. IX-28, E-25567
FIG. IX-29, E-25568
FIG. IX-30, E-25569

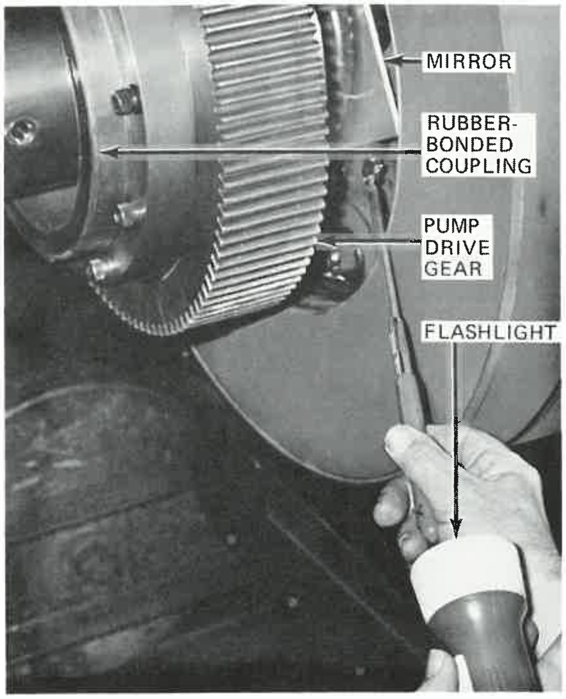


FIG. IX-27. CHECKING PUMP DRIVE GEAR MATCH MARK NUMBERS.

After fuel linkage has been moved thru its complete travel, check each fuel injection pump by pulling out the rack (Fig. IX-29) and allowing the spring to return it to the zero mm position. Note that no control rack stays stuck in the maximum fuel position.

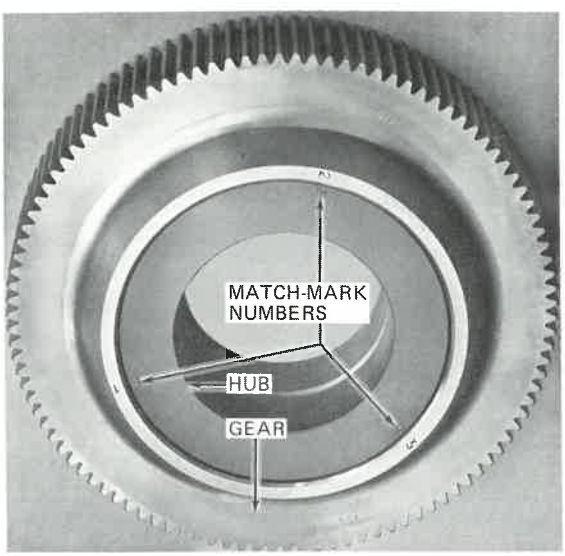


FIG. IX-28. MATCH-MARK NUMBERS ON BACK (FRAME) SIDE OF HUB AND GEAR.

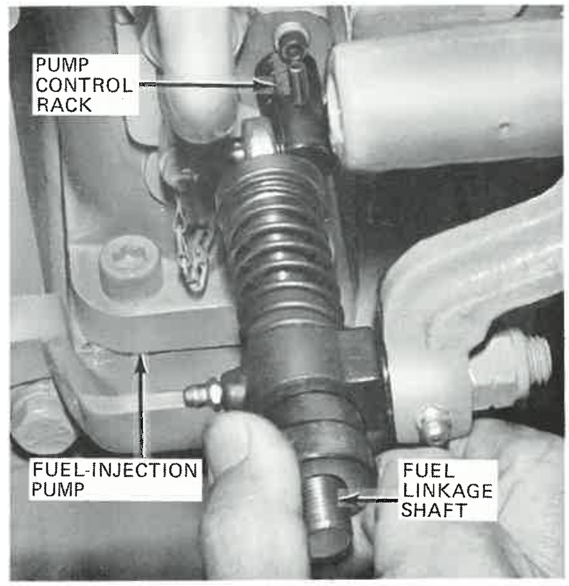


FIG. IX-29. "POP" TESTING TO IDENTIFY GOOD, OR BAD, FUEL INJECTION EQUIPMENT.

LEAKS

With engine idling, inspect the engine externally for system leaks. Lube-oil and fuel-oil leaks will be evident by oily films or flow patterns. Cooling-water leaks will be evident by discoloration due to the water treatment. Exhaust-gas leaks cause discolored or peeled paint or leave a carbon film adjacent to the leak.

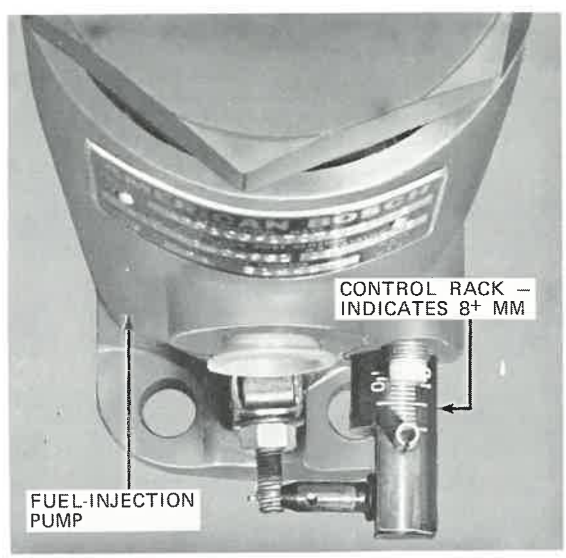


FIG. IX-30. INJECTION PUMP RACK SETTING DURING "POP" TEST.

IX

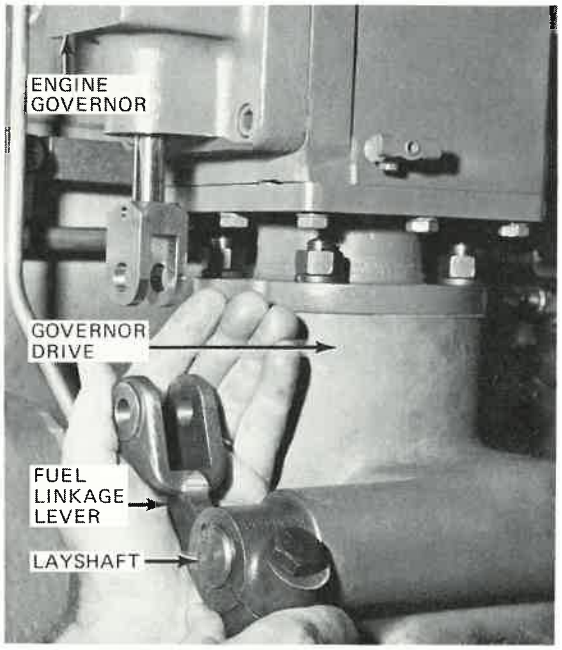


FIG. IX-31. MANUALLY MOVING FUEL LINKAGE.

FIG. IX-31, E-25570

NOISES

With engine idling, listen for excessive or unusual noises at each cylinder and at the exhaust stack. In addition to detecting such faults as excessive valve tappet clearance (clicking noise) or a defective exhaust valve (a louder-than-normal, periodic noise out the stack), this type of inspection may also identify other engine defects, such as a pounding (excessive clearance) bearing.

EXHAUST GAS

With engine idling, observe the color of the exhaust gas. A clear to light grey color is desirable. A blue cast indicates excessive lube oil in the exhaust gas, and this could result from scored cylinder liners, faulty piston rings, or bad turbocharger bearings and/or seals. A white cast indicates water in the exhaust gas which is probably caused by a defective top liner seal in a cylinder assembly. The white cast could also be a temporary condition due to the engine running cold.

ADJUSTMENTS

FUEL PUMP RACK SETTING

General

The following instructions cover the fuel pump rack settings for eight, twelve, and sixteen-cylinder engines. The settings given in Table IX-III are for eighth notch, full load (0.344 in. governor power piston gap) and for IDLE (31/32 to 1-1/32 in. power piston gap).

The settings given in the table will give the approximate horsepower expected from the engine; the precise horsepower output can only be achieved by load testing the engine and by fine adjustment of the control racks as required.

Fuel Header Pressure

The rack setting values given in Table IX-III are for locomotives whose fuel header pressure is set at 39-41 psi at IDLE engine speed.

TABLE IX-III

Engine Type	Loco-motive Appli-cation	Horsepower to Generator for Traction*	Notch 8 Engine Speed (rpm)	Notch 8 Tachometer Speed (rpm)	Injection Pump Size**	Recommended Fuel Lever and Length (in.)	Rack Settings (mm) ∆Engine Hot, N8 Speed, Full Load, 0.344 in. Gap	Rack Settings (mm) Idle Speed, 31/32 to 1-1/32 in. Gap□
FDL8	B18-7	1800	1045-1057	1553-1568	Large	132X1318 (3.250)	24,25-24,75	5,50-6,00
FDL12	B23-7 C23-7	2250	1045-1057	1553-1568	Large	132X1106-4 (2.375)	19,50-20,00	↑
FDL12	B28-7 C28-7	2750	1045-1057	1553-1568	Large	132X1317 (2.968)	22,5-23,0	|
FDL16	B30-7 C30-7	3000	1045-1057	1553-1568	Large	132X1251-1 (2.484)	19,50-20,00	↓
FDL16	B36-7 C36-7	3600	1045-1057	1553-1568	Large	132X1276-1 (2.843)	22,25-22,75	5,50-6,00

*Shown on the locomotive nameplate.

**A large pump is identified as a Part 132X1254-1 (Bendix) or Part 132X1343 (Bosch) pump.

∆NOTE: Experience shows that in many cases the rack readings on an engine, hot and running at full load, will average 0,5 mm higher than for the same engine cold and shut down.

□When the engine is running at IDLE speed, power-piston gap will vary due to variance in locomotive auxiliary loads.

FIG. IX-32, E-22594

FIG. IX-33, E-23479

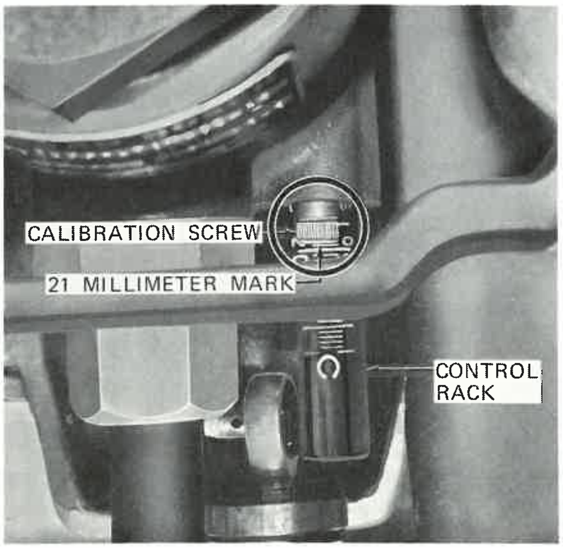


FIG. IX-32. CORRECT METHOD OF OBSERVING RACK READING — 21$^+$ MM READING SHOWN.

NOTE: *The header pressure at full speed and full load will be lower than the pressure at IDLE. This lower pressure varies with the engine horsepower output, and with the condition of the fuel strainer, fuel filter and fuel transfer pump.*

Reading Rack Setting

To correctly read a rack setting, always observe the control rack at a right angle to the direction of rack movement. Observing from an oblique angle will give an erroneous reading. The rack reading is obtained by sighting across the face of the calibration-screw head toward the etched indications (in millimeters) on the control rack, Fig. IX-32.

Adjusting Fuel Pump Racks

The racks of all fuel-injection pumps on an engine must be set to match the governor power piston gap and must be identical within the limits specified in Table IX-III. This is best accomplished with the engine shut down and one of the following safeguards used to prevent cranking the engine during the adjustment procedure:

1. Block the starting contactors OPEN.
2. Disconnect the electrical connector from the governor drive, Fig. IX-33.
3. Remove the barring-over cover from the governor drive, Fig. IX-33.

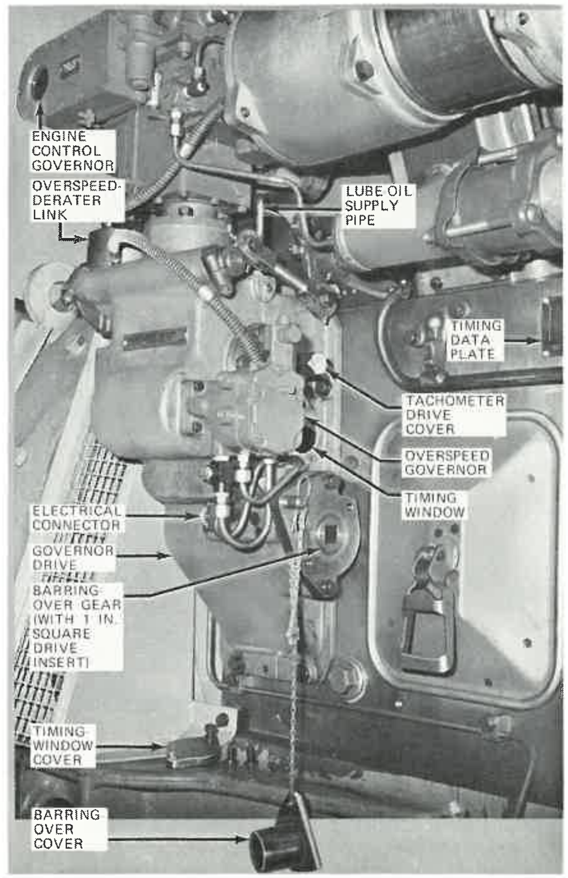


FIG. IX-33. GOVERNOR DRIVE MOUNTED ON ENGINE.

In general, the governor power piston and the fuel linkage first must be set up to simulate a Notch 8, full-load condition, after which each individual pump rack is adjusted to the correct millimeter setting.

Check and adjust racks using the following procedure:

1. Set up the governor power piston and fuel linkage as follows:
   a. Install the overspeed link compressor, Part 147X1580, on the side of the governor drive gear unit, Fig. IX-34.
   b. Turn compressor screw up to apply a force against the bottom of the overspeed-derater link to compress the link and raise the power piston. Raise the piston until the 0.344-in. gap gage, Part 147X1296, is firmly clamped and the overspeed-derater link is fully compressed. This will be evident when the top edge of the indicator is aligned with the lower groove on the outer casing.

IX

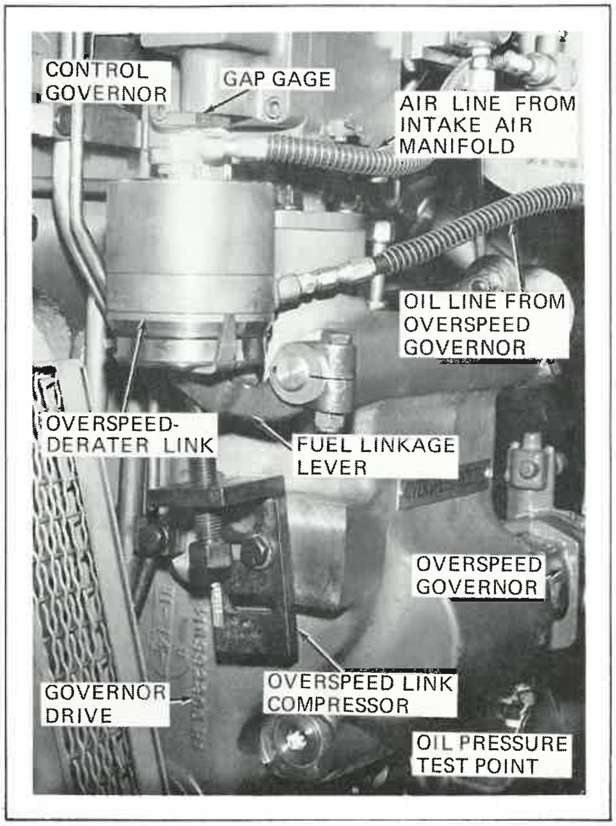


FIG. IX-34. OVERSPEED-DERATER LINK WITH ENGINE SHUT DOWN AND RACK-SETTING TOOLS APPLIED.

NOTE: *To avoid the physical effort required to compress the link, remove the oil inlet hose from the link and supply compressed air or hydraulic fluid (max. 200 psi pressure) to the oil inlet fitting.*

2. Check the Notch eight (N8) full load setting of all pump racks. Those racks with settings different from the values shown in Table IX-III must be reset using one of the following methods:

A. If pumps are operated by a nut and locknut type adjustable link, Fig. IX-35:

a. Using two wrenches, hold the adjusting nut and loosen the locknut.

b. Turn the adjusting nut to lengthen or shorten the link so the rack shows the correct millimeter setting.

c. Using two wrenches, hold the adjusting nut and tighten the locknut.

d. Repeat Steps a, b and c in Item A above for all pumps needing adjustment.

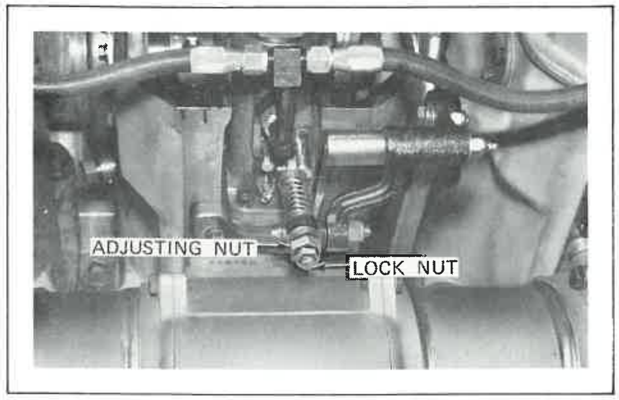


FIG. IX-35. FUEL PUMP RACK ADJUSTMENT — NUT AND LOCKNUT TYPE ADJUSTABLE LINK.

e. Back off the compressor screw completely and remove the link compressor and gap gage used for this operation. Check all racks, which should now read 0 to 3 mm, the correct reading for the engine SHUTDOWN condition.

WARNING: *Under no condition should the engine be started with the overspeed link compressor still in place. This could result in destruction of the engine and injury to personnel in the vicinity.*

B. If pumps are operated by a round knurled nut type adjustable link, Fig. IX-36:

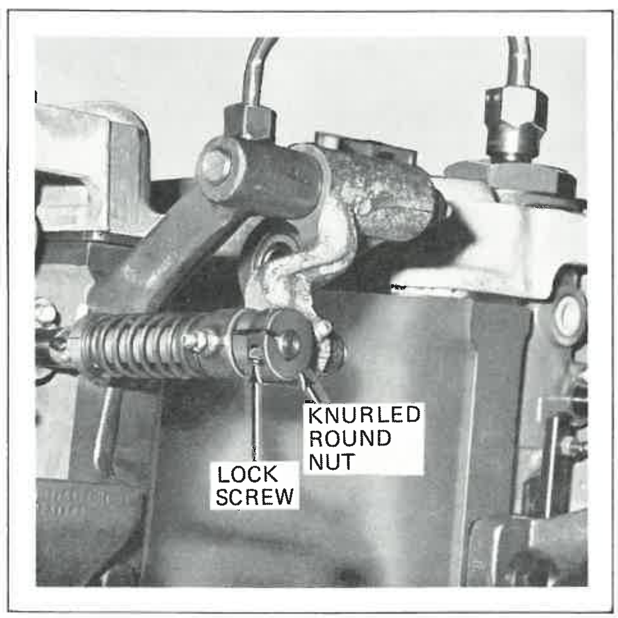


FIG. IX-36. FUEL PUMP RACK ADJUSTMENT — ROUND, KNURLED NUT-TYPE ADJUSTABLE LINK.

FIG. IX-34, E-21096

FIG. IX-35, E-18363A

FIG. IX-36, E-25339

IX

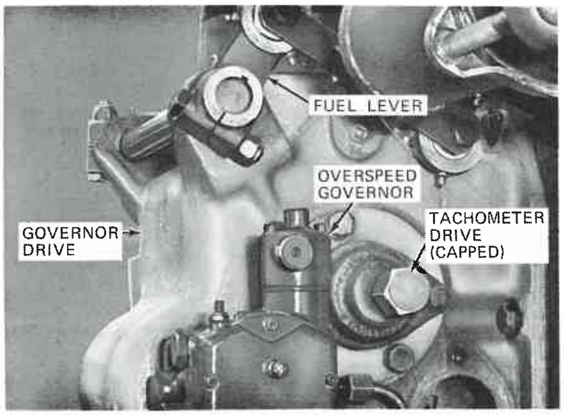


FIG. IX-37. FUEL LEVER.

FIG. IX-37, E-22595

FIG. IX-38, E-9973

a. Loosen the lock screw using a 9/64-in. hex key wrench.

b. By hand only, turn the round knurled nut to lengthen or shorten the link so the rack shows the correct millimeter setting.

c. Tighten the lock screw using a 9/64-in. hex key wrench.

d. Follow the same instructions given under Steps d and e in Item A above.

Fuel Linkage

The fuel linkage assemblies used on GE engines are, in general, quite similar and differ only in the following manner:

1. Quantities of parts (vary with number of cylinders)
2. Length of fuel lever, Fig. IX-37.

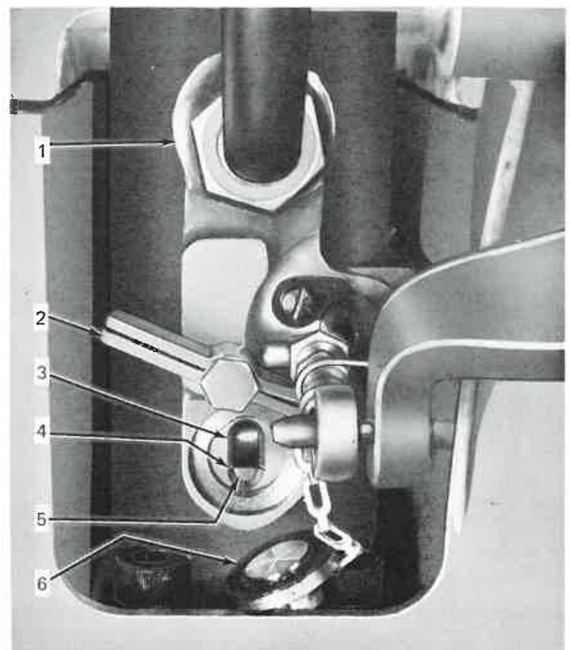
The fuel lever must be of such length that it will produce BOTH the maximum-horsepower control-rack value and the idle-speed control-rack value while the governor power piston moves thru its uniform length of travel; that is, from the IDLE position when the power-piston gap is 31/32 in. to 1-1/32 in. to the FULL SPEED, FULL POWER position when the gap is 11/32 (0.344) in.

Table IX-III gives the part number and center-to-center length for the fuel lever recommended for each locomotive application.

FUEL PUMP TIMING

Pump Variations

Several types of fuel injection pumps are in use on GE engines. There is, however, only one major difference with respect to timing. All Bendix pumps and all Bosch pumps



REF.	DESCRIPTION
1	INJECTION PUMP
2	PLUG CLAMP BAR
3	TIMING WINDOW
4	SCRIBE LINES
5	PLUNGER FOLLOWER
6	TIMING WINDOW PLUG

FIG. IX-38. CORRECTLY TIMED BENDIX PUMP OR BOSCH PUMP WITH SHORT PLUNGER FOLLOWER.

applied prior to early 1978 have a short plunger follower. Any of these pumps is correctly timed when the top of the plunger follower is aligned with the scribed lines in the pump timing window, Fig. IX-38.

Beginning in early 1978, Bosch pumps use a long plunger follower. A pump of this type is correctly timed when the scribed line on the side of the plunger follower aligns with the scribed lines in the timing window, Fig.,IX-39.

It should be noted that the plunger follower in the later Bosch design will be visible even when the plunger follower is at its lowest position. This is not true of the other style of pump.

Pump Timing

When timing the fuel injection pumps, it is necessary to refer to the following indicating marks:

1. The scribed lines at the pump timing windows, Figs. IX-38 and IX-39. These lines are visible after the timing covers on the front of the pumps are unclamped and removed.

IX

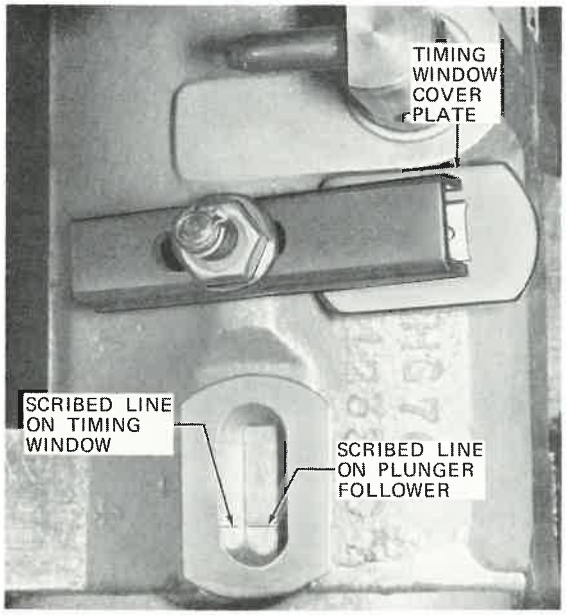


FIG. IX-39. CORRECTLY TIMED BOSCH PUMP WITH LONG PLUNGER FOLLOWER.

2. The degree marks on the forward side of the camshaft gear, Fig. IX-40. These marks are visible after removing the cover on the forward side of the governor drive, Fig. IX-41.

To adjust the timing it is necessary to remove the covers which seal the pump tappet rod compartment, Fig. IX-42. These covers are located on the lower front face of each cylinder.

The engine is barred-over by rotating the barring-over gear in the governor drive. This gear is made accessible by removing the cover from the forward side of the governor drive, Fig. IX-41. After moving the gear inward into engagement with the camshaft gear, apply either a ratchet wrench with a 1-in. square drive, Fig. IX-43, or an air-operated wrench, Fig. IX-44.

CAUTION: *The use of an impact wrench is not recommended for this operation, since internal damage may result.*

CAUTION: *Incorrect pump timing can cause excessive pump plunger travel, which may result in severe damage to the pump.*

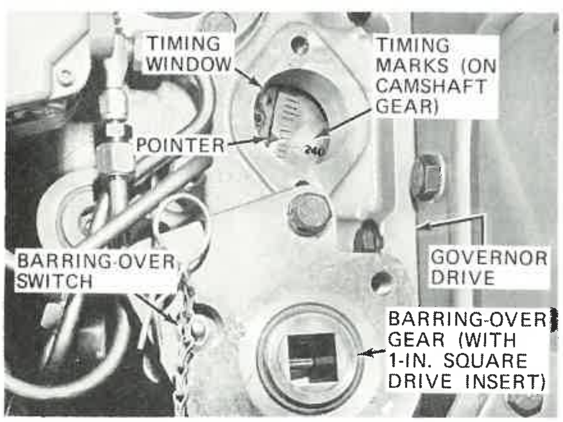


FIG. IX-40. GOVERNOR DRIVE WITH COVERS REMOVED.

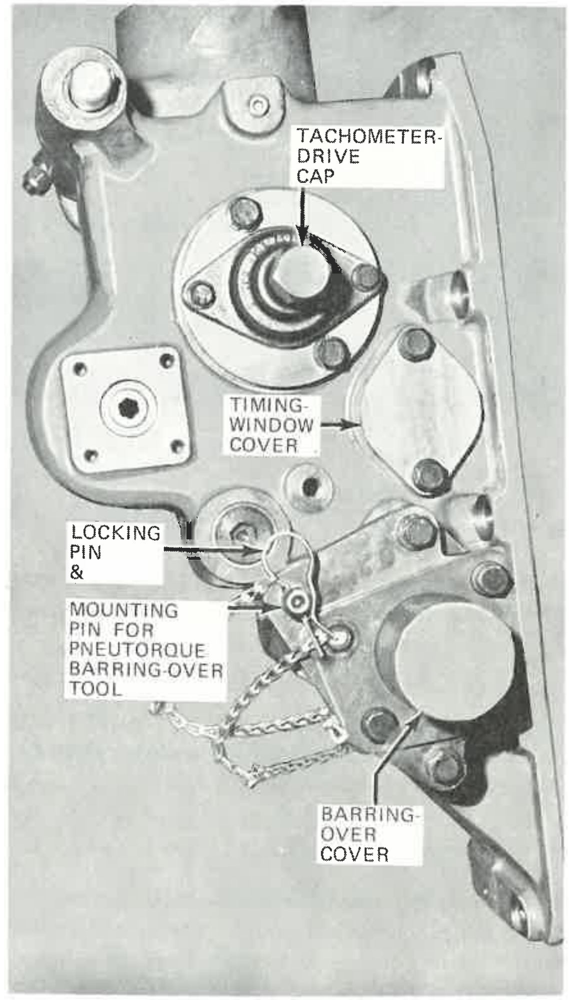


FIG. IX-41. ASSEMBLED GOVERNOR DRIVE, FORWARD SIDE.

FIG. IX-39, E-24779

FIG. IX-40, E-24341

FIG. IX-41, E-23484

IX

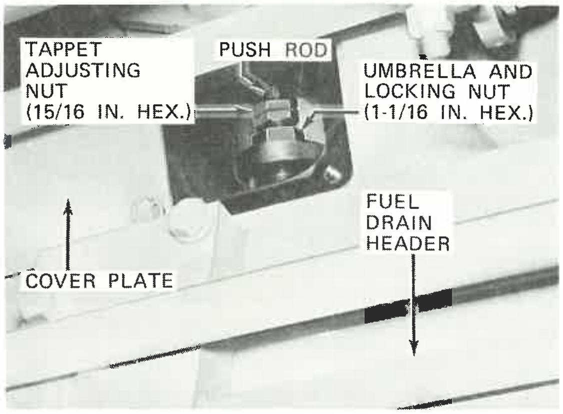


FIG. IX-42. FUEL INJECTION PUMP TAPPET ROD ADJUSTMENT.

FIG. IX-42, E-9979B

Pump timing is accomplished in the manner outlined below.

The No. 1 right cylinder pump for a 16-cylinder engine is used as an example and is a good starting point to use when all engine pumps are to be timed.

NOTE: *Tappet settings on inlet and exhaust valves of a cylinder can be checked and, if necessary, readjusted while the fuel pump on the cylinder is being timed.*

1. Back off the compression-release plugs one full turn on all cylinders.

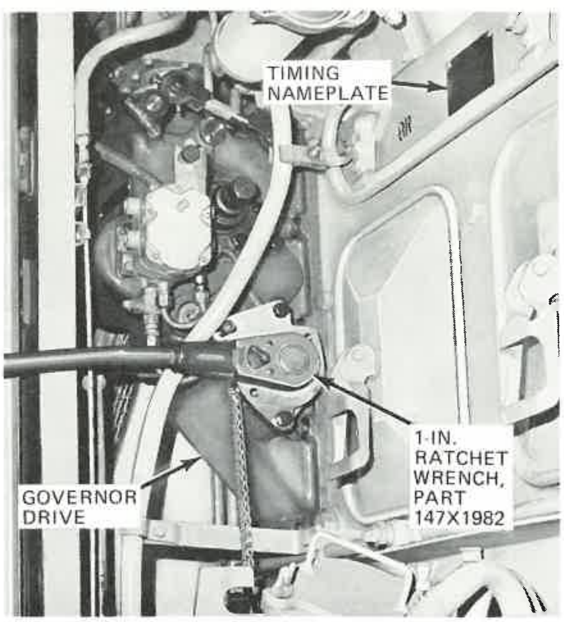


FIG. IX-43. BARRING-OVER ENGINE USING A 1-IN. RATCHET WRENCH.

FIG. IX-43, E-24342

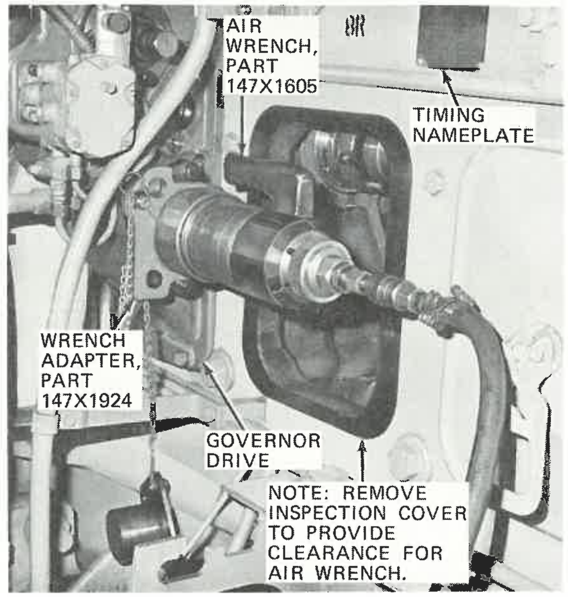


FIG. IX-44. BARRING-OVER ENGINE USING THE PNEUTORQUE AIR WRENCH.

FIG. IX-44, E-24343

2. Remove the cylinder-head covers and the plugs from the fuel-pump timing windows.

3. Remove the covers which seal the pump tappet-rod compartment near the bottom of each cylinder, Fig. IX-42.

4. Use the ratchet wrench or air-operated wrench, and slowly bar the engine over in its normal direction of rotation until the pointer in the timing window aligns with the 348.5-degree line. Refer to Figs. IX-40 and IX-45.

5. Assure all valves are closed on the 1-R cylinder (compression stroke). If the valves are closed, a small amount of free movement will be noted by manually moving the rocker arms. Another check is to observe the radial position of the fuel and valve cams for the particular cylinder. If the cylinder is on its compression stroke, the valve crosshead rollers will be off the lobe and on the base circle of the cam. The fuel crosshead roller will be rising on the lobe of its cam.

NOTE: *While this operation is not mandatory, it is recommended since it assures the integrity of the camshaft assemblies and the engine firing order.*

6. Adjust the fuel-pump tappet nut on the 1-R cylinder until the top edge of the plunger follower is exactly aligned with the scribed marks on the sides of the

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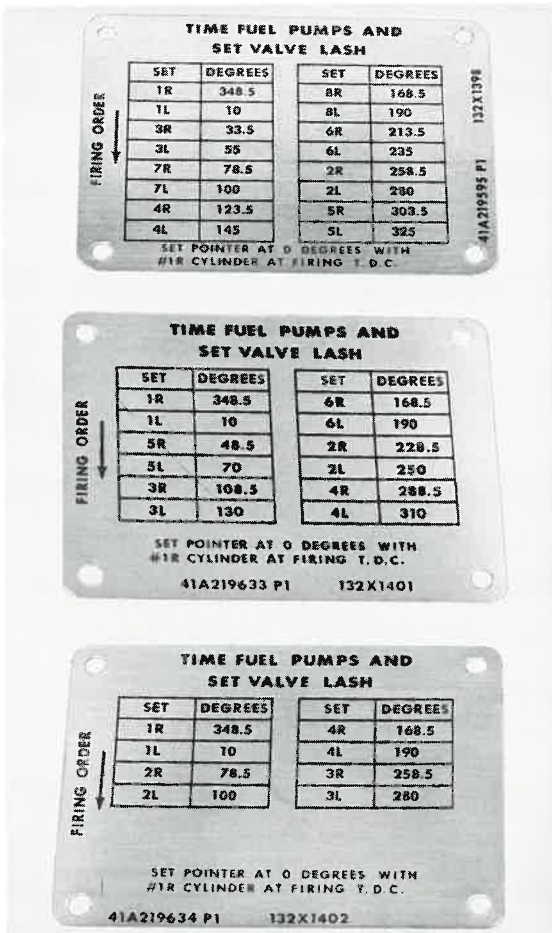

FIG. IX-45. TIMING NAMEPLATES FOR 8, 12 AND 16-CYLINDER ENGINES.

IX

fuel-pump timing window, Fig. IX-38, or the scribed line on the long plunger follower is aligned with the scribed lines on the sides of the timing window, Fig. IX-39.

7. Lock the tappet nut securely and recheck the alignment of the pump timing marks.

> **CAUTION:** *Use two wrenches, when tightening: 1-1/16 in. on the umbrella locknut, and 15/16 in. on the tappet nut. Failure to do so will cause overtorquing against the guide pin of the tappet rod. This will distort or damage the bronze tappet guide.*

8. Refer to the timing nameplate, Fig. IX-45, and following the timing order given on the nameplate, bar the engine to the degree value for timing the 1-L fuel pump. Time the 1-L pump by performing Steps 5, 6 and 7 above.

9. Proceed to the next cylinder in the firing order, and repeat until all have been timed. Be sure each tappet nut is locked before leaving it.

10. After all the pumps have been timed, replace the tappet-rod adjustment covers, cylinder-head covers, and fuel-pump timing-window plugs. Remove the barring-over tool and replace the timing window cover and barring-over cover on the governor drive. Tighten the compression-release plugs.

FIG. IX-45, E-24344

VALVE TAPPET CLEARANCE

NOTE: *This operation is most efficiently accomplished if it is done in conjunction with fuel-pump timing. See Fuel Pump Timing section.*

1. Properly position the piston in the cylinder. Remove the timing-window cover and the barring-over cover from the governor drive, Fig. IX-41. Move the barring-over gear inward into engagement with the camshaft gear, then apply either a 1-in. ratchet wrench, Fig. IX-43, or an air-operated wrench, Fig. IX-44, to the barring-over gear. Bar-over the engine to rotate the camshaft until the correct timing (degree) mark for the cylinder being worked on, as specified on the timing nameplate, Fig. IX-45, is exactly aligned with the pointer, Fig. IX-40. Check that both inlet and exhaust valves are closed, indicating that the piston is on the compression stroke.

2. Using standard tools, Fig. IX-46, or the special tool, Fig. IX-47, loosen the tappet locknut and adjust the tappet screw to give the following valve tappet clearances:

   Inlet Valves . . . . 0.018 to 0.020 in.
   Exhaust Valves . . . . 0.028 to 0.030 in.

   Tighten all locknuts with 50-55 lb.-ft. of torque and recheck the clearance. Bar-over the engine to the next cylinder (in the firing order) and adjust the tappet clearances. Continue this procedure until all valve tappets have been properly adjusted.

LUBE-OIL RELIEF VALVE

With engine shut down, install a 0-180 psi pressure gage in one of the test points in the oil piping between the lube-oil pump and the oil cooler. Refer to Fig. X-2.

With the engine running and with cold lube oil, advance the Throttle as required and note the maximum pressure

FIG. IX-46, E-13113

FIG. IX-47, E-22724

FIG. IX-48, E-25591

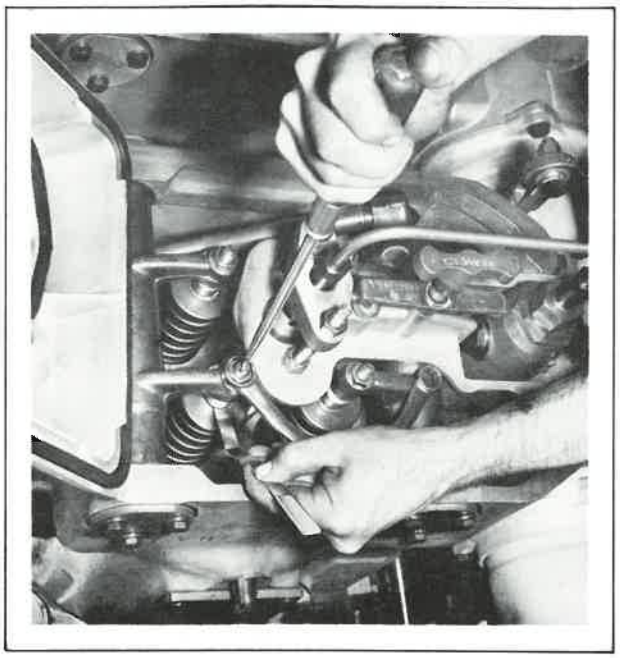

FIG. IX-46. ADJUSTING VALVE TAPPET CLEARANCE USING STANDARD TOOLS.

gage indication which is the relief valve setting. This should be 135 to 140 psi.

To adjust the relief valve, Fig. IX-48:

1. Remove the hood from the valve.
2. Loosen the pressure screw locknut.
3. Turn the pressure screw in (clockwise) to raise the operating pressure; turn the pressure screw out (counterclockwise) to lower the operating pressure.

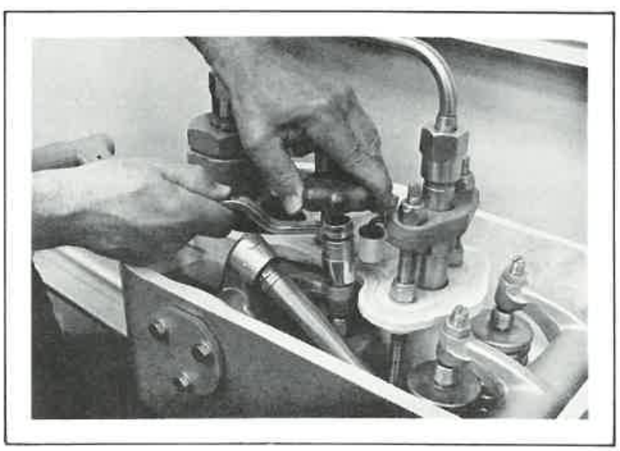

FIG. IX-47. ADJUSTING VALVE TAPPET CLEARANCE USING SPECIAL TOOL, PART 147X1042.

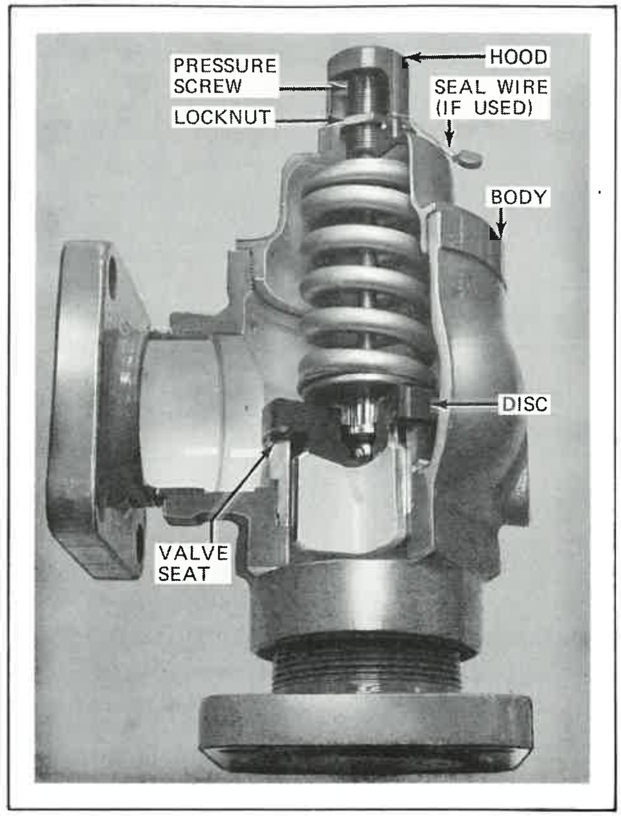

FIG. IX-48. LUBE-OIL RELIEF VALVE, CUTAWAY VIEW.

4. After achieving the correct operating pressure, as indicated on the pressure gage, lock the pressure screw with the locknut and replace the hood.
5. Shut down the engine and remove the test pressure gage.

IX

FUEL-OIL RELIEF VALVE

1. Install a calibrated 100 psi pressure gage in one of the test ports, Fig. IX-49.
2. Cap off the fuel header after it leaves the last injection pump. Refer to Fig. X-1.
3. Start the fuel transfer pump and observe the test pressure gage which should indicate 74 to 76 psi. Battery voltage during this test should be approximately 64 volts.

> **CAUTION:** *DO NOT START OR RUN THE ENGINE FOR THIS TEST.*

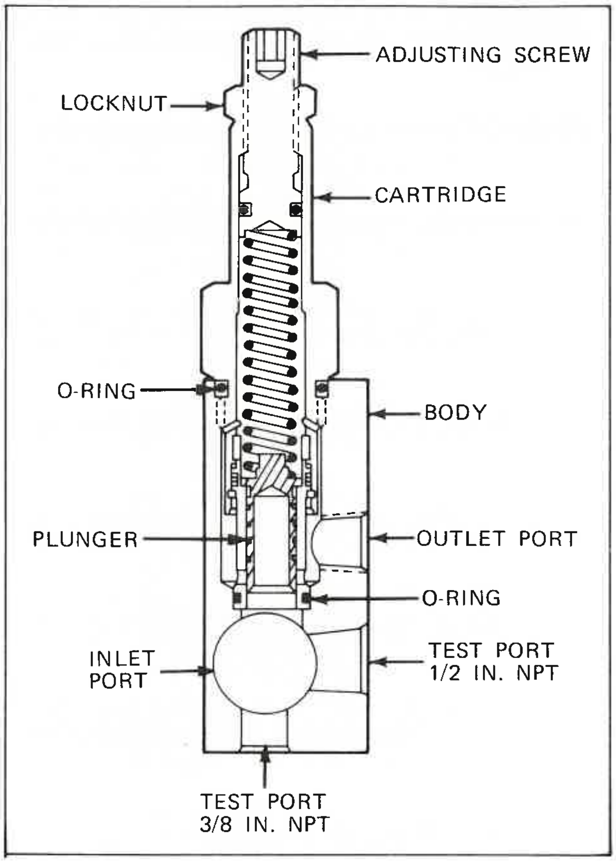

FIG. IX-49. FUEL-OIL RELIEF AND REGULATING VALVE.

4. To correct the valve setting, loosen the adjustment locknut, and turn the adjusting screw IN to raise the pressure. Turn the screw OUT to lower the pressure.

5. Tighten the locknut. Check the gage reading and stop the fuel transfer pump.

6. Remove the test gage and restore the piping to normal.

FUEL-OIL REGULATING VALVE

1. Install a calibrated 100 psi pressure gage in a test port, Fig. IX-49.

NOTE: *Be sure the fuel strainer element has been cleaned and a new element has been installed in the filter housing.*

2. Start the fuel transfer pump and engine. With the engine operating at idle speed, read the pressure indicated on the test gage. It should read approximately 38 to 42 psi.

3. Loosen the adjustment locknut. Adjust the screw to set the pressure. Turn the screw IN to raise the pressure or OUT to lower the pressure.

4. Tighten the adjustment locknut. Check the gage reading.

5. Stop the engine and fuel transfer pump, remove the test gage and replace the pipe plug.

REPLACEMENTS

FUEL-OIL FILTER

The fuel filter assembly consists of a steel can housing a filter element. It is connected to the fuel transfer pump discharge opening.

A gradual drop in fuel flow and header pressure indicates the fuel strainer or fuel filter has become restricted and should be either cleaned or replaced, respectively.

1. Shut down engine and fuel transfer pump.

2. Partially open filter cover then open spring-loaded valve beneath filter tank. Hold open for one minute. Fuel in the filter case will drain back to the main tank.

3. Remove filter cover. Remove and discard used filter element.

4. Flush filter tank with clean fuel oil. Again hold the drain valve open until tank is empty. Blow dry with shop air.

> **WARNING:** *Personal injury may result if proper eye protection is not worn when blowing with compressed air.*

5. Wipe a small amount of clean lube oil on the O-ring in the end of a new GE Part 132X1250 fuel filter element. Install the element.

6. Close and seal the lid of the filter housing, applying new O-ring cover gasket if necessary. Make sure drain valve is fully closed.

7. Start the fuel transfer pump. When fuel pressure gage reads approximately 40 psi, start the engine.

8. Inspect entire fuel system for any leaks and make corrections as necessary.

FIG. IX-49, E-17740

IX

FIG. IX-50, E-25377

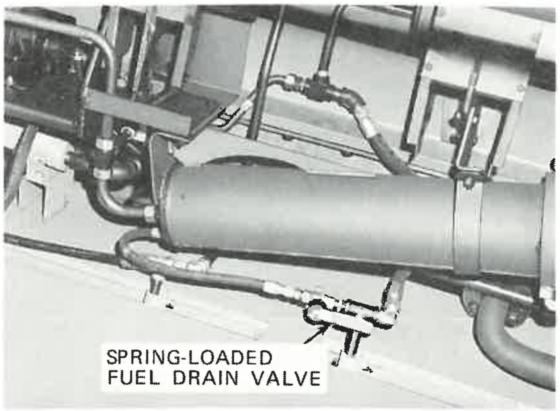

FIG. IX-50. TYPICAL FUEL DRAIN VALVE ARRANGEMENT.

FUEL-OIL STRAINER

Whenever a fuel-oil filter is replaced, the fuel-oil strainer should be inspected and cleaned. Beginning in 1978, some strainers having a coarser mesh strainer element were installed in the fuel system. This was done to keep the strainer from waxing up during cold weather operation. It can be regarded as a "throwaway" part. It may, of course, be cleaned if desired. The element will fit either bottom-opening or top-opening strainer housings.

FIG. IX-51, E-25407

FIG. IX-51. TYPES OF STRAINER ELEMENTS.

Cleaning Elements

1. Remove the drain plug from the strainer housing to drain it.
2. Loosen the wing nuts on the strainer cover and remove the strainer element. If it is a sump-type strainer, remove two bolts, remove sump and drain it.
3. Flush the element in a cleaning solution and blow dry with clean air. If the element is a coarse screen type, flush it only with a petroleum solvent (kerosene, diesel fuel). Do not use chlorinated hydrocarbons or a caustic solution. Discard if the rubber seal or mesh is damaged.

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and Government safety regulations.*

4. Flush out the strainer housing with clean fuel oil and blow it dry with clean air.
5. Inspect the cover O-ring and the rubber grommet of the fine-mesh type strainer. If either item is damaged, install a new one.
6. Replace the cleaned element.
7. Replace the drain plug if of that type. Fill the strainer shell with clean fuel oil.
8. Replace the strainer cover and tighten the cover wing nuts evenly and carefully. If sump type, reassemble the shell to the top cover.

LUBE-OIL FILTER ELEMENTS

Lube-oil filter elements must be replaced periodically on a planned schedule or if the pressure drop across the filter is too high a value. Water in the lube-oil system will permanently affect the performance of filter elements. Thus if a leaking lube-oil cooler or engine cylinder is changed out, the lube-oil and filter should be changed.

Changing Elements

1. Remove the vent plug, Fig. IX-54, and open the filter drain-back valve, Fig. IX-56. Drain the filter case.

FIG. IX-52, E-25435

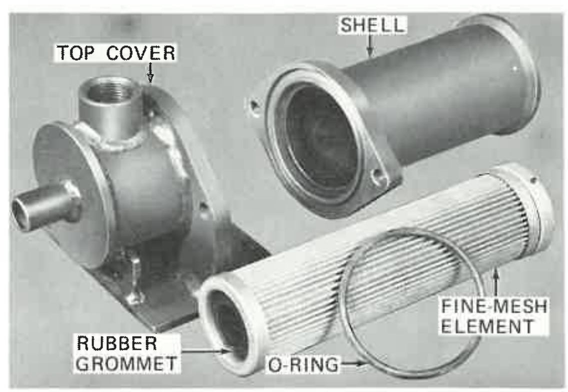

FIG. IX-52. DETAILS OF SUMP-TYPE STRAINER AND FINE-MESH ELEMENT.

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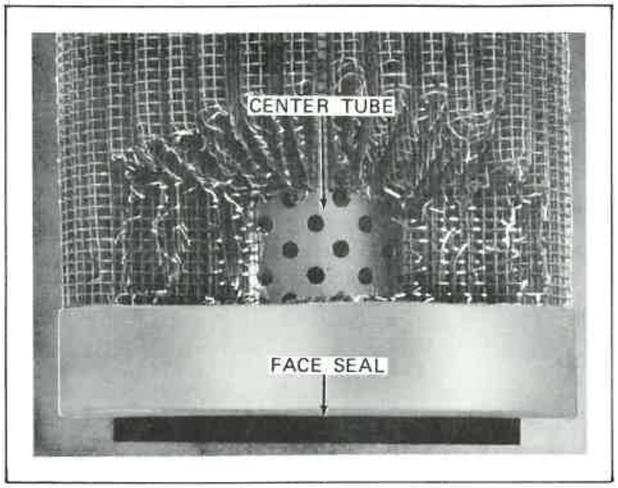

FIG. IX-53. CUTAWAY OF COARSE-MESH ELEMENT.

2. Close the drain-back valve.

3. Loosen the filter cover clamps and open the hinged cover.

4. Remove the wing nuts and element holddown plates. Inspect the elements for metal particles before discarding.

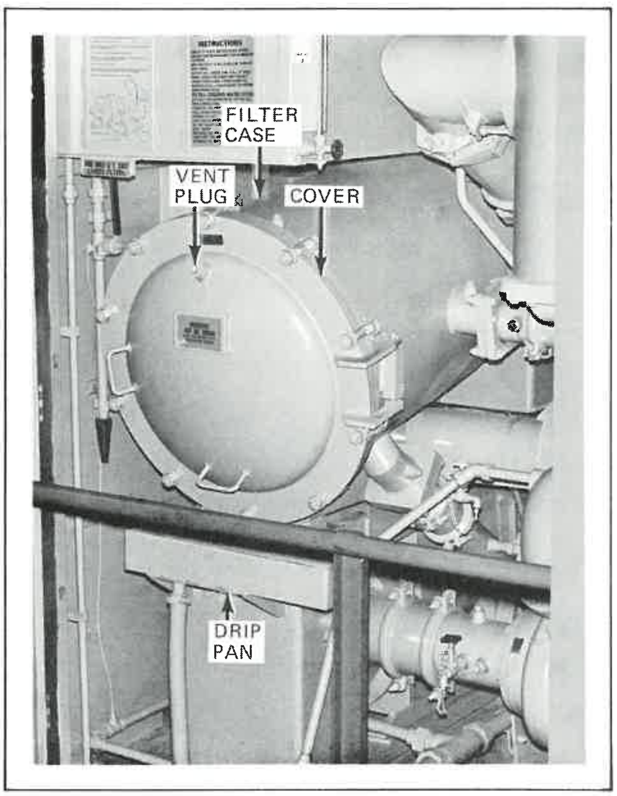

FIG. IX-54. LUBE-OIL FILTER.

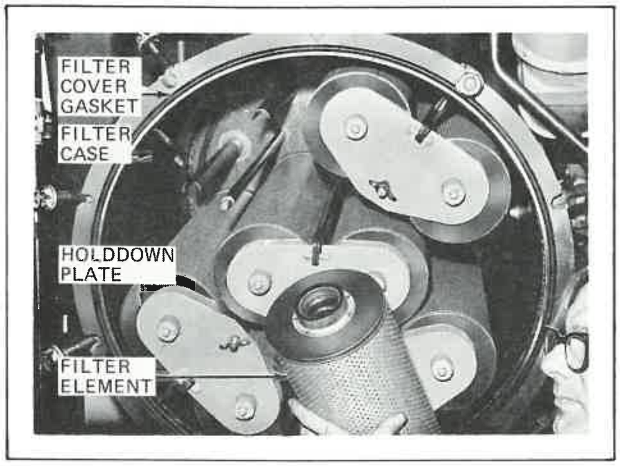

FIG. IX-55. RENEWING FILTER ELEMENTS.

5. Wipe the inside of the case clean.

6. Install new filter elements, Fig. IX-55.

NOTE: *Do not use cotton waste filters.*

7. Install the element holddown plates and tighten the wing nuts HAND-TIGHT ONLY. Be sure all elements are properly seated and clamped.

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

9. Replace and tighten vent plug.

FUEL INJECTOR NOZZLE

Removal

1. Remove the cylinder-head cover.

2. Clean the high-pressure line with a stiff-bristle brush and fuel oil before disconnecting.

3. Remove the high-pressure line between the pump and nozzle. Cover all openings with threaded or plastic caps.

4. Remove the two nuts which secure the nozzle clamp.

5. Remove the fuel injector nozzle from the cylinder head. Use the knocker, Part 147X1856, to facilitate removal, Fig. IX-57.

FIG. IX-53, E-25408

FIG. IX-54, E-25436

FIG. IX-55, E-25437

FIG. IX-56, E-25438

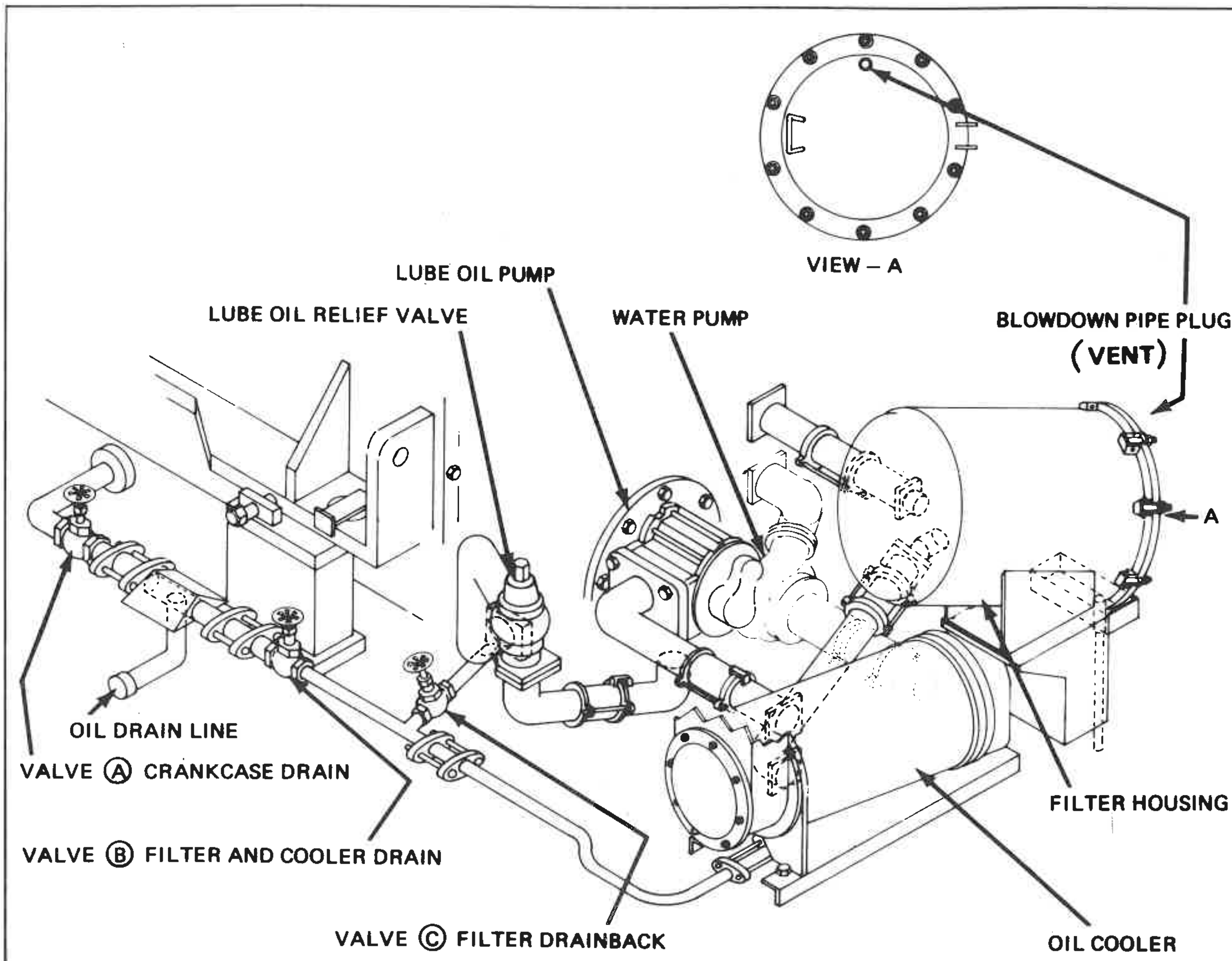

FIG. IX-56. LUBE-OIL PIPING DIAGRAM.

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CAUTION: *Handle the fuel injector nozzle with care and take measures to prevent dirt from entering the nozzle. DO NOT BUMP THE TIP. Place protective plastic caps or plugs over connections and put a protective cover over the tip end. RETURN INJECTORS FOR REPAIR PROTECTED IN THE SAME MANNER AS NEW NOZZLES ARE RECEIVED.*

Installation

1. If difficulty is encountered in removing a fuel injector nozzle from the cylinder, the nozzle recess in the cylinder head is probably encumbered with carbon, scale, etc. This must be cleaned before installing a new nozzle. This may be done in the following manner:

   a. Use a 1-in. diameter cup wire brush (0.020-in. diameter wire) on a 15-in. extension, driven by a portable power drill.

   b. The entire length of the recess should be cleaned, but the seat is of particular importance.

   c. If it is necessary to clean the recess with the cylinder on the engine, be sure the valves are closed and the cylinder-head cover is in place.

   d. Apply air pressure through the compression-release hole to blow dirt up through the recess, instead of allowing it to fall down on the face fit and into the cylinder.

2. Place a new copper gasket on the small end of the nozzle. A small amount of grease can be used to hold the gasket in place.

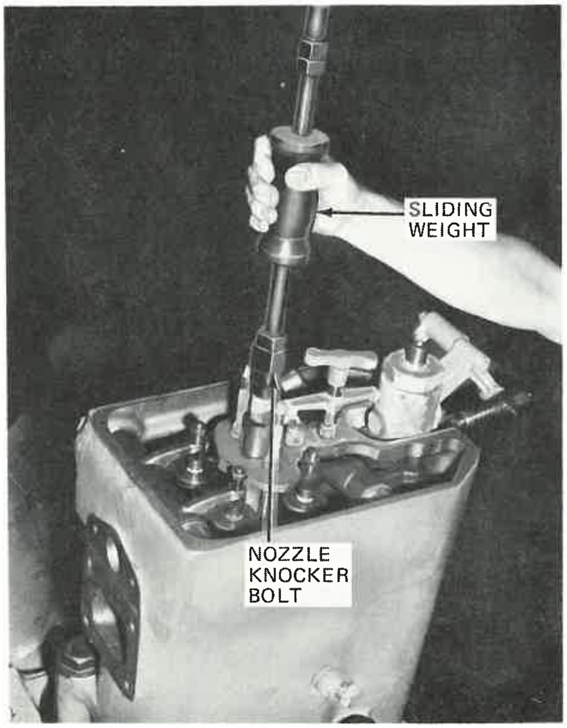


FIG. IX-57. KNOCKER USED TO REMOVE INJECTOR FROM CYLINDER.

3. Insert the small end of the nozzle into the recessed port. Orient the fuel drain, and place the clamp over the nozzle and studs.

4. Apply self-locking nuts and tighten them to 30-35 lb.-ft. of torque.

CAUTION: *Proper tightening of the nozzle clamp nuts is important. If they are not tight enough, the exhaust gases will cause a carbon build-up between the fuel injector nozzle and recess, causing the nozzle to be bound in place. If the clamp nuts are tightened excessively, parts of the nozzle assembly will become distorted, causing the nozzle valve to leak. Excessive tightening of these nuts can also cause cracks to develop between the nozzle recess and valve-seat bores of the cylinder head and, in extreme cases, can result in unseating of the exhaust and inlet valves.*

5. Remove the protective caps from the ends of the high-pressure line and from the pump and nozzle connections. Apply the high-pressure line, and tighten the nuts with 140-150 lb.-ft. of torque. Assure no dirt gets into the connection. Check for leaks at these points when the engine is started.

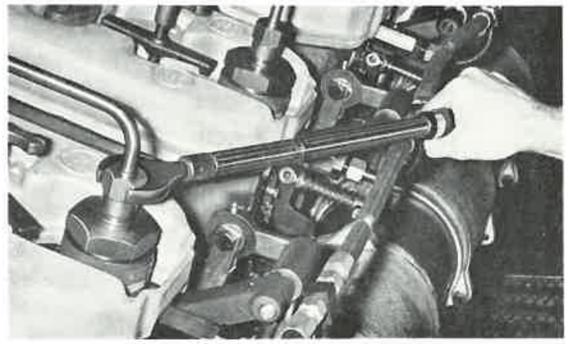


FIG. IX-58. TIGHTENING HIGH-PRESSURE LINE NUTS.

FUEL INJECTION PUMP

Removal (Fig. IX-59)

1. Remove the cylinder-head cover.

2. Remove the fulcrum nut, then remove the adjustable link which connects the pump rack to the bellcrank.

3. Clean the high-pressure line with a stiff-bristle brush and fuel oil before disconnecting.

4. Remove the high-pressure line between the pump and injector. Cover all openings with threaded or plastic caps.

5. Disconnect the tee connection between the fuel header lines and the pump at the pump. Cover the tee connection after the fuel has drained from the header. Apply a plastic plug to the inlet connection of the pump.

CAUTION: *Be careful not to damage the pump control rack while loosening the mounting bolts.*

6. Remove the mounting bolts at the base of the pump, using special wrenches, GE Part 147X2021 and 147X1497-2, Fig. IX-60. Lift the pump from the engine. Cover the area where the pump was removed to prevent foreign matter from entering the engine (unless the spare pump is installed immediately).

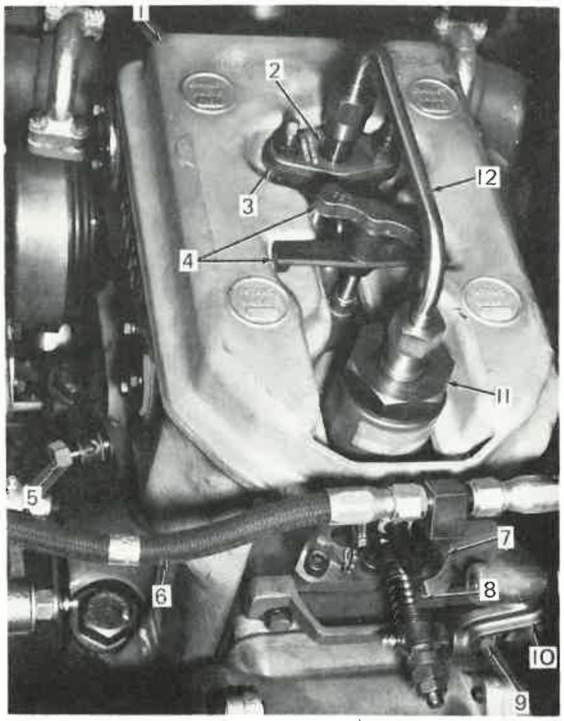
FIG. IX-57, E-19803
FIG. IX-58, E-22629

IX

FIG. IX-59, E-17742

FIG. IX-60, E-22628

FIG. IX-61, E-25611



REF.	DESCRIPTION
1	CYLINDER-HEAD COVER
2	FUEL INJECTOR
3	FUEL-INJECTOR CLAMP
4	COVER CLAMP
5	COMPRESSION RELEASE
6	FUEL HEADER LINE
7	TEE CONNECTION
8	ADJUSTABLE LINK
9	FULCRUM NUT
10	BELLCRANK
11	FUEL-INJECTION PUMP
12	HIGH-PRESSURE LINE

FIG. IX-59. UPPER-CYLINDER DETAILS.

Installation

CAUTION: *Before installing pumps on the engine, shorten the tappet-rod length. Remove the cover at the bottom of the cylinder, Fig. IX-61. Loosen the locknut and tappet nut, using two open-end wrenches, 15/16 and 1-1/16 in. Turn the tappet adjusting nut four or five full turns clockwise. Excessive tappet-rod travel can damage the pump and tappet-rod assembly.*

NOTE: *When installing a pump, be careful that no dirt or foreign matter enters the fuel-oil lines, connections, or the engine. Keep the plugs or seals in place until the connections are to be made.*

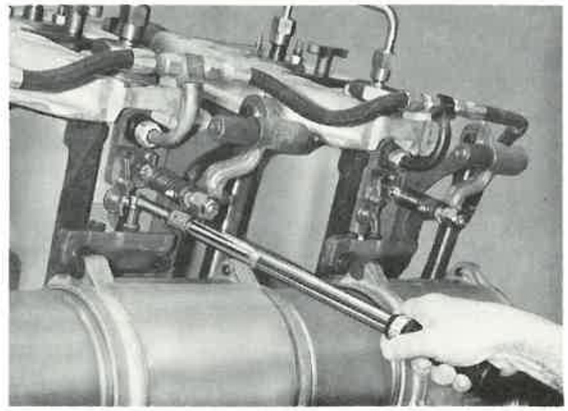


FIG. IX-60. TIGHTENING INJECTION PUMP MOUNTING BOLTS.

1. Install the pump in the cylinder, using a new O-ring around the base, and tighten the mounting bolts to 45-50 lb.-ft. of torque. Use special wrenches, GE Part 147X2021 and 147X1497-2, Fig. IX-60.

2. Torque the 1-5/16 in. hex. adapter fitting to 90-100 lb.-ft. Connect the tube from the fuel header to the adapter fitting. Replace the damaged ferrule as required. Torque the 1-in. hex. nut to 40-45 lb.-ft. Nuts on each end of the fuel jumper hoses should be torqued to 30-35 lb.-ft. DO NOT OVERTIGHTEN.

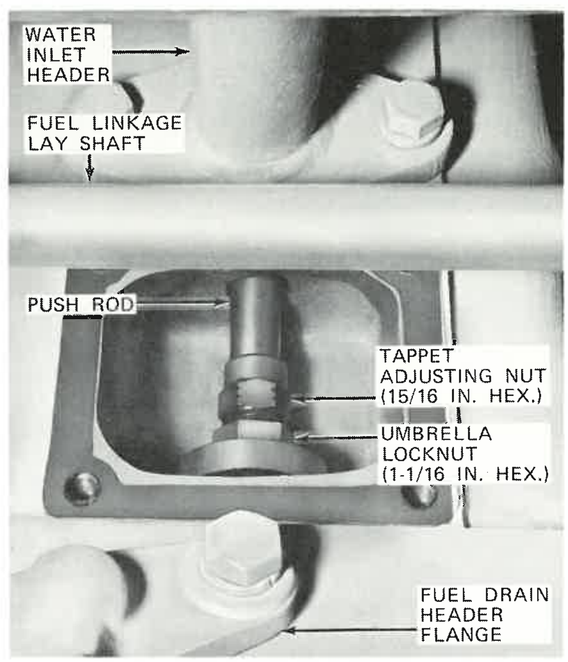


FIG. IX-61. FUEL INJECTION PUMP TAPPET ROD ARRANGEMENT.

IX

3. Connect the high-pressure line between the pump and injector. Tighten both nuts with 140-150 lb.-ft. of torque, using the special wrench, GE Part 147X1595-1, Fig. IX-58.

4. Install the adjustable link between the pump rack and the bellcrank. Secure with the fulcrum nut torqued to 30-35 lb.-ft.

5. Check the pump rack setting and adjust if required. Refer to ADJUSTMENTS section.

6. Check the pump timing. Refer to ADJUSTMENTS section.

7. Replace the cylinder-head cover.

WATER PUMP

FIG. IX-62. WATER PUMP.

Removal

1. Drain the lube oil from the forward-end cover. See Section X, LUBRICATING-OIL SYSTEM.

2. Drain the water system. See Section X, COOLING WATER SYSTEM.

3. Remove the pipe flange bolts, loosen the inlet pipe Dresser coupling, and slide the coupling on the pipe to clear the joint.

4. Remove the pump inlet and discharge pipes.

5. Mount a suitable lifting hoist over the pump, and attach it to the pump lifting eyebolt.

6. Remove the pump mounting bolts, install the jack bolts in threaded holes in the flange, and evenly jack the pump from its rabbet fit.

Installation

NOTE: *If the gear is being replaced, thoroughly clean the tapered fits. Make sure the large flat washer between the drive gear nut and the drive gear is assembled with the chamfer toward the gear. Torque the nut to 200-220 lb.-ft. and install a new cotter pin.*

1. Install the pump, using a new gasket. Properly align the drive-gear teeth and the pump register fit. Install the bolts finger-tight.

CAUTION: *Care must be taken to insure the pipe flange alignment is correct; otherwise, the pump casing may be distorted and broken.*

2. Assemble the cast discharge pipe, using new gaskets. Assemble discharge elbow and pump mounting bolts finger-tight first; then snug all bolts lightly, and finally tighten securely.

3. Reassemble the inlet pipe using new gaskets.

4. Before barring-over the engine, fill the water system to the proper level and add treatment.

5. Add lubricating oil to the crankcase to the proper level.

NOTE: *A small amount of water seal leakage may be noted on a newly installed pump. However, after a short period of operation, the water seal should become seated, thus stopping all leakage.*

FIG. IX-62, E-20897

LUBRICATING-OIL PUMP

Removal

1. Drain the oil from the crankcase, the forward-end cover, the oil cooler and the filter. See Section X, LUBRICATING-OIL SYSTEM.

2. Disconnect the discharge pipe at the pump.

3. Install a 3/4 in.-10 lifting eyebolt into the pump casing and attach a crane hook to support the pump weight. Lift and remove the pump from the engine.

IX

FIG. IX-63, E-9927

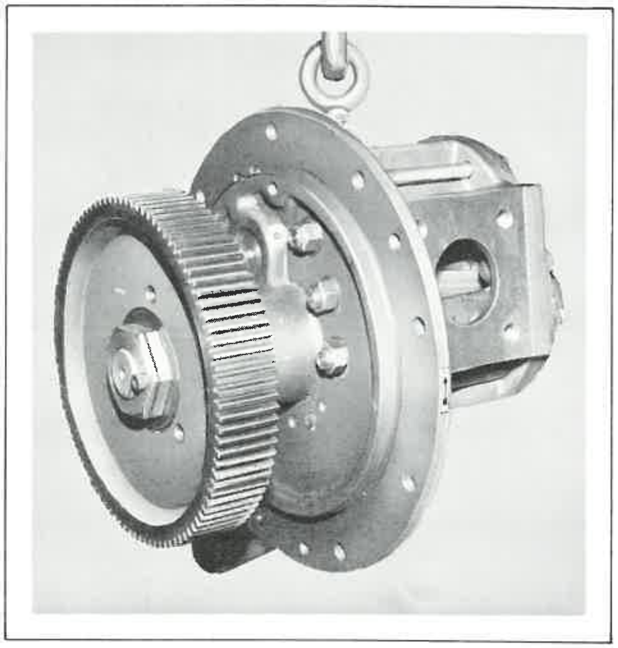


FIG. IX-63. LUBRICATING-OIL PUMP.

Installation

NOTE: *If the drive gear is being replaced, thoroughly clean the tapered fits and install a key. Torque the large drive gear nut to 375-400 lb.-ft. Tighten the lock screw on the nut to 30-36 lb.-ft.*

1. Clean the gasket surfaces, and use new gaskets where needed.

2. Insert a 3/4 in.-10 lifting eyebolt into the oil-pump housing. Position the pump on the engine with an overhead crane.

3. Hand-tighten the pump and discharge pipe bolts to ensure the compression pipe coupling is aligned.

4. When the pipes are aligned, tighten the mounting bolts to 90 lb.-ft. (122 N·m) of torque if bolts are dry; to 70 lb.-ft. (95 N·m) of torque if bolts are lubricated.

Clean the oil drain valves and fill the crankcase to the proper level before starting the engine. After starting the engine, check the lube-oil pump for overheating or unusual noises.

POWER ASSEMBLY REMOVAL

A power assembly consists of a complete cylinder, piston, piston rings, connecting rod and bearings.

Cylinders may be removed either with or without their respective pistons and connecting rods, depending on the nature of work to be performed. Cooling water must be drained before cylinder removal. Lube oil should be drained if extensive work is to be performed, to guard against contamination of the oil.

NOTE: *When removing cylinders only, install new piston rings. See Piston Rings section.*

To remove a cylinder, proceed as follows:

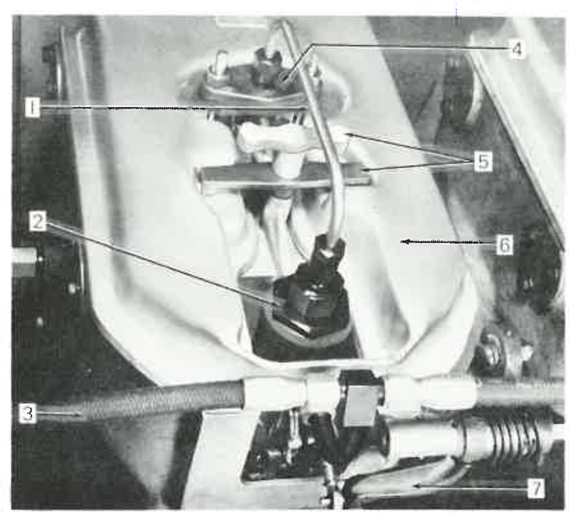
1. Disconnect and remove the following parts from the cylinder:

   a. Cylinder cover.

   b. Fuel-header lines at flexible hose couplings. Cap the lines and the pump inlet connection to keep the dirt out.

   c. Water inlet and discharge headers. Loosen the compression couplings and remove the bolts from the flanges. Remove the upper water connection and compression elbow.

FIG. IX-64, E-9985A



REF.	DESCRIPTION
1	HIGH-PRESSURE LINE
2	FUEL-INJECTION PUMP
3	FUEL-HEADER LINE
4	FUEL-INJECTION NOZZLE HOLD-DOWN CLAMP
5	CLAMP BAR AND THREADED TEE-HANDLE
6	CYLINDER COVER
7	PUMP-RACK LINKAGE

FIG. IX-64. UPPER-CYLINDER DETAILS.

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d. Exhaust manifold at the cylinder flange.

e. Air intake manifold, by unbolting the clamp rings and slipping the tube sections free of the intake manifold section.

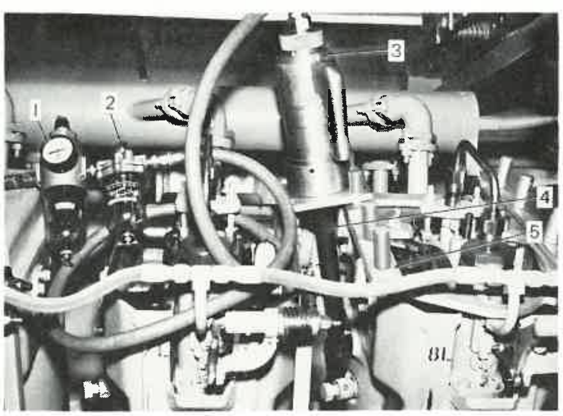
f. Fuel-rack vertical link. Remove the self-locking nut and bolt from the upper fuel linkage lever bearing.

2. Bar-over the crankshaft until the piston in the cylinder to be removed is near top dead center with all valves closed.

3. Remove the short crossover push rod, and then the two vertical push rods. Use the rocker arm depressor, Part 147X1040-1, to rotate the rocker arms for necessary end clearance. Do not bend the push rods by excessive prying or forcing. The fuel-pump push-rod assembly will be removed with the cylinder.

4. Remove the four cylinder-mounting bolts, using power-wrench arrangement, Part 147X1568, as shown in Fig. IX-65, or an impact wrench, Part 147X1684.

CAUTION: *If it should be necessary to apply heat to the bolt head to facilitate removal, replace the bolt, because heat changes the tensile strength of the bolt.*



REF.	DESCRIPTION
1	REGULATING VALVE AND GAGE
2	OILER
3	AIR WRENCH
4	EXTENSION WITH SOCKET
5	REACTION FRAME

FIG. IX-65. AIR-DRIVEN WRENCH ARRANGEMENT FOR CYLINDER MOUNTING BOLTS.

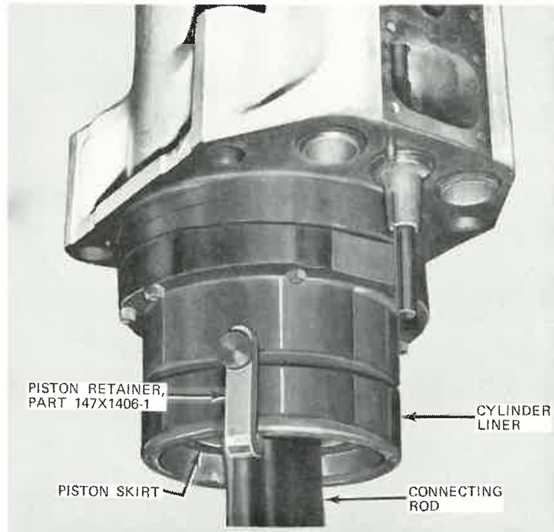


FIG. IX-66. VIEW OF TOOL APPLIED TO RETAIN PISTON IN CYLINDER.

NOTE: *If the connecting rod and piston are to be removed with the cylinder assembly, proceed as follows:*

1. *To hold the piston assembly in the cylinder, apply the piston retainer, Part 147X1406-1 as shown in Fig. IX-66.*
2. *If an articulated rod is to be removed, remove the articulated-rod pin bolts.*
3. *If a master rod is to be removed, disconnect the articulated rod and remove the master-rod bearing cap. Push the articulated rod and piston up in the cylinder and secure the rod with wire to provide working room. Use rod shank pad, Part 147X1828, on the master rod to avoid damage to other parts during removal.*

5. Attach the cylinder lifter, Part 147X1606, over the water discharge opening on the back of the cylinder, as shown in Fig. IX-67. Use only the high-strength bolts supplied with the lifting tool. Be sure they are tight.

6. After making sure the cylinder has been completely disconnected, carefully lift the cylinder, guiding it during removal.

If the piston and connecting rod are not removed with the cylinder, open the cylinder compression release plug. Protect the piston from damage which would be caused by its falling and scuffing against the engine frame as the cylinder is lifted off. Apply the piston guide, Part 147X1091-1, to protect and guide the piston when the crankshaft is rotated with cylinders removed.

FIG. IX-65, E-16542

FIG. IX-66, E-19821A

IX

FIG. IX-67, E-13553

FIG. IX-67. CYLINDER LIFTING TOOL APPLIED FOR ANGULAR LIFT.

CAUTION: *If pistons and rods are not properly supported when cylinders are removed, in certain positions of the crankshaft, the articulated connecting rods can contact and damage the articulating pin bushings.*

NOTE: *If desirable, with the cylinder removed, the piston may be detached and removed while the rod remains in the engine.*

POWER ASSEMBLY INSTALLATION

Whenever a cylinder assembly is removed from an engine, the O-rings on the crosshead guides should be renewed. See Crossheads and Guides in Section IX.

A cylinder may be installed either with its piston and connecting-rod assembly or separately. The general procedure is the same in either case. Proceed as follows:

1. Make sure the piston and rings are in good condition; see Piston section.

CAUTION: *Do not use chrome rings with chrome liners. Do not use iron rings in Tufftrided* liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations.*

2. Properly stagger the ring end gaps around the piston as described in Piston instructions. Coat the piston with a liberal quantity of clean engine lube oil. Apply the ring compressor, Part 147X1089.

3. Back out all four valve-tappet adjusting screws to provide maximum clearance between the tappet buttons and the valve stems. Adjust the fuel-pump tappet rod to its minimum length.

4. Lubricate with Lubriplate Spray Lube "A"**, Part 147X1614, and apply new rubber O-rings to the radius at the lower cylinder extension, the valve push-rod ferrules, and the fuel-pump push-rod guide.

5. If the piston and rod assembly is in the engine, remove the piston guide, Part 147X1091-1, and insert the piston support bar, Part 147X1090, Fig. IX-71, under the piston and across the frame opening. Turn the crankshaft to position the piston firmly against the support bar. Install two guide pins, Part 147X1367, in diagonal opposite holddown bolt holes. Lift the cylinder at a 22-1/2 degree angle, using the cylinder lifter, Part 147X1606, and carefully lower it over the piston. The ring compressor will be pushed down and can be removed after it drops free of the bottom ring. Then, turn the crankshaft to raise the piston sufficiently to remove the support bar. Lower the cylinder into place.

NOTE: *If the piston and rod assembly is to be installed at the same time as the cylinder, the piston may be held in the cylinder by using the piston retainer shown in Fig. IX-66. Install the left-bank cylinders with the master rods first, followed by the right-bank cylinders with the articulated rods. Use suitable protection with the master rod to avoid damage to other parts. Complete the installation of connecting rods as specified under CONNECTING ROD instructions.*

6. Coat the cylinder mounting-bolt threads and washer face with Lubriplate 630-AA grease, Part 147X2163. Install the bolts finger-tight.

7. Tighten the cylinder mounting bolts EVENLY to 1300-1400 lb.-ft. of torque.

8. Connect the air intake and exhaust manifolds, and the water headers, using new gaskets. Install and connect the fuel header lines.

9. Connect the injection-pump-rack vertical link. Check pump-rack travel as described in Fuel Pump Rack Setting instructions, and adjust as necessary.

*Product of Kolene Corp.

**Product of Fiske Bros. Refining Co., Newark, N.J.

IX

Inserting Push Rods

To obtain sufficient clearance when installing push rods, each valve crosshead roller must be off the high portion of its cam. With the rollers on the base circle of the cams, proceed as follows:

1. Insert the vertical push rods into their sockets in the crossheads; then, install the short crossover push rod.

2. Rotate the rocker arms, using rocker arm depressor, Part 147X1040-1, Fig. IX-68, until the push rods can be inserted into their respective rocker-arm sockets.

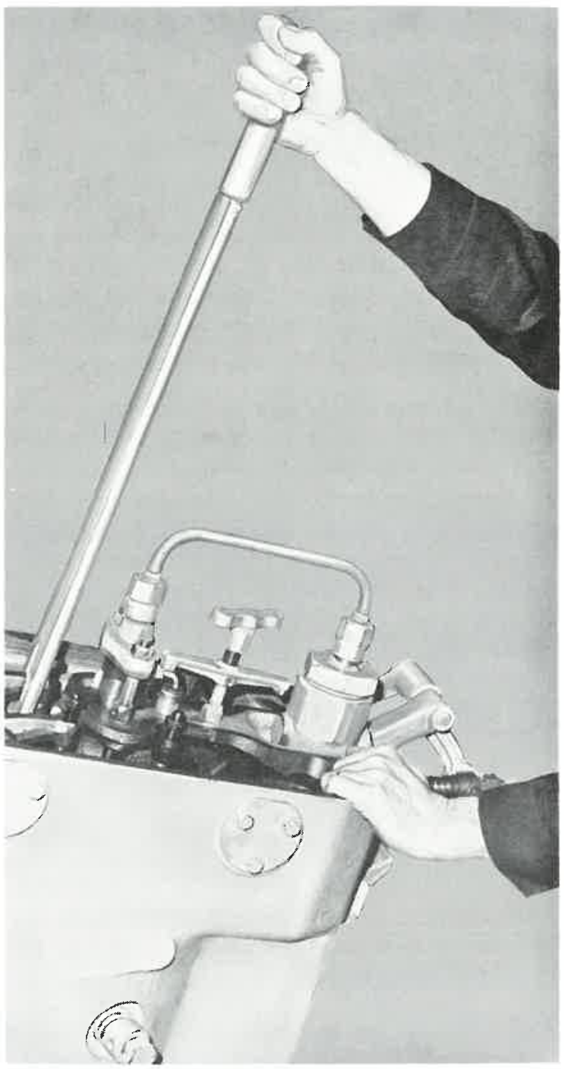


FIG. IX-68. DEPRESSING VALVE SPRING WITH ROCKER ARM DEPRESSOR TOOL.

Adjusting Tappet Clearance and Pump Timing

Valve tappet clearance and fuel-pump timing can both be done at the same positioning of the piston in the cylinder. Fuel injection pump racks must also be set. See Fuel Pump Rack Setting, Fuel Pump Timing and Valve Tappet Clearance Setting under ADJUSTMENTS section.

PISTON RINGS

Piston Ring Wear

Ring wear is the result of many factors, some of which are as follows:

1. Type of service and terrain
2. Effectiveness of engine air filter maintenance
3. Type of fuel and lube oil used
4. Degree of lube-oil control
5. General quality of engine maintenance.

Because of these factors, it is impossible to coordinate the rate of ring wear with engine operating time or locomotive miles traveled under all conditions. Therefore, for best economy, the rate of ring wear and thus the ring renewal periods can be determined best after a period of service under actual operating conditions.

For most efficient operation and best economy, it is recommended that piston rings, removed from an engine for any reason, be discarded and new rings applied. Any sticking rings or rings which show scuffing, burning or other abnormal conditions MUST be renewed regardless of wear.

Also, any time that a cylinder is changed out, piston rings should be renewed.

CAUTION: *Cylinder scoring and severe shortening of ring and liner life will result if chrome rings are used with chrome liners or iron rings with Tufftrided liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations. See Fig. IX-70.*

Rings may be renewed after cylinders are taken off, without removing the pistons from the engine. When on or near top dead center, the pistons extend above the engine main frame. To renew rings, proceed as follows:

1. After the old rings are removed, clean the ring grooves to assure full ring side clearance. The ring scraper tool, Part 147X1098, Fig. IX-69, should be used to clean carbon from the ring grooves.

CAUTION: *Care must be exercised when removing carbon so the ring grooves do not become damaged.*

FIG. IX-68, E-20915

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FIG. IX-69, E-19813

FIG. IX-70, E-21062

FIG. IX-71, E-19823

FIG. IX-69. CLEANING PISTON RING GROOVE WITH SCRAPER, PART 147X1098.

Insure foreign material does not enter the crankcase. Dirt and cleaning materials from groove cleaning can cause serious damage to bearings and other internal engine parts.

2. When installing rings, always use the ring expander tool, Part 147X1099, to prevent permanent distortion of the rings.

3. Install the oil-control ring first. Assemble the expander spring in the ring groove. Then, place the ring, SCRAPING EDGES DOWN, over the expander

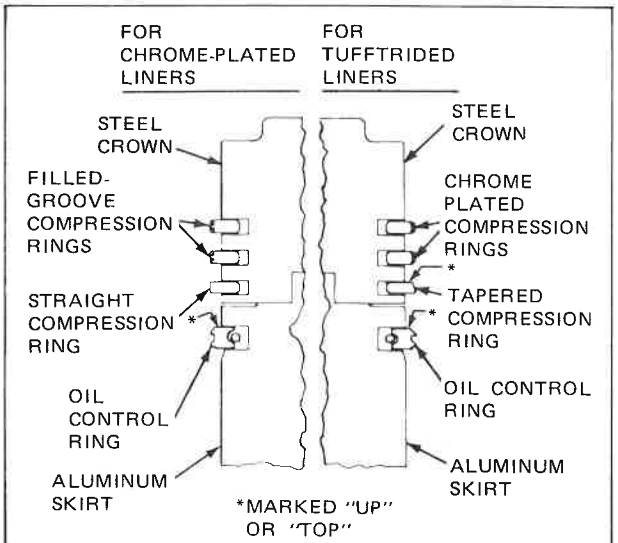

FIG. IX-70. PISTON RING ARRANGEMENTS.

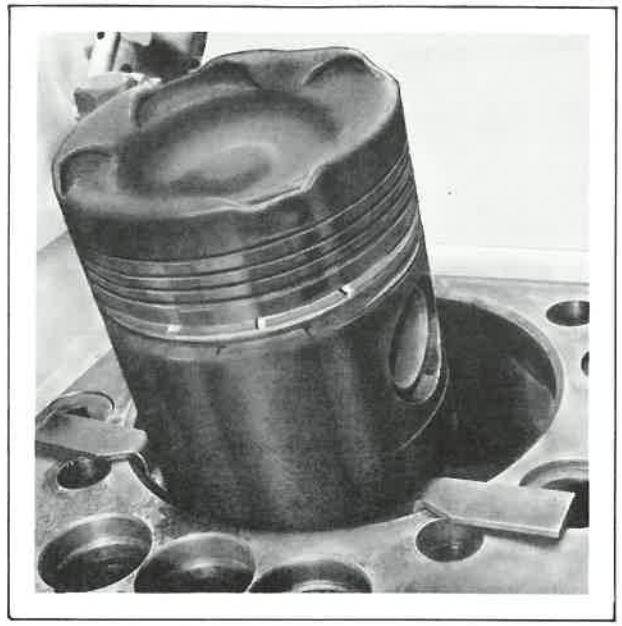

FIG. IX-71. PISTON SUPPORT BAR UNDER PISTON.

spring, and in its groove. Position the oil-ring end gap 180 degrees from the expander spring joint.

4. Install the compression rings as indicated by their markings. Rings not marked may be installed with either side up.

5. Assure all rings fit freely in their grooves at all positions around the piston. Then stagger the end gaps of adjacent rings approximately 90 degrees with no two in line.

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PISTON

Removal

To replace a piston it is necessary to remove the cylinder assembly first. See Power Assembly Removal section. The cylinder bore should be inspected for scoring or excessive wear, particularly in the ring reversal area, to determine if it is suitable for reuse with a new piston.

Proceed as follows to replace a piston:

1. With the piston near top dead center, lift the cylinder assembly partially off the piston and apply a piston support bar, Part 147X1090, under the piston. Rest the piston support bar on the main frame and bar the engine back until the piston rests on the cradle of the piston support bar, Fig. IX-71.

2. Lift the cylinder completely off the engine.

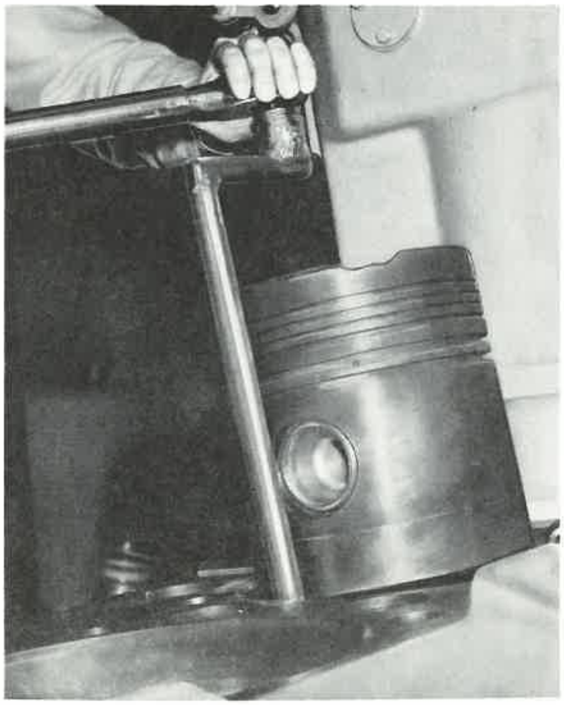


FIG. IX-72. LOOSENING PISTON PIN BOLTS.

3. Using a piston pin bolt wrench, Part 147X1841, and a piston pin bolt socket, Part 147X1511, use a 3/4-in. drive ratchet to loosen the piston pin bolts, Fig. IX-72.

4. Carefully remove the piston. Save the piston pin for reuse in a new piston.

IX

Installation

1. Coat the piston pin liberally with clean lube oil and install it. Install a piston pin guide pin into one of the threaded holes in the piston pin. A guide pin may be purchased as Part 147X1326, or it may be made from a piston pin bolt with the head cut off and the end bullet-nosed, Fig. IX-73.

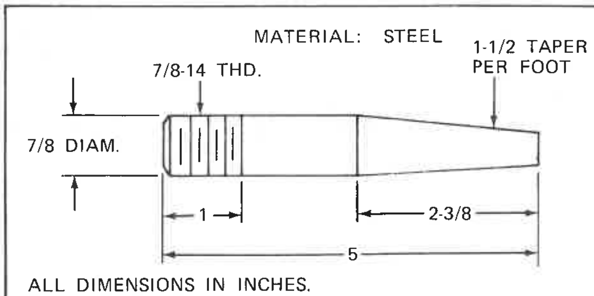


FIG. IX-73. PISTON PIN GUIDE PIN.

2. Lower the piston, with piston pin and guide pin in place, onto the connecting rod, allowing the guide pin to enter one of the piston pin bolt holes in the connecting rod.

3. Coat the threads and washer faces of the piston pin bolts with Molykote G-n*, Part 147X1143-1. Install a piston pin bolt and spacer in the other piston pin bolt hole and finger tighten. Remove the guide pin from the first bolt hole and install the remaining pin bolt and spacer. Using a torque wrench and the piston pin bolt wrench, tighten the piston pin bolts evenly in increments of 100-125 lb.-ft. to 400 lb.-ft. Then loosen the bolts and retighten them evenly in increments to a final torque value of 250 lb.-ft.

CAUTION: *Unless the pin bolt spacer is installed correctly – flat surface to bolt head and convex surface to concave seat in the rod – the bolt on which a spacer is incorrectly installed may come out, with resultant failure of the second bolt. This will cause serious damage to the engine main frame and other components.*

4. Install new piston rings, using a Part 147X1099 ring expander, Fig. IX-74. Stagger the ring end gaps of adjacent rings approximately 90 degrees apart with no two in line. Refer to Piston Rings section.

5. Support the piston with the piston support bar and coat the piston with clean lube oil. Apply the ring compressor, Part 147X1089, Fig. IX-75.

FIG. IX-74. APPLYING RINGS WITH RING EXPANDER TOOL.

*Product of Dow Corning Corp.

FIG. IX-72, E-20357

FIG. IX-73, E-25602

FIG. IX-74, E-19817

FIG. IX-75, E-19819

FIG. IX-76, E-21062

FIG. IX-75. APPLYING RING COMPRESSOR.

6. Lower the cylinder assembly onto the piston until the rings enter the liner. Remove the ring compressor and piston support bar and lower the cylinder into place.

7. Secure the cylinder assembly and reassemble all components. Refer to Power Assembly Installation section.

CAUTION: *Cylinder scoring and severe shortening of ring and liner life will result if chrome rings are used with chrome liners or iron rings with Tufftrided liners. Refer to your Renewal Parts Catalog for the proper ring and liner combinations. See Fig. IX-76.*

CAMSHAFT SECTIONS AND BEARINGS

Two sectionalized camshafts, one mounted in each side of the engine frame, are driven by gearing directly from the crankshaft. Both camshafts rotate in the same direction, opposite to the crankshaft rotation, and at one-half the crankshaft speed.

Each sectionalized camshaft is made up of individual precision-machined sections which are fastened together by threaded dowels and nuts. See Figs. IX-77 and IX-80. The intake, fuel, and exhaust cams are integral parts of each hollow section. The journal and cam sections are treated to provide hardened wear surfaces.

The sections containing the cams are stamped with the letters L (left) or R (right) on the edge of the forward flange. This identifies their location with respect to the left or right banks of the engine. The edge of the other flange is stamped with numbers (see Table IX-IV) which are used to

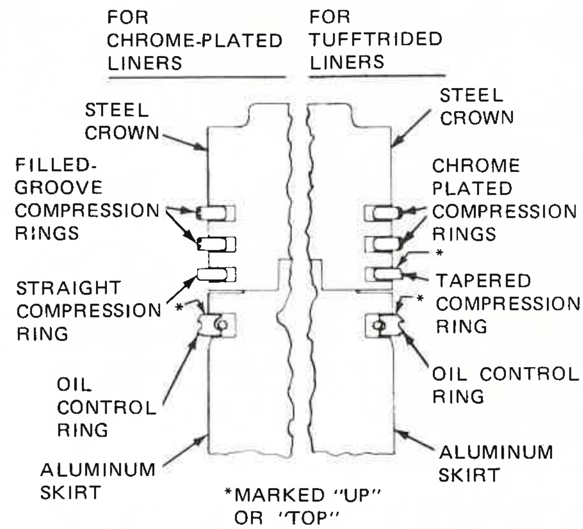


FIG. IX-76. PISTON RING ARRANGEMENTS.

TABLE IX-IV, CAMSHAFT MARKINGS

Cylinder Location (Right or Left Bank)	Engine Model 16 Cyl.	12 Cyl.	8 Cyl.
8	8		
7	3/7		
6	6	6	
5	1/5	4/5	
4	4	4/5	4
3	3/7	3	3
2	2	1/2	2
1	1/5	1/2	1

properly index the section's position in the shaft with respect to the corresponding cylinder. These sections are interchangeable within their respective camshafts but, because of the reversal between the inlet and exhaust cams, they are not interchangeable between the left and right bank camshafts.

A stub section is located at the drive end of each camshaft. This is a universal piece which may be assembled, by proper indexing, to either the left or right bank camshaft.

When assembling a complete camshaft or replacing a section of either camshaft, the sections must be properly indexed with respect to their location in the shaft. Beginning at the drive end of the shaft, align the numeral of

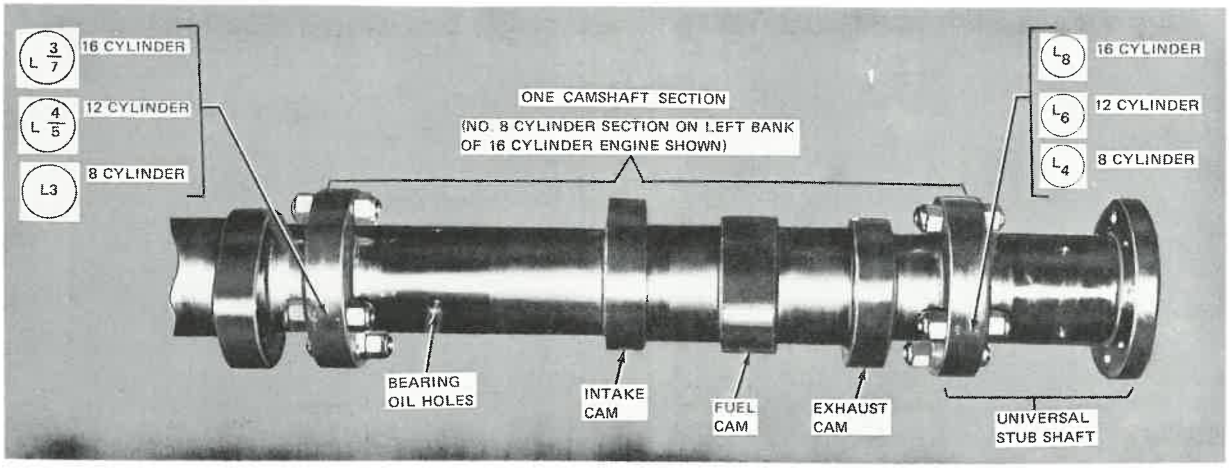


FIG. IX-77, E-16168A

FIG. IX-77. DETAILS OF SECTIONALIZED CAMSHAFT.

the last cylinder (8, 6 or 4) with the proper bank letter (L or R) on the stub section and bolt them together. Rotate the shaft so the bank letter on this section is plainly visible, and align the numeral for the next cylinder (e.g., 7 marked $\frac{3}{7}$ shown in Fig. IX-77) next to the bank letter. Bolt this section to the previous one and proceed to the next section in a like manner, until the free end of the engine is reached. See Table IX-IV for proper numerical markings.

> **CAUTION:** *Camshaft sections are not interchangeable between the right and left bank of the same engine nor are sections interchangeable between engines having different numbers of cylinders. For example, a section from a 12-cylinder engine cannot be used in either an 8-cylinder or a 16-cylinder engine.*

A cover bolted over the end of the free-end camshaft section closes the end of the central oil passage in the shaft.

Support Bearings (Fig. IX-78)

Removable aluminum-alloy split bearings support each shaft within the engine frame in the line-bored bearing seats. The bearings are held in place by bolts extending from outside the engine frame into tapped holes in the bearings. The tapped holes are reinforced by helical steel thread inserts.

The two bearing halves are aligned by hollow steel dowels and are held together by bolts threaded into the steel thread inserts. The two bearing halves are match-marked with numerals and should always be installed as a set. The bearings may be removed from the engine for inspection or replacement without disturbing the camshaft.

Thrust Bearings

A thrust bearing assembly, located next to the drive gear on each camshaft, controls the longitudinal shaft movement. A steel thrust ring, positioned by a dowel, is located between the camshaft flange and the drive gear. A semi-circular, grooved bearing is bolted to the engine frame and fits over the thrust ring to restrict the longitudinal travel, Fig. IX-79.

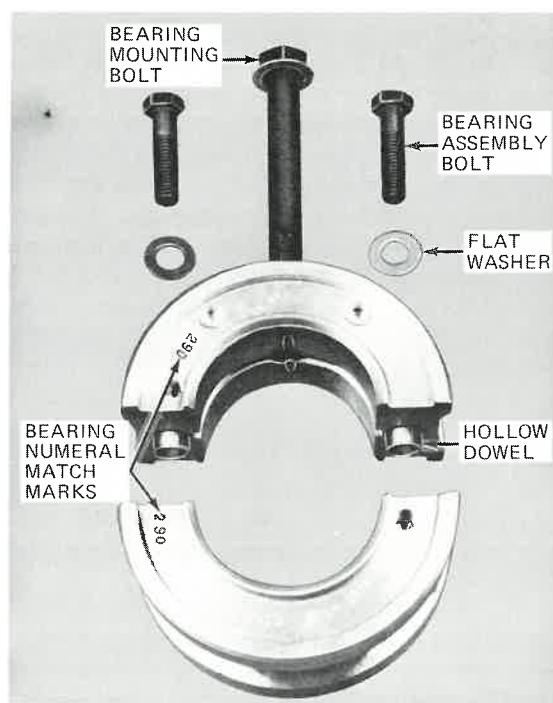


FIG. IX-78, E-13239

FIG. IX-78. CAMSHAFT BEARING ASSEMBLY.

IX

FIG. IX-79, E-13320

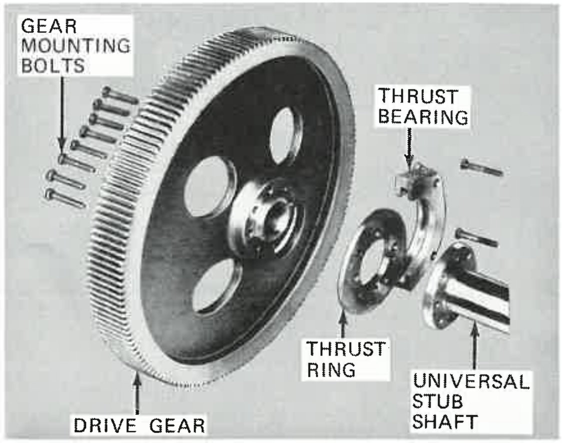


FIG. IX-79. CAMSHAFT DRIVE AND THRUST BEARING ASSEMBLY.

By properly positioning the drive gears, the thrust bearing bolts may be removed through holes in the gear webs without removing the drive gears.

Drive Gears

The drive gears and thrust rings are bolted together and to the camshaft drive flange. An indexing dowel in the hub of each gear correctly positions the timing dots on the gear with respect to its camshaft. The timing dots are located on the side of the gear rim facing the generator-end of the engine.

Removing Camshaft Bearings

To inspect or renew a camshaft bearing, proceed as follows:

1. Remove the crankcase inspection cover and the bearing mounting bolt which extends through the side of the engine frame.

   If more than one bearing is to be removed, place wooden blocks under the camshaft to support it after the first bearing is removed. If all the bearings are being removed, remove the center bearing first, and work toward both ends.

2. Carefully tap the bearing from its bore with a soft hammer.

3. Remove the bearing assembly bolts, then separate the halves and remove the bearing from the shaft.

CAUTION: *Do not pry bearing halves apart. Instead, while removing the bearing assembly bolts and while the last few threads are still engaged, lightly tap each bolt head to separate the bearing halves.*

To install a bearing, reverse the above procedure. Use a new stat-o-seal washer with the bearing mounting bolt and lubricate both sides of the stat-o-seal with Lubriplate. Torque the bearing assembly bolts to 35-40 lb.-ft. Torque the bearing mounting bolts to 40-45 lb.-ft.

NOTE: *A coat of clean engine crankcase oil on the bearing and its bore will make bearing installation easier.*

Removing Camshafts

To renew a single section of the camshaft, proceed as follows:

1. Compress the valve springs and release the valve push-rods from their sockets on ALL cylinders in the bank of the engine where a camshaft section is to be removed. Use rocker arm depressor, Part 147X1040-1.

2. Lift the valve and fuel crossheads (on all cylinders in the bank), and lock them up using a locking pin inserted through the hole in the crosshead guide. To raise the fuel crosshead against the pump spring pressure, force a hardwood or fiber wedge between the roller and cam.

3. Bar-over the engine until the index marks on the flanges of cam section to be removed are visible in the crankcase inspection opening.

4. Remove the mounting bolts from the two cam bearings adjacent to the section to be replaced. Then, carefully push the bearings out of their bores in the frame.

5. Loosen the bearing assembly bolts and separate the bearing halves. Use care not to damage the bearing. Bearing halves can be separated by not completely removing the bolts, then tapping lightly on the head of the bolts until the bearing has separated from the hollow dowel.

6. Remove the four nuts from the cam section flange toward the drive end of the camshaft. Using a pry bar placed against a cam and the engine frame, separate the sections. Push the free end of the shaft towards the free end of the engine until the opening between the flanges is approximately equal to the width of a cam roller.

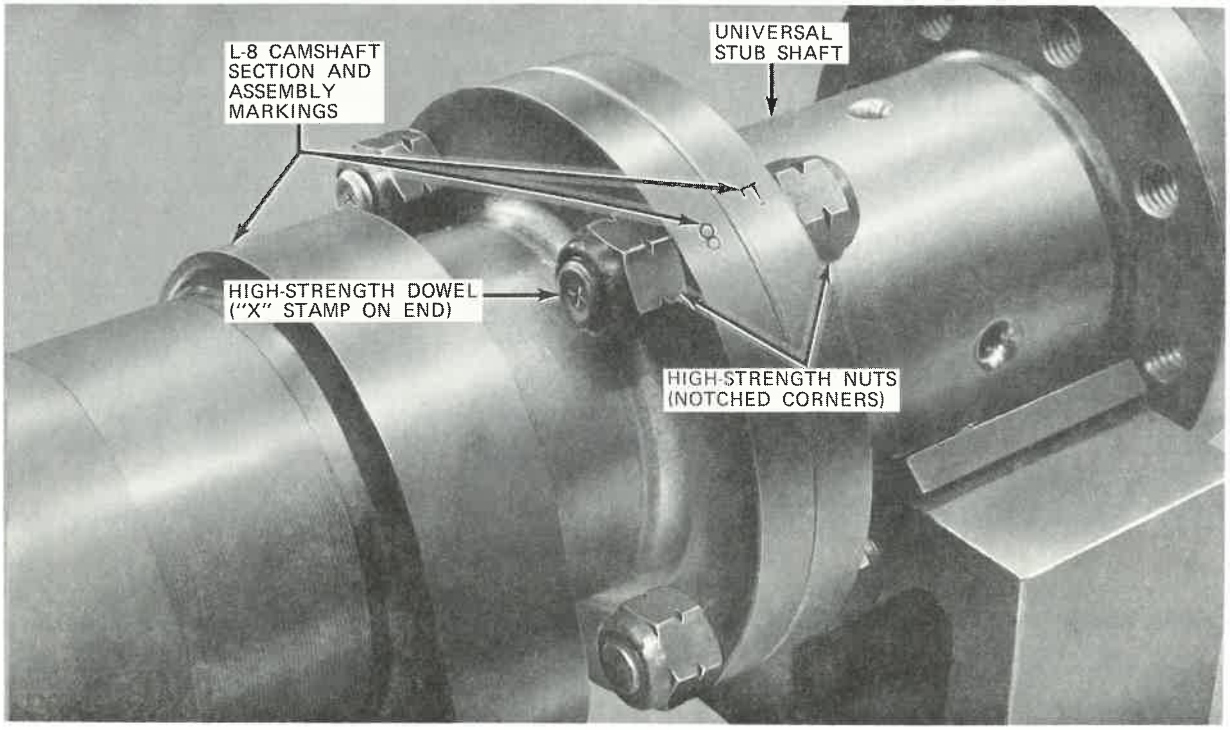


FIG. IX-80, E-25603

FIG. IX-80. CAMSHAFT ASSEMBLY WITH NEW STYLE HIGHER STRENGTH DOWELS AND NUTS.

7. Remove the remaining four nuts which attach the cam section, and remove the section through the inspection opening.

8. Install the new section in the reverse of the above sequence. Observe the index markings as previously described. Use special care to keep flanges and pilots clean and free of burrs. Tighten camshaft dowel nuts to 80-90 lb.-ft. of torque. Older style dowels and nuts must be assembled dry. Current production dowels and nuts should be lubricated on the dowel threads and the nut faces with Molykote G-n. Torque to the same value. See Fig. IX-80 for identifying newer style dowels and nuts.

9. After replacing a camshaft or any section:

   a. Remove the lock pins from all crossheads.
   b. Replace the push rods.
   c. Reset all the valve clearances.
   d. Check the timing on all fuel pumps.

CONNECTING ROD

Removal

Since the cylinder assembly must be removed before a master or articulated rod can be replaced, it is recommended that the cylinder, piston and rod be removed as a complete power assembly. Refer to Power Assembly Removal section for the general procedure.

To remove a rod, proceed as follows:

1. Removing either rod requires the articulated rod to be disconnected. Remove the articulated rod pin bolts, using a Part 147X1458-1 wrench and a Part 147X1823 torque wrench.
2. Install an art rod pin retainer to hold the art rod pin in place until the rod is reassembled, Fig. IX-82.
3. If the master connecting rod is to be removed, loosen the connecting rod cap bolts and back them off, leaving several threads engaged. Use the ratcheting torque wrench, Part 147X1823 and 1-1/8 in. socket, Part 147X1866. See Fig. IX-83.
4. Tap the cap sideways with a heavy brass bar. The cap will drop onto the bolt heads. Remove the bolts and the cap.
5. Remove the power assembly as described in Power Assembly Removal section. If the art rod is not being removed, bar the engine so that the art rod is in its topmost position and block or otherwise secure it in that position.

IX

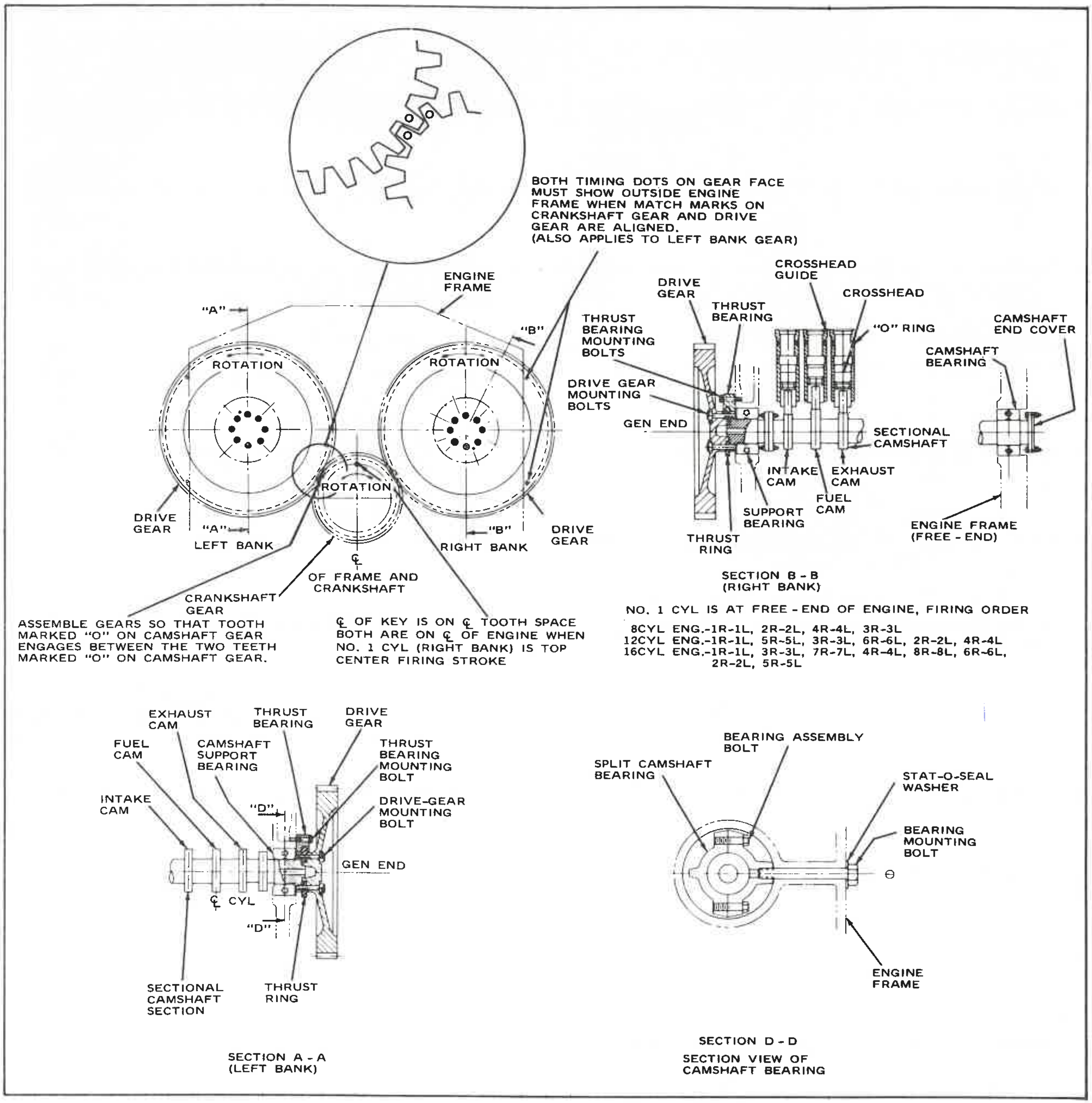


FIG. IX-81. CAMSHAFT DRIVE AND ASSEMBLY.

FIG. IX-81, E-13238A

> **CAUTION:** *Protect the rod journal with a protective pad, Part 147X1827, while the journal is exposed.*

6. Separate the piston and rod assembly from the cylinder assembly.
7. With the rod and piston secured in a rod holding fixture, Part 147X1651, remove the connecting rod from the piston pin. Remove piston pin bolts with wrench, Part 147X1499.

Installation

1. Lubricate the threads and washer faces of the piston pin bolts with Molykote G-n. With the rod secured in a rod holding fixture, Part 147X1651, assemble the piston, with piston pin, to the rod with bolts and spacers. Tighten the piston pin bolts evenly in increments of 100-125 lb.-ft. to 400 lb.-ft. of torque. Then loosen the bolts and retighten to a final torque value of 250 lb.-ft.

IX

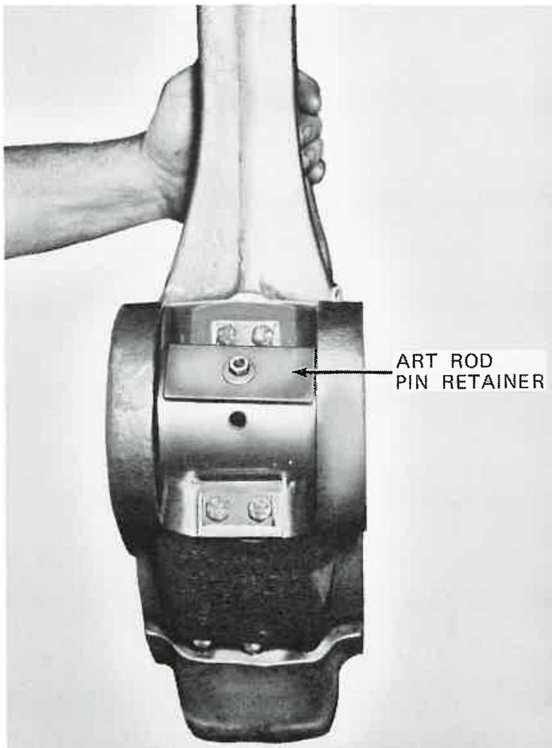


FIG. IX-82. ART ROD PIN RETAINER, PART 147X1474.

CAUTION: *Unless the piston pin bolt spacers are installed correctly; flat surface to bolt head and convex surface to concave seat in the rod, the bolts may loosen and result in serious damage to the main frame and other engine components.*

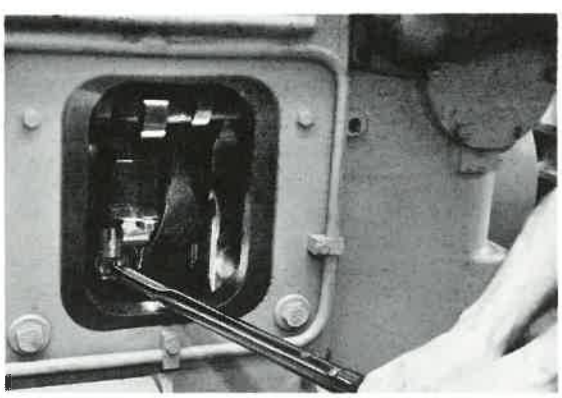


FIG. IX-83. TIGHTENING CONNECTING ROD CAP BOLTS.

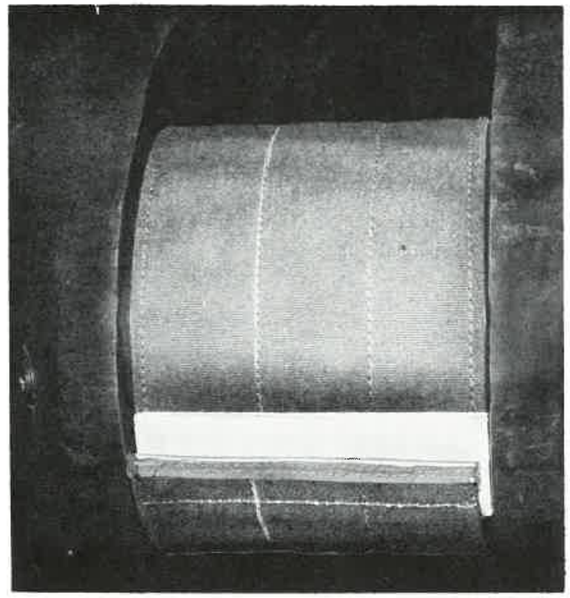


FIG. IX-84. PROTECTIVE PAD ON ROD JOURNAL.

2. Renew the piston rings – see Piston Rings section.

3. Clean the bore of the rod and rod cap and assemble new bearing shells. Coat the threads and washer faces of the cap bolts with Molykote G-n. Assemble the cap to the rod and torque the cap bolts alternately in increments of 100-125 lb.-ft. to 400-420 lb.-ft. Then disassemble the rod cap. Secure the upper bearing shell with two bearing retainers, Part 147X1492-1.

4. Coat the piston, rings and bearing shells with clean lube oil. Compress the piston rings using a ring compressor, Part 147X1089, and lower a cylinder assembly over the piston and rod assembly. The ring compressor will fall off. Secure the piston and rod assembly in the cylinder with a piston retainer, Part 147X1406-1. See Power Assembly Installation section.

5. Lift the power assembly and lower it into position on the rod journal after removing the protective pad. If installing an assembly with an art rod, remove the art rod pin retainer and thread an art rod guide pin, Part 147X1122, into one of the art rod pin bolt holes. Lower the art rod onto the art rod pin, Fig. IX-85.

6. Coat the art rod pin bolts and/or the master rod cap bolts with Molykote G-n on the threads and washer faces.

FIG. IX-82, E-20352
FIG. IX-83, E-22472
FIG. IX-84, E-20361

FIG. IX-85, E-20353

FIG. IX-86, E-25604

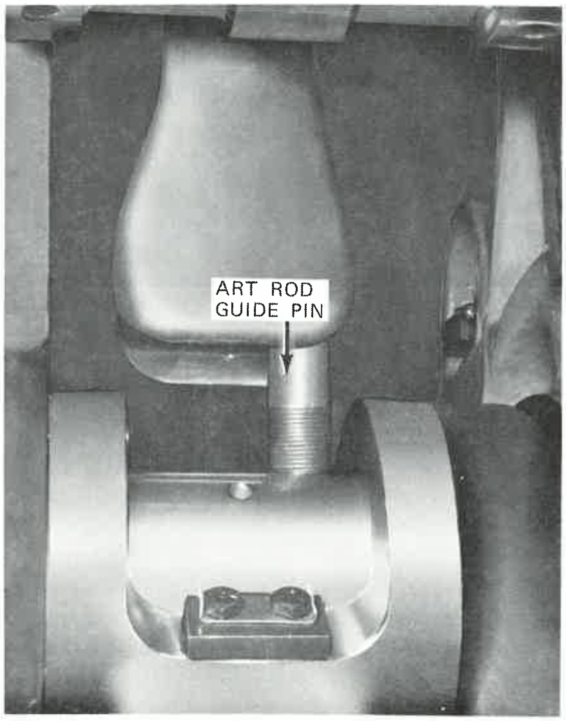


FIG. IX-85. INSTALLING ART ROD USING GUIDE PIN, PART 147X1122.

CAUTION: *Unless the art rod pin bolt spacer is installed correctly – flat surface to bolt head and convex surface to concave seat in the rod – the bolts may loosen and result in serious damage to the main frame and other engine components.*

7. After removing the two bearing retainers, assemble the rod cap. Tighten the master rod cap bolts alternately in increments of 100-125 lb.-ft. to 400-425 lb.-ft. Tighten the art rod pin bolts alternately in the same increments to 450 lb.-ft. Loosen the art rod pin bolts and retighten to a final torque value of 375 lb.-ft.

MAIN BEARINGS AND THRUST COLLARS

Semicircular bearing shells support the crankshaft within the engine. They are secured by bearing caps which are bolted in place.

The bearing shells are precision type and are replaceable without machining or scraping. Each bearing shell has a steel back which supports two or more layers of carefully formulated bearing material.

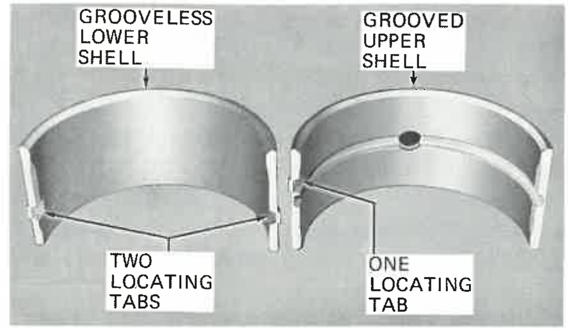


FIG. IX-86. UPPER AND LOWER MAIN BEARING SHELLS.

New Series locomotive engines are equipped with grooveless main bearing shells in the lower position and a grooved main bearing shell in the upper position. Each bearing half with oil groove contains one locating tab which locates it in its correct position; each grooveless bearing half contains two locating tabs which prevent inadvertent installation in the upper position. See Fig. IX-86.

CAUTION: *Under no circumstances should a grooveless bearing be installed in the upper position. With all oil to that journal blocked off by the grooveless bearing, the engine can be expected to fail in only a few revolutions of the crankshaft.*

Inspection

Lower main bearing can be inspected by dropping the cap nuts and cap just far enough to view the bearing surface. Completely removing the nuts is not necessary. The upper bearing half, however, can only be inspected by removing the bearing cap and then rolling the upper bearing half out of its position. It must be rolled so that the locating tab comes out first.

A bearing shell should be replaced if one-third of the bearing area is worn down to the bronze-colored copper/lead matrix. It is good practice to inspect bearings adjacent to the worn bearing also.

Removal

NOTE: *Refer to LOCOMOTIVE MAINTENANCE TOOLS, GEG-14700, for specialized tools available for performing this operation.*

To remove a main bearing, use the following procedure:

1. Loosen the cap nuts two to three turns.
2. Remove the bearing-cap side bolts and loosen the side bolts of the adjacent bearings.

NOTE: *To facilitate removal of the cap from the frame, spread the frame slightly using a frame expander, Part 147X1314 (mechanical) or 147X1742 (hydraulic).*

3. Loosen the bearing cap by tapping downward with a lead hammer or brass drift.

4. Remove the nuts and cap containing the lower half shell. Keep a firm grip on the bearing cap, as it is heavy.

5. Usually the upper half shell can be rolled out by hand. However, it may be necessary to apply the barring-over tool to the engine and a removal tool, Part 147X1342, to a crankshaft oil hole. Then rotate the crankshaft to roll the shell out in the proper direction, so that the locking tab rolls out and not in.

Handle the bearing shells carefully so they do not become damaged in any way.

Installation

Inspect the crankshaft journal to assure it is in good condition.

1. Clean the surfaces of the crankshaft journal, main frame, bearing shells and bearing cap.

2. Coat the journal and inner bearing surfaces with clean engine lube oil.

3. Roll the upper grooved bearing shell into place. To avoid damage to the bearing, assure the lock tabs are properly seated.

4. Seat the lower shell in the bearing cap.

5. Position the bearing cap on its dowel and apply the cap nuts and side bolts finger-tight. Use new O-rings on the bearing-cap side bolts, and apply Lubriplate Spray Lube "A," GE Part 147X1614, to the O-rings and the washer face and threads of the bolts. Also apply Molykote G-n, GE Part 147X1143-1, or Lubriplate to the threads and contact face of the stud bolt nuts. While either lubricant is acceptable, less torque will be required when using Molykote to achieve the stretch value for the stud bolts.

6. Tighten side bolts to approximately 75 lb.-ft. Tighten bearing cap nuts to achieve correct stud stretch value, using a stretch gage, Part 147X1860. On 8-cylinder engines, stretch studs 0.025 in. to 0.027 in. On 12 and 16-cylinder engines, stretch studs 0.027 to 0.033 in. Then torque side bolts to 265-275 lb.-ft.

IX

Thrust Collars

Two half-ring thrust collars, fitted to the engine frame at the second main bearing from the generator end, control the axial thrust of the crankshaft. These collars are loosely fitted and are held in place by the main bearing cap and the crankshaft.

Each thrust collar is marked at its outer edge with a serial number, catalog number and drawing number.

The collars are of solid bronze, have a heavy lead-tin plate on the thrust-bearing surface and a thin lead-tin flash plate all over.

The bearing face of the collar can be identified by its radial oil grooves. WHEN INSTALLED, THE SIDE OF THE COLLAR CONTAINING THE OIL GROOVES MUST FACE THE CRANKSHAFT.

To determine if renewal of the thrust collars is necessary, the crankshaft thrust clearance should be measured. See Crankshaft End-Play in CHECKS section.

CAUTION: *Consult your Renewal Parts Catalog for the correct thrust collar part number.*

If thrust collars must be replaced, proceed as follows:

1. Remove the main bearing cap which retains the thrust collars.

2. Roll the thrust collars out of their fits in the web, Fig. IX-87.

3. Coat new thrust collars with clean lube oil and install, making sure the oil grooves face the crankshaft.

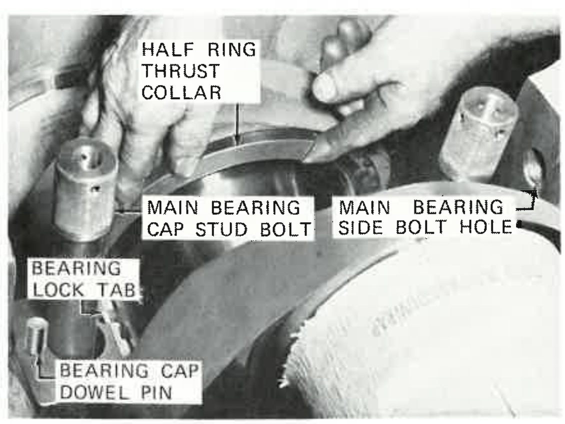


FIG. IX-87, E-9914A

FIG. IX-87. INSTALLING THRUST COLLARS.

FIG. IX-88, E-16540

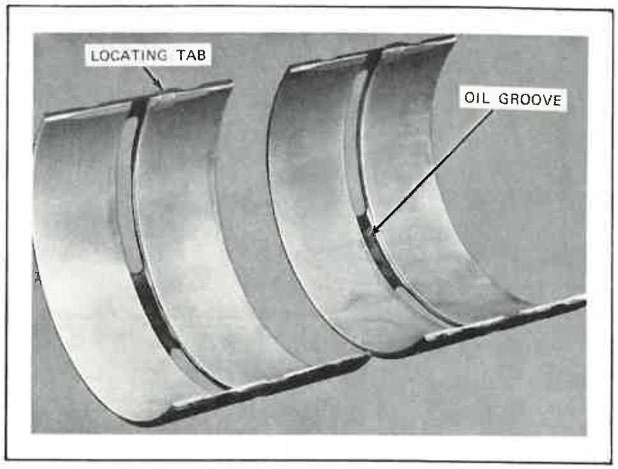


FIG. IX-88. CONNECTING ROD BEARING SHELLS.

4. Check thrust clearance.

5. Install main bearing cap.

CONNECTING ROD BEARINGS

The connecting rod bearing shells, shown in Fig. IX-88, are precision-type and are replaceable without machining or scraping. They are constructed with a solid steel back which is plated on the running surface with specially formulated bearing metals. Each shell has a locating tab which properly locates and secures it in position in the rod or in the cap. Any shell may be applied in either position, as shells are interchangeable. Each bearing shell is stamped along its radial edge with a serial number, a part number and a catalog number.

> **CAUTION:** *The locating tab slot is on one side only of the rod and the rod cap. The tab on the shell must be positioned in the slot, or it will be crushed in and cause a bearing failure and, possibly, further serious damage.*

Connecting rod bearings may be replaced without removing the connecting rod from the engine. Bearings are replaced as follows:

1. Bar the engine to position the journal near its topmost position.

2. Loosen the cap bolts several turns. Use 1-1/8 on. socket, Part 147X1866, and ratcheting torque wrench, Part 147X1823. See Fig. IX-83.

3. Tap the bearing cap sideways with a heavy brass bar. The cap will separate from the journal. Remove the nuts and cap.

4. Block or otherwise secure the piston and rod in its upper position and bar the engine over to get the journal out of the way.

5. Using a wood or fiber block as a drift, tap the bearing shells out of their fits.

6. Clean the bearing shell fits to make sure there are no high spots. File off any high spots on the split line of the rod and cap. Stone off any high spots on the back of the bearing shells. DO NOT LUBRICATE BETWEEN THE ROD BORE AND THE BEARING SHELLS.

7. Verify that the lock tabs on the shells are properly positioned and tap the shells into place with a wood or fiber drift. DO NOT USE ANY METAL OBJECT AS A DRIFT.

8. Lubricate the rod journal with clean lube oil. Bar the engine to position the rod journal up close to the rod and lower the piston and rod assembly onto the journal.

9. Coat the threads and washer faces of the cap bolts with Molykote G-n, Part 147X1143-1. Tighten the bolts in increments of 100-125 lb.-ft. to a final torque of 400-420 lb.-ft.

CROSSHEADS AND GUIDES

Three crosshead assemblies are mounted in the engine frame under each cylinder. The crossheads transmit reciprocating force from the cams to the push rods to operate the valves and the fuel injection pump on each cylinder, Fig. IX-89.

FIG. IX-89, E-14927A

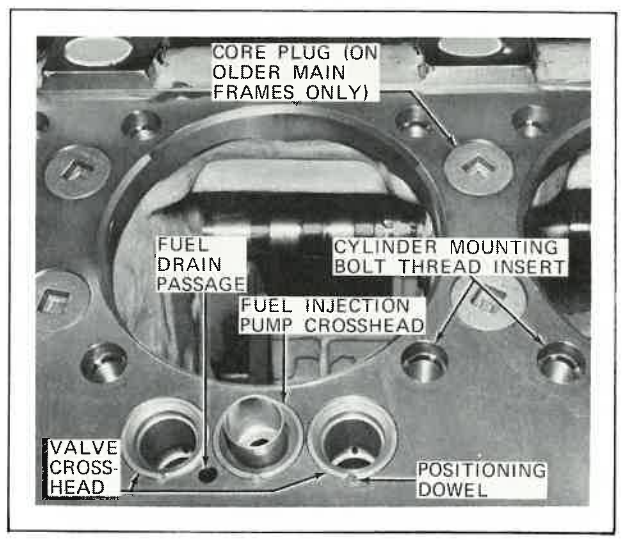


FIG. IX-89. CYLINDER LOCATION WITH CROSSHEADS INSTALLED.

IX

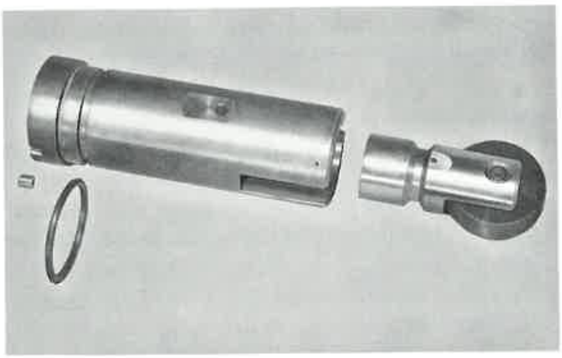


FIG. IX-90. VALVE CROSSHEAD AND GUIDE ASSEMBLY.

FIG. IX-90, E-9925

The assemblies for the air and exhaust valves are alike and consist of two major parts: the crosshead with its hardened roller, and a guide in which the crosshead operates, Fig. IX-90.

Parts of the fuel crosshead assembly are similar in appearance, but are not interchangeable with those for the valves. The fuel crosshead assembly consists of the following major parts: a guide, spring retainer, spring and crosshead. The fuel crosshead assembly, when installed in the engine, is spring-loaded to insure the crosshead and its roller will run smoothly on the lobe of the camshaft, Fig. IX-91.

Valve Crosshead Guides

The valve crosshead guides are identical and interchangeable. They are individually positioned in their bores in the main frame by dowel pins and are held down by the flange of the cylinder above them. An O-ring around each guide, near its upper end, forms an oil seal between the guide and its frame bore. Another O-ring forms a seal between the cylinder base and the crosshead guides.

Fuel Crosshead Guides

The fuel crosshead guide is positioned and sealed in the same manner as the valve crosshead guides. It differs from those for the valves in having a wider roller guide slot to accommodate the wider roller, a larger crosshead to guide locking pin hole, and a different machining arrangement on its inside diameter to properly position the spring retainer.

Valve Crossheads

Two designs of crossheads have been used and they are:

1. Part 124X1033-4 – Used until early 1978. This crosshead had a hardened push rod bearing at its upper end, and a hardened cam roller operating on a free-floating steel bushing at its lower end.
2. Part 124X1068 – Used starting in early 1978. This crosshead had a hardened push rod bearing at its upper end, and a hardened cam roller operating on a bronze pin at its lower end.

Both crossheads are interchangeable as a complete assembly and can be used in either the air or exhaust position.

Drilled oil passages in the crosshead and crosshead guide and an annular groove around the crosshead permit intermittent oil flow upward through each valve push rod to lubricate the upper cylinder parts.

IX

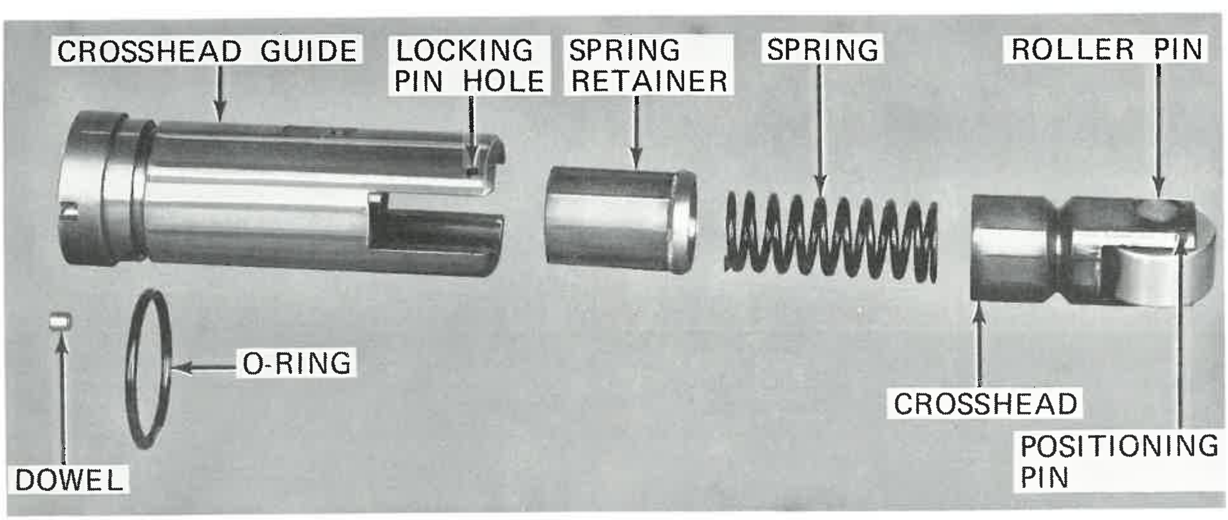


FIG. IX-91. SPRING-LOADED FUEL CROSSHEAD AND GUIDE ASSEMBLY.

FIG. IX-91, E-14928

Fuel Crossheads

Fuel crossheads are similar in appearance, but are not interchangeable with valve crossheads. They are arranged with different oil passages and can be identified by the flat tappet-rod bearing insert at their upper end. The fuel crossheads have a wider cam roller which is held in place by a large roller pin and a positioning pin, Fig. IX-91.

Removal and Installation

After the cylinder has been removed, the crosshead assemblies and positioning dowel pins can be pushed upward and removed. To lock the valve crosshead in its guide, bend a piece of 1/16-in. iron wire about one in. long into an "L" shape. Push the crosshead up in its guide, and insert the lockwire through the 1/8-in. locking hole from the guide bore outward. The end of the wire must not protrude beyond the guide, or it will interfere during guide removal. Use the same procedure for locking the fuel crosshead in its guide as is used for the valve crosshead, but use a 3/16-in. wire in 1/4-in. guide locking hole.

A crosshead and guide may be renewed without completely removing the cylinder. With the piston at top dead center, disconnect the cylinder and lift it just high enough to permit removal of the crosshead assembly, but not high enough to disengage the piston rings from the cylinder bore. Immerse crosshead in SAE-10 lubricating oil for five minutes, then install the new crosshead assembly with lubricant applied to the sealing O-ring. Position the assembly and insert the dowel. Apply new O-rings to the push rod ferrules. Then restore the cylinder to position and reconnect.

NOTE: *Use care when handling crossheads and guides. Burrs may be formed on the edge of the guide bore if the crosshead is dropped into the guide with the guide inverted. Burrs must be removed to prevent binding of the crosshead during operation. Also, in case of a push rod failure, the crosshead will probably be stuck in the guide and should be carefully inspected for damage.*

RUBBER-BONDED PUMP DRIVE COUPLING

The pump drive gear assembly is mounted on the crankshaft and is used to transmit the torque, needed to drive the water and lube oil pumps, from the crankshaft to the pump idler gear. The assembly consists of the following basic parts, Fig. IX-92:

1. Gear hub
2. Gear ring
3. Gear coupling.

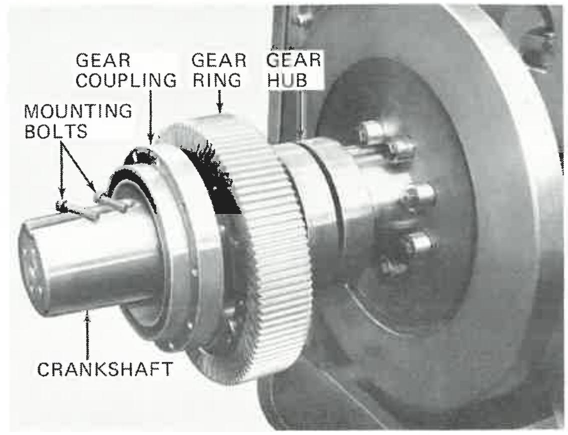


FIG. IX-92. TYPICAL PUMP DRIVE GEAR ASSEMBLY.

The gear coupling is made of two basic parts, the clamp ring and the coupling, which are put together with a press fit. The coupling has an inner flange and an outer sleeve held together with a bonded resilient material, Fig. IX-93.

Coupling Replacement

NOTE: *To gain access to the coupling, it is first necessary that the drive hub and guard be removed from the forward end of the engine. It is also necessary to remove the lube-oil fill assembly from the left side of the forward-end cover, and remove the bearing from the forward-end cover.*

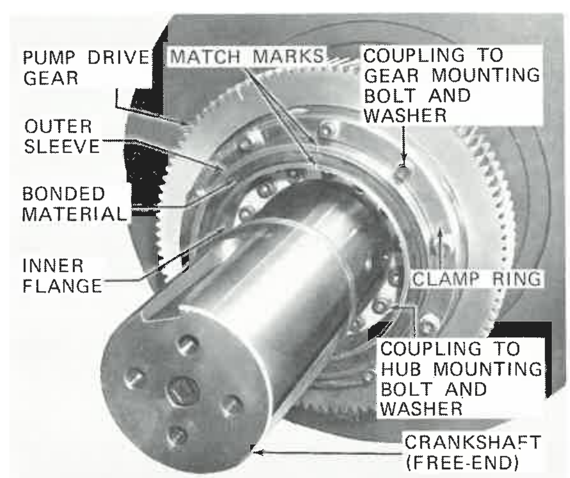


FIG. IX-93. FRONT VIEW OF PUMP DRIVE GEAR ASSEMBLY.

Thru the opening around the crankshaft, created by removing the bearing:

1. Remove the bolts and washers holding the coupling to the gear.

2. Remove the bolts and washers holding the coupling to the hub.

3. Remove the defective coupling, install a new coupling, and secure to hub and gear with bolts and washers. Tighten bolts to 44-49 lb.-ft. of torque.

NOTE: *It may be necessary to bar the engine, or rotate the gear, to achieve bolt-hole alignment and alignment of match-mark numbers on the back face of the hub and gear. See Figs. IX-94 and IX-95.*

4. Replace forward-end bearing, other parts removed from the forward end of the engine and the lube-oil fill assembly.

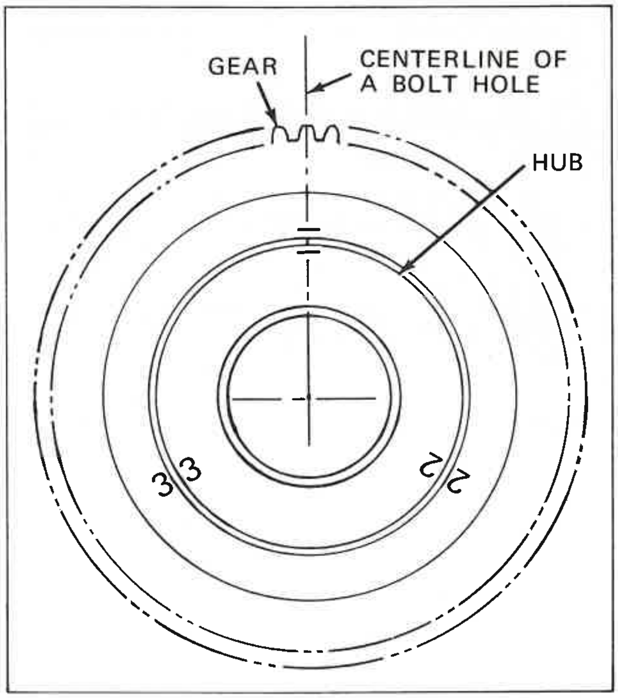


FIG. IX-95. MATCH-MARK NUMBERS ON BACK (FRAME) SIDE OF HUB AND GEAR.

FIG. IX-95, E-21433

OVERSPEED-DERATER LINK

Removal

With the engine shut down:

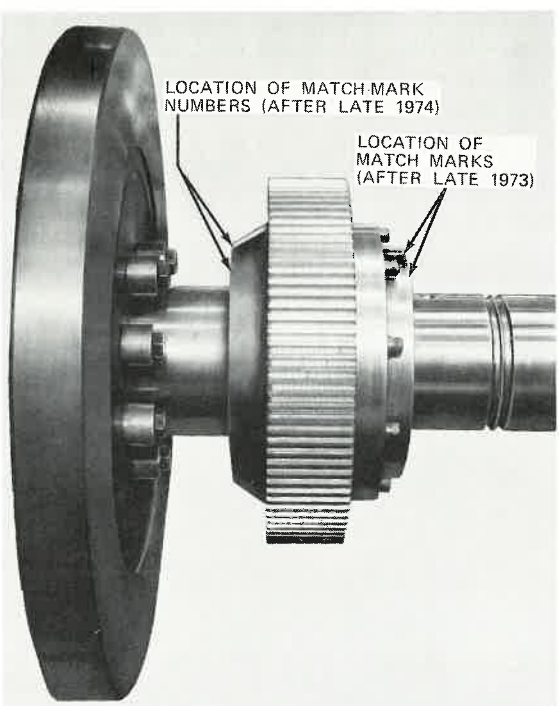


FIG. IX-94. SIDE VIEW OF PUMP DRIVE GEAR ASSEMBLY.

FIG. IX-94, E-14934A

1. Disconnect the air and oil lines at the link, Fig. IX-96.

2. Remove the cotter pins and clevis pins which connect the link to the control governor and the fuel-control linkage.

3. Remove the 90-degree fitting from the air inlet in the top cover of the link.

Installation

1. Install the 90-degree fitting in the air inlet in the top of the link.

2. Position the link and install the clevis pins which connect the link to the control governor and the fuel-control linkage. Secure clevis pins with new cotter pins.

3. Connect the air and oil lines to the links.

4. Check the fuel injection pump rack settings and make adjustments as required. See Fuel Pump Rack Setting in ADJUSTMENTS section.

5. Start the engine and check for proper operation of the link. Also check for leakage at the hose connections and the I.D. of the outer casing.

FIG. IX-96, E-14950A

FIG. IX-97, E-21624

FIG. IX-98, E-25557

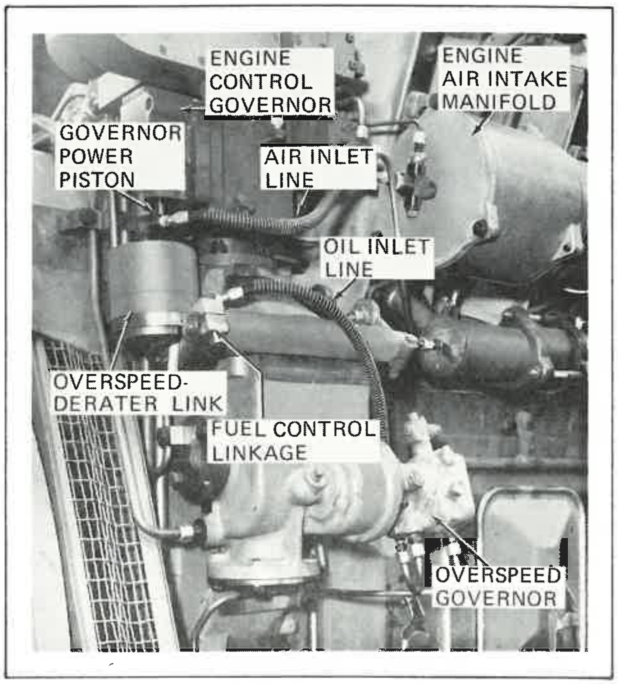


FIG. IX-96. VIEW OF OVERSPEED-DERATER LINK MOUNTED ON ENGINE.

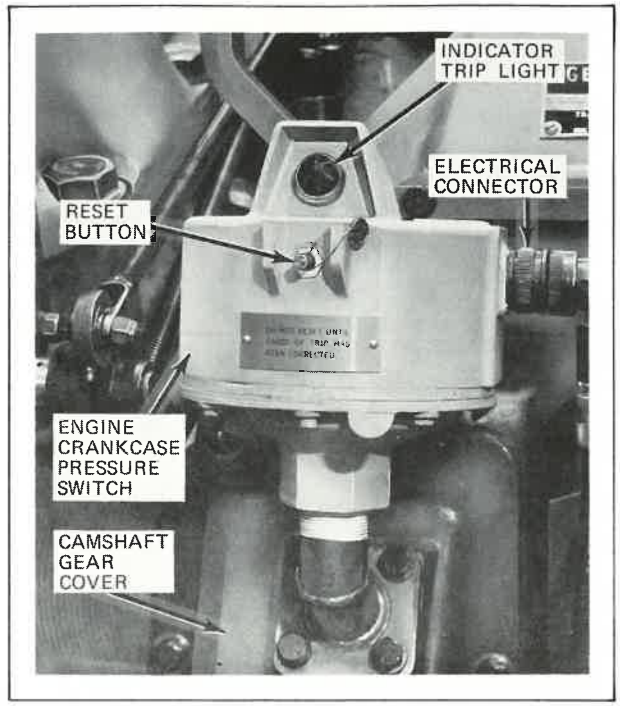


FIG. IX-97. ENGINE CRANKCASE PRESSURE SWITCH MOUNTED ON ENGINE.

CRANKCASE PRESSURE SWITCH

Removal and Installation

The crankcase pressure switch is an important protective device and should be immediately replaced if found defective.

To remove it, disconnect the electrical connector and remove the four mounting bolts and lockwashers. When installing a replacement, use a new gasket at the mounting flange. Secure with four mounting bolts and lockwashers. Connect the electrical connector, push in the reset button and apply seal wire and seal.

OVERSPEED GOVERNOR

Removal and Installation

To remove the overspeed governor, disconnect the oil supply line, oil drain line and pressure line to overspeed link. Cap the lines to keep out dirt. Remove the four mounting bolts and pull the governor straight out off its spline. Remove the protective caps from the replacement governor and cap the holes in the old governor with them.

Clean off old gasket material and mount the new governor using a new gasket. Reconnect all piping and push in reset button. Check for leaks after the engine is started.

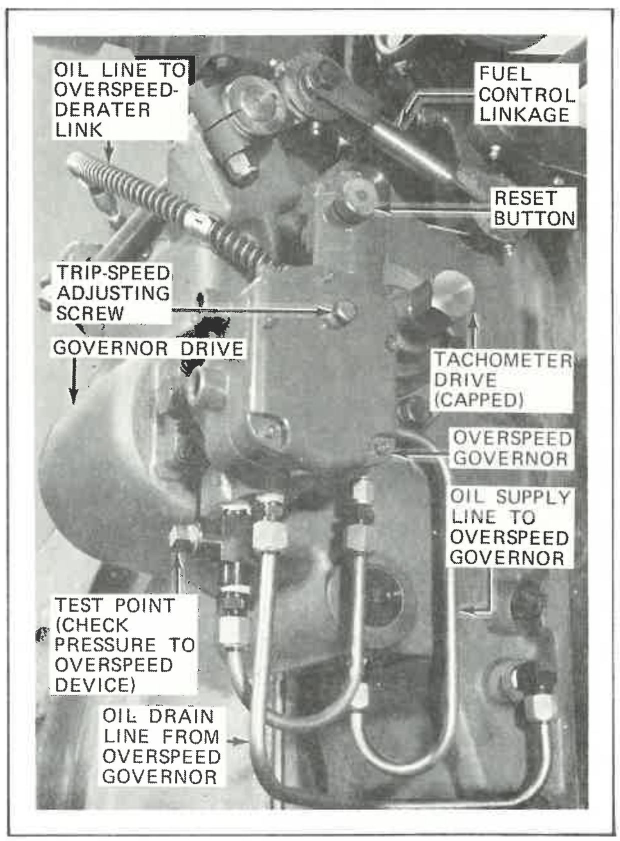


FIG. IX-98. OVERSPEED GOVERNOR.

IX

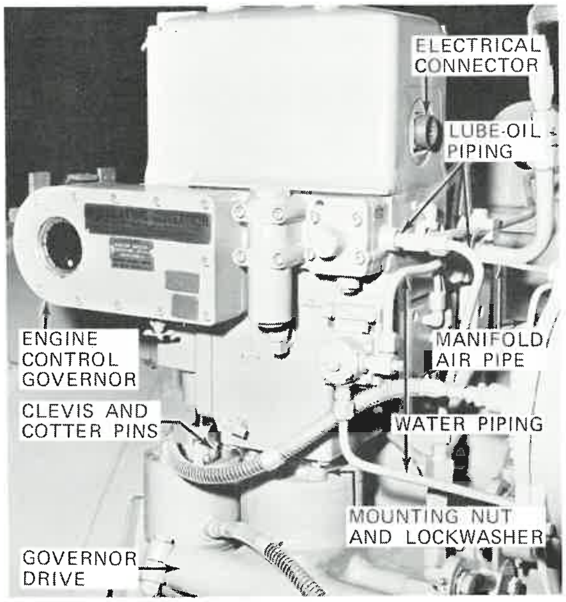


FIG. IX-99. ENGINE CONTROL GOVERNOR.

ENGINE CONTROL GOVERNOR

Removal

1. Remove the hatch in the engine cab above the governor.

2. Disconnect the electrical connector plug from the governor.

3. Remove the cotter pin from the power piston clevis and remove the clevis pin to disconnect the governor from the overspeed link and fuel linkage.

4. Disconnect air, oil and water lines to the governor and cover the ends of all fittings.

5. Remove the mounting nuts. Install a 3/8-in. eyebolt in the top case and lift the governor straight up from its spline in the gear box.

Installation

1. Make sure the governor drive shaft and mounting surfaces are clean. Install a new gasket on the mounting surface.

2. Hoist the governor into position over the gear box, aligning the spline drive and lowering the governor into position. No force should be required to properly seat the governor.

3. Assemble the nuts and lockwashers to secure the governor in position. Reconnect the overspeed link to the power piston tail rod, making sure the linkage does not bind.

4. Reconnect all the external piping and tighten fittings securely.

5. Add oil to the line on the sight glass but not over. After the engine is run, purge the governor of all entrapped air. It may be necessary to add a little more oil as the internal chambers of the governor fill with oil. Don't overfill. There is enough oil in the governor if it is visible in the sight glass.

NOTE: *Refer to governor instructions, GEI-81978 (in backshop manual) for air purging procedure.*

6. Attach the electrical connector. Adjust the racks on the fuel pumps. See Fuel Pump Rack Setting in ADJUSTMENT section.

FIG. IX-99, E-25610

EXHAUST MANIFOLD — MULTI-PIPE

The multi-pipe exhaust manifold is used on all locomotives equipped with an 8-cylinder engine.

Removal

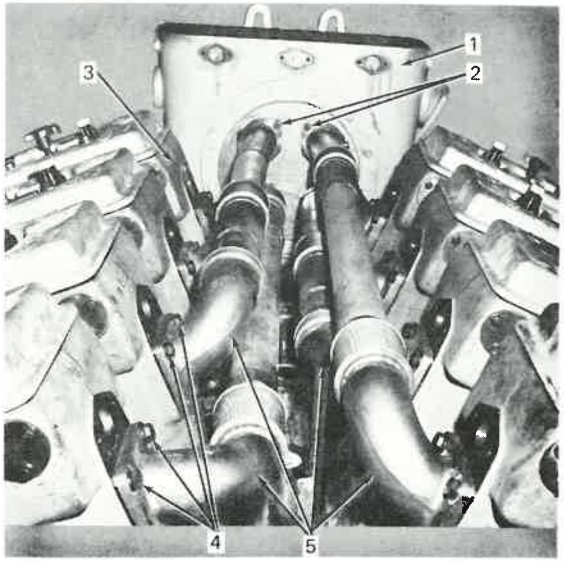
For the pipe section being removed, remove bolts, lockwashers and hardened flat washers at the two cylinders and at the turbocharger.

NOTE: *When necessary, remove a good top pipe section to gain access to a bad lower pipe section.*

Installation

1. Before installing pipe sections on the engine, wire brush all bolt threads and retap all threaded holes. Apply high-temperature anti-seize thread compound, Part 147X1640, to all threads of bolts and tapped holes and to the washer face of the bolt heads. Use new gaskets and coat both gasket faces with anti-seize compound, Part 147X1640. Applying anti-seize compound in the manner described will facilitate future disassembly.

2. Apply pipe section in place and install all bolts finger-tight. Use bolts and lockwashers at the cylinder connections; use bolts and hardened flat washers at the flange clamps at the turbocharger. See Figs. IX-100 and IX-104.



REF.	DESCRIPTION
1	TURBOCHARGER
2	BOLTS – FLANGE TO TURBOCHARGER
3	CYLINDER
4	BOLTS – FLANGE TO CYLINDER
5	EXHAUST MANIFOLD SECTIONS

FIG. IX-100. MULTI-PIPE EXHAUST ARRANGEMENT.

FIG. IX-100, E-17756

3. Center all exhaust manifold flanges at the turbocharger between the two securing bolts and the two prick-punch marks on the face of the turbine-inlet flange. Alternately tighten each bolt in increments up to the final torque of 120-130 lb.-ft. (163-176 N·m). Loosen each bolt and retighten to the final torque value.

4. Check the fit of the manifold to the turbocharger. The assembled manifold flange must be square with the face of the turbocharger within 0.020 in. (0,5 mm). For example, if the flange touches the face of the turbocharger at one point, a 0.020 in. (0,5 mm) feeler gage shall not enter the joint face anywhere around the circumference.

5. Tighten the flanges at the cylinder, tightening the bolts alternately in increments, and in a criss-cross pattern, up to the final torque value of 100-110 lb.-ft. (136-149 N·m). Loosen each bolt and retighten to the final torque value.

6. After engine is started, check all connections for exhaust leakage.

7. After a few hours of operation, retighten all bolted connections.

EXHAUST MANIFOLD – SINGLE-PIPE

The single-pipe exhaust manifold is used on all locomotives equipped with a 12 or 16-cylinder engine.

Replacement of Main Section

To replace a manifold main pipe section, perform the following steps:

NOTE: *Any main pipe section may be replaced without removing the water header. Carefully clean elbow joint parts and inspect for nicks which will not seal. Seal rings are reusable.*

1. Unbolt the elbow clamp rings on the elbows attached to the section to be removed, and on the left and right elbow of section just ahead of this one.

2. Remove the cylinder mounting bolts on the two elbows attached to the section to be removed. Also remove the elbow mounting bolts from the cylinder just ahead of the section to be removed. Remove elbows.

3. Remove the main clamp rings from both ends of the section to be removed.

4. Carefully lift out the section, rotating to clear the water discharge header.

5. Install the new section in the reverse order, being careful to align the section to the mounted elbows before torquing the main and elbow clamp rings. Torque the main pipe clamping bolts to 70-75 lb.-ft. and the elbow clamping bolts to 18-20 lb.-ft.

6. Retorque all clamping ring bolts one month after section replacement.

Replacement of Transition Section

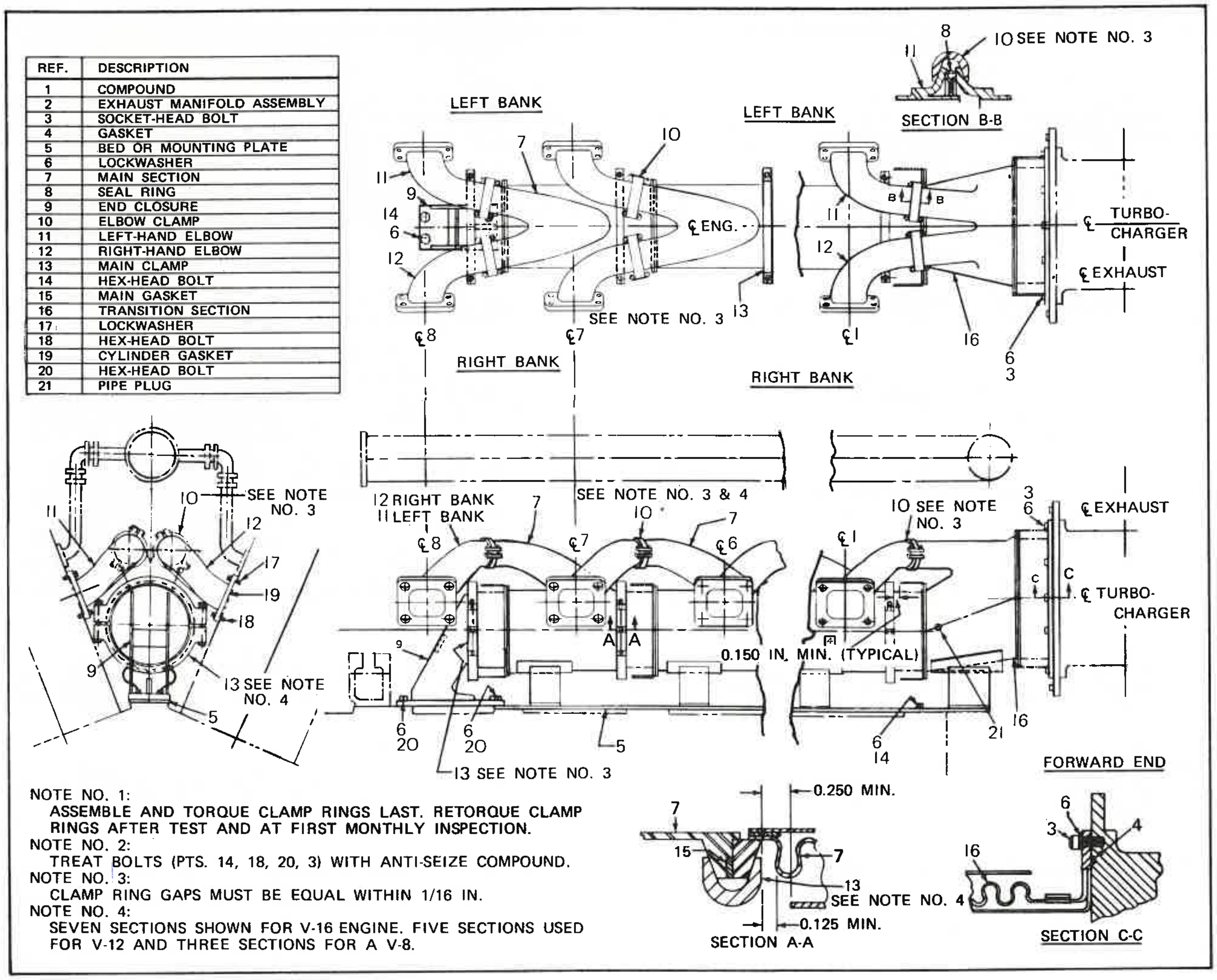
To replace a transition section, proceed as follows:

1. Remove the top six socket-head bolts holding the turbo inlet casing to the turbo housing (to permit sliding the transition section straight up).

2. Unbolt the elbow clamp rings and elbows for cylinders 1L and 1R, and remove the elbows.

3. Remove the clamp ring at the forward end of the first main pipe section.

4. Remove the clamp-ring bolts which secure the transition section to the turbocharger.



REF.	DESCRIPTION
1	COMPOUND
2	EXHAUST MANIFOLD ASSEMBLY
3	SOCKET-HEAD BOLT
4	GASKET
5	BED OR MOUNTING PLATE
6	LOCKWASHER
7	MAIN SECTION
8	SEAL RING
9	END CLOSURE
10	ELBOW CLAMP
11	LEFT-HAND ELBOW
12	RIGHT-HAND ELBOW
13	MAIN CLAMP
14	HEX-HEAD BOLT
15	MAIN GASKET
16	TRANSITION SECTION
17	LOCKWASHER
18	HEX-HEAD BOLT
19	CYLINDER GASKET
20	HEX-HEAD BOLT
21	PIPE PLUG

NOTE NO. 1:
ASSEMBLE AND TORQUE CLAMP RINGS LAST. RETORQUE CLAMP RINGS AFTER TEST AND AT FIRST MONTHLY INSPECTION.
NOTE NO. 2:
TREAT BOLTS (PTS. 14, 18, 20, 3) WITH ANTI-SEIZE COMPOUND.
NOTE NO. 3:
CLAMP RING GAPS MUST BE EQUAL WITHIN 1/16 IN.
NOTE NO. 4:
SEVEN SECTIONS SHOWN FOR V-16 ENGINE. FIVE SECTIONS USED FOR V-12 AND THREE SECTIONS FOR A V-8.

FIG. IX-101, E-13439C

FIG. IX-101. SINGLE-PIPE MANIFOLD.

IX

5. Lift this section up and out toward the left side of the engine.

6. Reverse these procedures to install a new section. Torque the manifold clamping bolts to 70-75 lb.-ft. and the mainfold to turbo inlet clamp bolts to 70-75 lb.-ft. Torque the cylinder exhaust port to manifold elbow bolts to 100-110 lb.-ft.

7. Retorque all bolts one month after section replacement.

Seal Rings

The seal rings between manifold sections and cylinder elbows may be reused if they are within the dimensional limits as shown in Fig. IX-102 and if the sealing surface is not nicked or dented.

When installing a seal ring, make sure that the spring wire retainer is on the side toward the cylinder connection. The manifold elbow has clearance to accommodate this retainer. Should the ring be put on with the spring retainer toward the main section, clearance will be lacking and a leak will probably result. See Fig. IX-103 for correct application of seal ring retainer.

TURBOCHARGERS

General

Since several different models of turbochargers are used on General Electric diesel engines, the replacement instructions that follow will be all inclusive. Therefore, disregard operations that are not applicable.

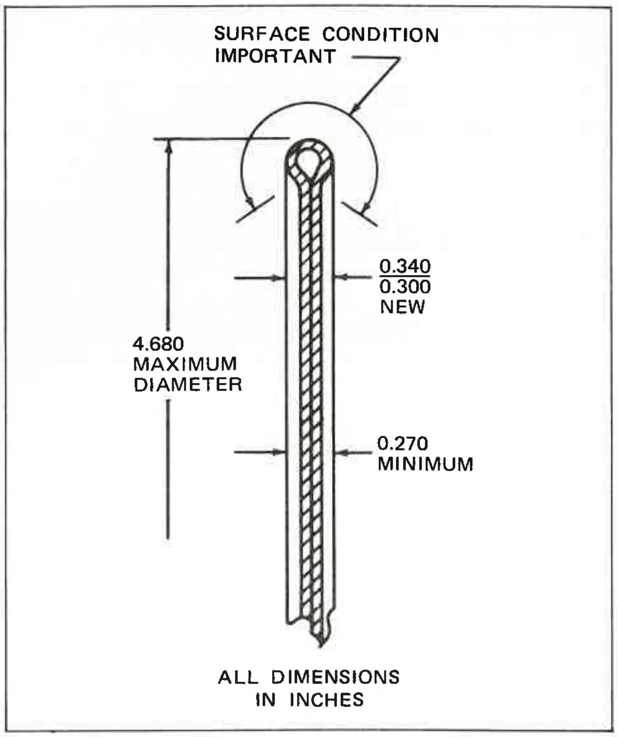


FIG. IX-102. SEAL RING DIMENSIONAL LIMITS.

FIG. IX-102, E-23572

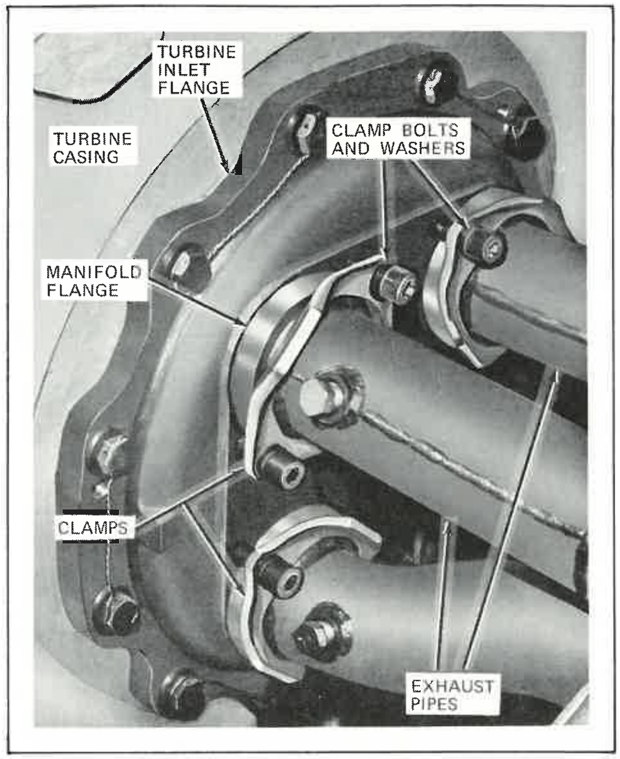


FIG. IX-104. TURBO INSTALLATION DETAILS — TURBINE END, WITH MULTI-PIPE EXHAUST MANIFOLD.

FIG. IX-104, E-23321

Removal

1. Drain the locomotive cooling water system.
2. Remove the hatch over the turbocharger.
3. Disconnect the crankcase breather from the exhaust stack, Fig. IX-107. Remove the four aspirator hoses, Fig. IX-106. Remove the exhaust stack from the turbocharger turbine casing.
4. Remove the intercooler support bar, Fig. IX-105.
5. Remove the two compression couplings from the water discharge header, Fig. IX-105.
6. Disconnect the exhaust manifold from the turbine inlet assembly as follows:

   a. For multi-pipe manifold:

      Remove the bolts and heat-treated washers from each clamp, Fig. IX-104.

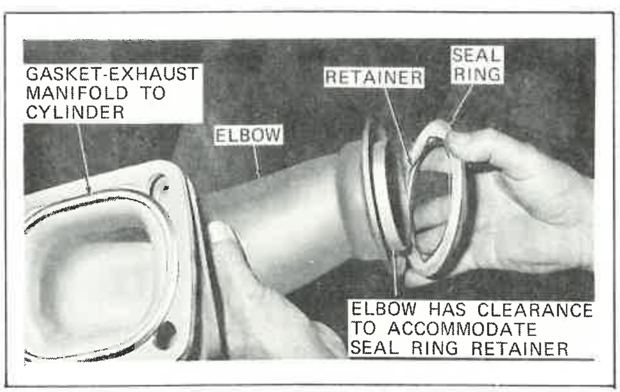


FIG. IX-103. SEAL RING RETAINER CORRECTLY APPLIED.

FIG. IX-103, E-23573

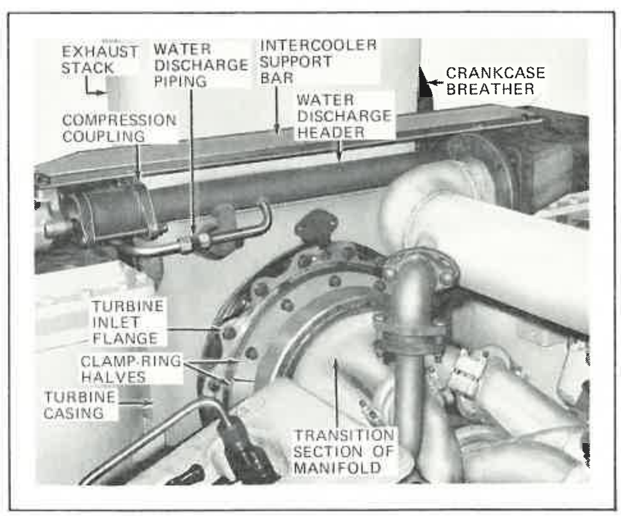


FIG. IX-105. TURBO INSTALLATION DETAILS — TURBINE END, WITH SINGLE-PIPE EXHAUST MANIFOLD.

FIG. IX-105, E-24458

IX

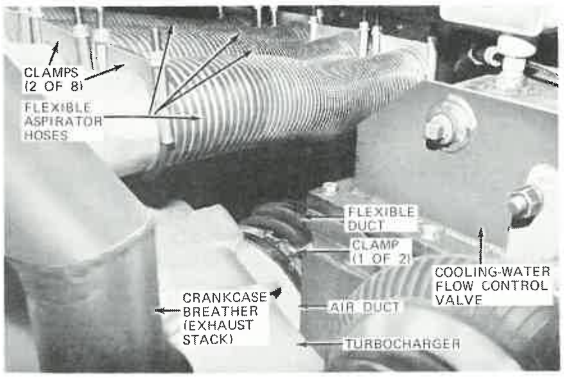


FIG. IX-106. TURBO INSTALLATION DETAILS, COMPRESSOR END.

b. For single-pipe manifold:

(1) Remove bolts and lockwashers which secure the clamp-ring halves, Fig. IX-105, to the turbine inlet flange. Remove the clamp-ring halves.

(2) Remove the lockwires and the four lower bolts and washers which secure the turbine inlet flange to the turbine casing.

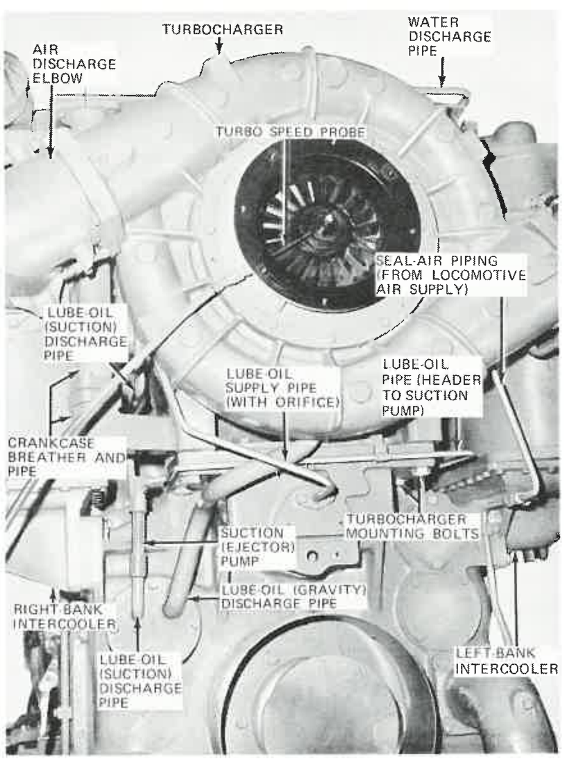


FIG. IX-107. TURBO INSTALLATION DETAILS, COMPRESSOR END.

7. Remove the two air-discharge elbows, Fig. IX-107.

8. Remove clamps, flexible duct and metal air duct, Fig. IX-106, from the compressor end of the turbocharger.

9. If so equipped, disconnect the CHEC-excitation speed pick-up probe at the terminal box.

10. Refer to Fig. IX-107. Disconnect and remove the external lube-oil piping in the following order:

a. Lube-oil supply pipe, with orifice, at the forward-end cover and the turbine casing.

b. Lube-oil suction discharge pipe at the suction pump and the turbine casing (if turbo is equipped with a lube-oil suction pump).

c. Lube-oil pipe at the suction pump and the forward-end cover (if turbo is equipped with a lube-oil suction pump).

d. Lube-oil discharge pipe at the turbine casing.

e. The cover-discharge pipe together with the suction pump from the forward-end cover.

11. Disconnect the seal air piping at the turbine casing (if turbo is supplied seal air from the locomotive air supply).

12. Remove the four mounting bolts and lockwashers, Fig. IX-107, which secure the turbocharger to the forward-end cover.

13. Use lifter and/or lifting sling to remove turbocharger from engine. Slightly rock the turbocharger, as it is lifted, to free the two rear feet from their locating dowels.

CAUTION: *Exercise care in removing the turbocharger so as not to damage the exhaust manifold.*

14. After positioning the turbocharger on the floor:

a. Remove the water discharge header and retain for application on the replacement turbocharger.

b. Remove the CHEC-excitation speed pick-up probe from the blower inlet and retain for application on the replacement turbocharger (if turbo was equipped with probe).

FIG. IX-106, E-24460

FIG. IX-107, E-24459

IX

c. If the turbocharger was removed because of a failure (and not for a periodic replacement), thoroughly examine the turbocharger and DETERMINE THE CAUSE OF FAILURE. Failure to do so will probably result in a repeat failure. If failure was caused by foreign material, it is MANDATORY that all traces of this material be removed from the system; that is, it may be necessary to remove and clean the exhaust manifold, or it might be necessary to remove the air filters and clean and inspect the filter clean-air plenum. Also inspect the inlet side of both intercoolers for foreign material.

d. Apply protective covers and pipe plugs to all openings in the removed turbocharger. Apply new covers and plugs or remove from the replacement turbocharger.

e. Remove the crankcase breather cover and clean the screen assembly.

CAUTION: *If turbocharger is being replaced because of bearing failure, check the cavity in the top of the forward-end cover when the screen assembly is removed; make certain the pipe-tapped hole is fitted with a pipe plug. Failure to plug this hole will result in a loss of lube-oil supply to the turbocharger bearings.*

Installation

If turbocharger is being installed as a result of a failure (and not for a periodic replacement), correct the cause of the failure. Apply new gaskets and lockwashers and install turbocharger in the following manner:

1. From the replacement turbocharger, remove all protective covers and the pipe plugs from the lube-oil and seal-air inlets (if so equipped). Make certain no foreign material is in the turbocharger.

2. Pour some clean engine lube oil into the oil inlet near the top of the turbine casing, and rotate the rotor assembly several revolutions.

3. Using new gaskets, assemble the water discharge header, Fig. IX-105, to the turbine casing.

4. If so equipped, install the CHEC-excitation speed pick-up probe. Check gap between end of probe and outside diameter of rotor cap, which must be 0.028-0.090 in. (0,711-2,286 mm). See Fig. IX-108.

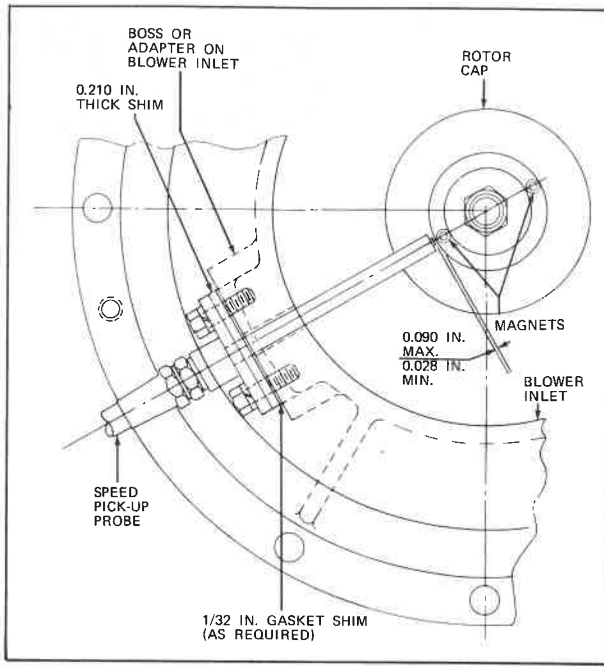


FIG. IX-108. AIR INLET VIEW OF TURBOCHARGER.

CAUTION: *If speed pick-up probe is not used, apply a suitable cover plate, Part 126X1545, over the probe hole. Otherwise, harmful dirt will be pulled into the turbo thru the probe hole and delivered into the engine.*

5. Clean the mounting surface of the forward-end cover and deburr the locating dowels, if required. Apply a light film of grease to the two dowels, and install two new O-rings around the water supply openings.

6. Using a suitable lifter and/or lifting sling, hoist and raise the turbocharger. Clean and deburr (if required) the four mounting feet. Position the turbocharger to align the two dowel holes in the rear feet with the locating dowels. Slightly rock the turbocharger while lowering it onto the forward-end cover.

CAUTION: *Exercise care while installing the turbocharger to avoid damaging the exhaust manifold.*

7. Using new lockwashers, assemble the four mounting bolts. Using mounting bolt wrench set, Part 147X1952, tighten bolts with a torque of 150-165 lb.-ft. (203-224 N·m).

NOTE: *When using mounting bolt wrench set, Part 147X1952, apply 93-103 lb.-ft. (126-140 N·m) of torque (as indicated on the torque wrench) to achieve the 150-165 lb.-ft. (203-224 N·m) of torque required on the mounting bolts.*

8. Wash and blow out all lube-oil piping, then refer to Fig. IX-107 and assemble them in the reverse order used at removal. Refer to Step 10 under "Removal" section.

> **CAUTION:** *The lube-oil supply pipe must have an orifice in the flange that is open and must be of the correct size to assure correct lube-oil pressure and flow to the turbocharger bearings. Orifice diameter must be per Table IX-V.*

TABLE IX-V, ORIFICE SIZES

Engine Type	Engine Max. Speed	Turbo Type	Orifice Diam. (in.)
FDL8	1000 or 1025	H584	0.200/0.196
FDL8	1050	H584, BC370 or 7S1408	0.157/0.155
FDL12	1025 or 1050	H581 or 7S1412	0.157/0.155
FDL16	1000 or 1025	H581	0.157/0.155
FDL16	1025 or 1050	BCO65 or 7S1616	0.352/0.348
FDL16	1050	BCO80 or 7S1616	0.352/0.348

9. Connect the seal air piping to the turbine casing (if turbo is supplied seal air from the locomotive air supply).

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10. If used, connect the CHEC-excitation speed pick-up probe at the terminal box.

11. Assemble the metal air duct to the compressor end of the turbocharger. Assemble the flexible duct and secure with two clamps, Fig. IX-106.

12. Assemble the two air-discharge elbows between the turbocharger and the intercoolers in the following manner:

   A. Inspect the elbows and flanges. Pay particular attention to the four lugs on each elbow. Make sure they are all present, square and the welds holding them to the elbow are not cracked. Replace or repair any elbows that have defective lugs or fewer than the required four. Check O-ring seats for wear. Don't use the elbow if those seats are worn appreciably. Leaks will result.

   B. Install the two studs in each intercooler, using lockwashers under the nuts. Torque the nuts to 55-60 lb.-ft. (75-81 N·m). Apply an extra nut and lockwasher on each stud. Run the nut up near to the stud-locking nut, with the lockwasher on the outside, ready to bear against the elbow lug.

   C. Screw two more studs into each of the turbo-end bolting flanges. Do not thread studs through the flanges. If this is done, it will be impossible to make a tight seal between flange and turbocharger. Use lockwashers under the nuts and torque to 55-60 lb.-ft. (75-81 N·m). Again, apply an extra nut and lockwasher on each stud, positioning them as was done on the intercoolers.

   D. Preassemble the two elbows and flanges, using new red O-rings, Part 115X1902. Do not use Part 115X1268 black O-ring ahead of the intercooler. It will not withstand the higher air temperature. Before applying the O-rings, lubricate with Lubriplate Spray Lube "A," Part 147X1614. This reduces the probability of O-ring damage during installation.

   E. Slide the turbo-end flange (with O-rings) onto the elbow. Take care not to disturb the O-ring in the flange groove. Make certain the studs enter the holes in the lugs. Loosely apply lockwashers and nuts to the outer end of the studs.

   F. Apply the elbow, with preassembled flanges and O-rings, to the engine. The shorter end goes into the turbo; the longer one into the intercooler. Position elbow so each end enters its hole squarely.

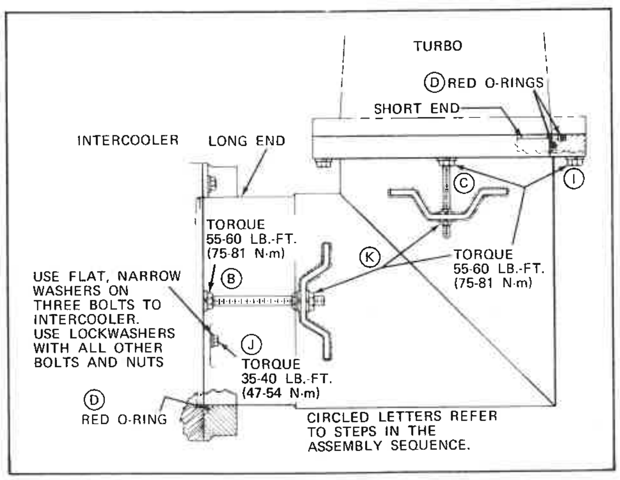

FIG. IX-109, E-23340A

FIG. IX-109. TOP VIEW OF RIGHT-HAND TURBO AIR ELBOW INSTALLATION. CIRCLED LETTERS REFER TO STEPS IN THE ASSEMBLY SEQUENCE.

G. Finger-tighten the four bolts (with lockwashers) attaching the turbo-end flange.

H. Then slide the flange and O-ring into position against the intercooler. Install and finger-tighten the three bolts with flat, narrow washers in that flange.

I. Again, check to make certain the elbow is squarely positioned and all four studs are through their respective lugs. Then, tighten the four bolts on the turbo-end flange evenly, in a criss-cross pattern, to 55-60 lb.-ft. (75-81 N·m).

J. Torque the three bolts on the intercooler flange evenly to 35-40 lb.-ft. (47-54 N·m).

K. Run the inside nuts and lockwashers on the studs up against the lugs until they touch plus 1-1/2 to 2 turns. Then, torque the outside nuts to 55-60 lb.-ft. (75-81 N·m). Use two wrenches simultaneously, if necessary, to keep the studs from turning. Do not bend or distort the lugs during this operation.

13. Connect the exhaust manifold to the turbine inlet assembly as follows:

a. For multi-pipe manifold, Fig. IX-104:

(1) Using high-temperature anti-seize thread compound, Part 147X1640, coat both sides of four new gaskets.

(2) Make sure all manifold to turbocharger bolt threads are clean. If necessary, wire-brush all bolt threads and retap all threaded holes. Apply high-temperature anti-seize thread compound to all threads of bolts and tapped holes and to the washer face of bolt heads.

(3) With gaskets in place, assemble all bolts and hardened washers finger-tight. Center each exhaust manifold flange at the turbocharger between the two securing bolts and the two prick-punch marks on the face of the turbine-inlet flange. Alternately tighten each bolt in increments up to the final torque of 120-130 lb.-ft. (163-176 N·m).

(4) Check the fit of the manifold to the turbocharger. The assembled manifold flange must be square with the face of the turbocharger within 0.020 in. (0,5 mm). For example, if the manifold flange touches the face of the turbocharger at one point, a 0.020-in. (0,5-mm) feeler gage shall not enter the joint face anywhere around the circumference.

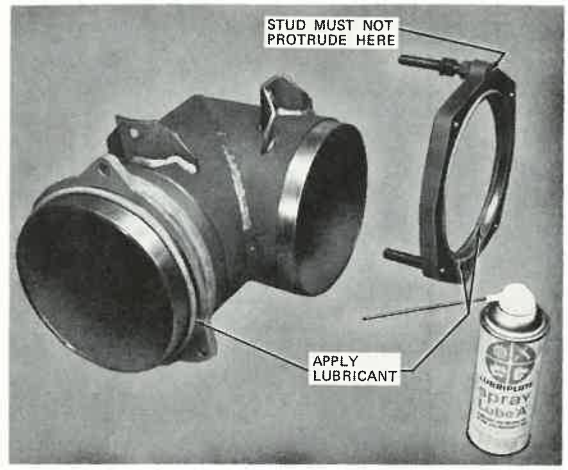

FIG. IX-110. ELBOW PARTIALLY PREASSEMBLED.

b. For single-pipe manifold, Fig. IX-105:

(1) Assemble the four lower bolts and washers which secure the turbine inlet flange to the turbine casing. Torque bolts to 120-130 lb.-ft. (163-176 N·m). Lockwire bolt pairs.

(2) Make sure all manifold turbocharger bolt threads are clean. If necessary, wire-brush all bolt threads and retap all threaded holes. Apply high-temperature anti-seize thread compound, Part 147X1640, to all threads of bolts and tapped holes and to the washer face of bolt heads.

(3) With a new gasket installed in the groove in the turbine inlet flange, assemble the lower clamp ring half and secure with bolts and new lockwashers finger-tight. The joint line of the clamp ring should be near horizontal.

(4) Assemble the top clamp ring half and secure with bolts and new lockwashers. After equalizing the gaps at the joint line, alternately tighten all bolts up to the final torque of 70-75 lb.-ft. (95-102 N·m).

14. Using new gaskets, assemble the two compression couplings to the water discharge header, Fig. IX-105.

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15. Assemble the intercooler support bar, Fig. IX-105.

16. Install the stack and secure with bolts and lockwashers. Torque bolts to 55-60 lb.-ft. (75-81 N·m).

17. Connect the crankcase breather pipe to the crankcase breather and to the stack. Assemble and connect the four aspirator hoses, Fig. IX-106.

18. Reassemble the hatch over the turbocharger.

19. Fill the cooling-water system with properly treated water.

Operational Checks

After the turbocharger work has been performed and the engine is running, listen near the turbocharger and near the exhaust stack for unusual noises, such as parts rubbing.

If possible, load the engine and observe that turbocharger is performing its function. This will be evident by an indication of pressure on the turbocharger air pressure gage.

Check the installed turbocharger for water, oil, air and exhaust leaks and correct if found.

TRANSPORTATION SYSTEMS BUSINESS DIVISION

ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

ENGINE SUPPORT SYSTEMS

CONTENTS

INTRODUCTION

This section covers the various engine support systems on-board the locomotive. The intent of this section is to provide an understanding of how individual items of equipment contribute to the functioning of each pertinent system. This will aid maintenance personnel in diagnosing malfunctions and determining the correct procedure to be followed to resolve problems. It also is intended to be used in conjunction with the Section IX Diesel Engine instructions to diagnose problems when they occur.

It should be noted that variations in the systems will exist between different models of locomotives and between railroad customers. Also, because of the complexity of the systems, liberties have been taken in the method of presentation. Some engine support systems are presented as diagrams and some as line drawings. In all cases, the diagrams and drawings are intended for the general guidance of personnel.

FUEL-OIL SYSTEM

DESCRIPTION

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

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

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

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

X

GENERAL ELECTRIC

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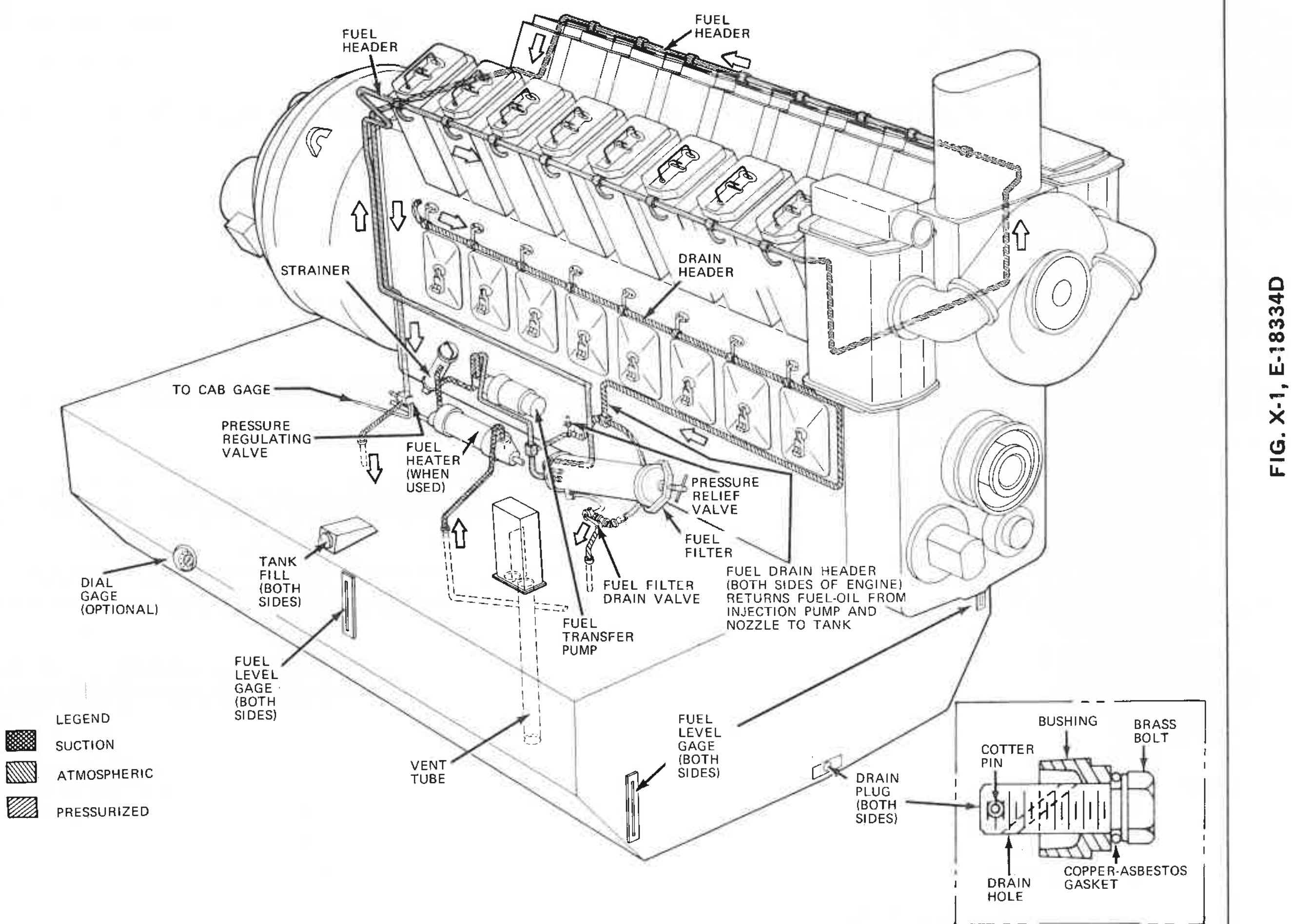

FIG. X-1. DIESEL ENGINE FUEL-OIL SYSTEM (TYPICAL).

X

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

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

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

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

FUEL TANK

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

ELECTRIC EMERGENCY FUEL CUT-OFF SYSTEM

The electrically-operated, emergency fuel cut-off system is arranged with three emergency trip switches; one located on the right side just forward of No. 1 lifting lug; one on the left side just above the No. 1 end of the fuel tank; and one in the operator's cab. Momentarily depressing any one of these switches will cause the fuel-booster pump to stop, thus stopping the flow of fuel to the engine. At the same time, a signal to the governor stops the engine. Once tripped, the system is restored to normal by depressing a "reset" button in the operator's cab; or upon starting the engine, the system is reset automatically.

FILLING AND DRAINING

Fuel Oil

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

Filling

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

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

Draining

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

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

LUBRICATING-OIL SYSTEM

DESCRIPTION

The diesel-engine lubricating-oil system, Fig. X-2, provides pressure lubrication to bearings within the engine and carries away heat produced by friction and combustion.

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

This system is use-d to prevent unfiltered oil and the harmful foreign materials it might contain from contaminating the engine and its components. A low oil

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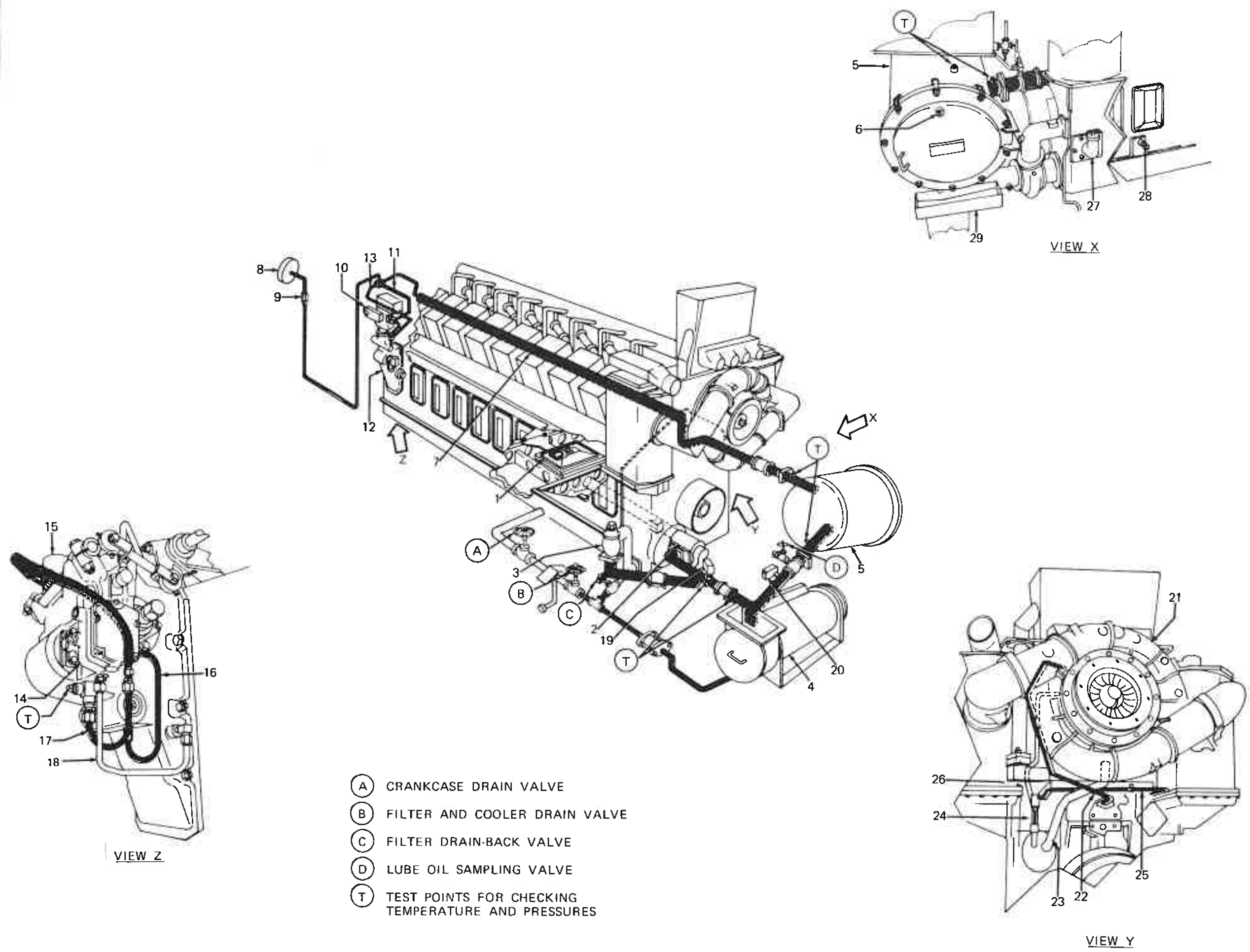

REF.	DESCRIPTION
1	CRANKCASE SUCTION STRAINER
2	MAIN LUBE OIL PUMP
3	RELIEF VALVE
4	COOLER
5	FILTER
6	FILTER VENT
7	CAST-IN HEADER
8	CAB PRESSURE GAGE
9	GAGE SNUBBER
10	CONTROL GOVERNOR
11	OIL LINE TO CONTROL GOVERNOR
12	GOVERNOR DRIVE ASSEMBLY
13	OIL LINE TO GOVERNOR DRIVE
14	OVERSPEED GOVERNOR
15	OVERSPEED-DERATER LINK
16	OIL SUPPLY LINE TO OVERSPEED GOVERNOR
17	OIL LINE – GOVERNOR TO LINK
18	OIL DRAIN LINE – OVERSPEED GOVERNOR TO CRANKCASE
19	LUBE OIL TEMPERATURE SWITCH (LOTS)
20	HOT OIL TEMPERATURE SWITCH (HOTS)
21	TURBOCHARGER
22	OIL SUPPLY LINE TO TURBOCHARGER
23	GRAVITY OIL DISCHARGE PIPE FROM TURBOCHARGER
24	SUCTION (EJECTOR) PUMP (IF USED)
25	OIL LINE FROM HEADER (IF USED)
26	SUCTION OIL DISCHARGE PIPE (IF USED)
27	OIL FILL ASSEMBLY
28	OIL LEVEL DIPSTICK
29	FILTER DRIP PAN

FIG. X-2. LUBRICATING-OIL SYSTEM.

FIG. X-2, E-24367

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pressure device is provided in the control governor. This device samples the existing oil pressure, and should the pressure drop to a sub-normal value, it will cause the engine speed and load to go to a reduced value. If the pressure drops to a dangerously low value (approximately 4 psi), the device will cause engine shutdown.

The lubricating-oil system consists of the following components in their order of oil flow, Fig. X-2:

1. Engine crankcase
2. Pump
3. Relief valve
4. Cooler
5. Filter
6. Engine supply system.

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

OIL FLOW OUTSIDE THE ENGINE

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

OIL FLOW INSIDE THE ENGINE

The main engine supply header and branch passages within the main frame conduct oil to all main bearings and to four of the camshaft bearings. Oil enters the crankshaft from the main bearings and flows through angularly-drilled passages in the shaft to the crankpin bearings.

The oil passes from the crankpin up through both connecting rods to lubricate the piston pins. The oil then passes to the piston crowns. It is shaken-around in the chamber under the piston crown thereby cooling the whole piston head, and then flows out through drain holes back to the crankcase.

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

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

The oil then flows upward through the valve push rods to supply lubrication to the valve operating parts at the top of the cylinder. Oil return is through the valve push rod cavities to lubricate the cams and cam rollers, and then to the crankcase.

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

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

Lubricating oil is piped to the governor drive assembly through a pipe that is flange-connected to the engine oil header at the generator end. The oil from the governor drive returns to the crankcase internally.

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

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

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

LUBRICATING-OIL PRESSURE

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

The low lube-oil pressure device will stop the engine and turn on a yellow indicating light in the operator's cab if a condition of insufficient oil pressure exists.

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

FILLING, DRAINING AND CHANGING OIL

Filling

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

1. Check that drain Valves A, B and C are closed, Fig. X-2.
2. Fill the crankcase, through the oil fill pipe or through a crankcase inspection opening, with the correct quantity of new lubricating oil. The oil must conform to the required specifications. Fill the crankcase to the FULL level mark on the dipstick.
3. With the engine idling, the oil level must be between the FULL and LOW marks on the dipstick.

Regardless of time or mileage, the lube oil should be changed whenever contamination with water or fuel oil reaches or closely approaches the condemning limits given in the lubrication and servicing instructions. It should also be changed when it is contaminated with fine metal particles. Such contamination can result from scoring of pistons, piston rings, liners, crossheads or guides; failure of gears or bearings; and any other similarly worn or failing parts.

Draining

The lubricating-oil system is drained by the use of three valves which are identified as Valve A, Valve B and Valve C, Fig. X-2. The following list identifies the valve, or combinations of valves, which must be opened to drain the various portions of the system.

1. Valve A (the crankcase drain valve) is opened to drain the main oil supply from the engine crankcase.
2. Valve B (the end-cover drain valve) drains the oil filter and oil cooler overboard.
3. Valve C (the filter drain-back valve) drains the oil filter and oil cooler back to the crankcase.
4. With Valves B and C both open, the oil filter, oil cooler and front end drain overboard.

Changing Oil

1. With the engine stopped, remove the pipe cap from the drain pipe. The pipe extends below the platform over the fuel tank on the right side of the engine.
2. Arrange barrels or a drain-hose system to catch the used oil.
3. Open the crankcase drain Valve A, end cover drain Valve B, and filter drain-back Valve C.
4. Remove the vent plug on the filter cover.
5. When the old oil is completely drained, close Valves A, B and C. Replace the vent plug in the filter cover and reapply the cap to the drain pipe.

COOLING WATER SYSTEM

DESCRIPTION

The locomotive cooling water system, Figs. X-3 and X-4, maintains an essentially constant engine operating temperature throughout its load range and with wide variations in ambient temperature. Fig. X-3 shows a simplified version of Fig. X-4.

Considerable heat is generated as a result of fuel combustion in the diesel engine, friction caused by moving parts in the engine and air compressor, compression of the intake air by the turbocharger and compression of air by the air compressor. Unless this heat is removed at the same rate it is generated, the heat would soon destroy gaskets, seals, hoses, etc. and would ultimately destroy the engine and air compressor.

Most of the generated heat is transferred from the metal masses directly to the coolant; about 20 percent of the engine heat is transferred first to the lube oil and then, thru the lube-oil cooler, to the coolant. Heat then is transferred from the coolant to the atmosphere thru the radiator sections. When equipped, the warm coolant heats the fuel oil thru a fuel-oil heater.

A pressurized, dry-radiator type system is employed. The rate of transfer of heat from the coolant to the atmosphere is dependent on atmospheric temperature and pressure, and the heat rejection from the engine is controlled by a fluid-amplifier flow-control valve in the system.

The principal components in the system are:

1. Water storage tank
2. Lube-oil cooler
3. Water pump
4. Water inlet headers
5. Water outlet header
6. Cylinders
7. Intercoolers
8. Turbocharger
9. Fluid-amplifier flow-control valve
10. Radiator sections
11. Air compressor
12. Fuel-oil heater (optional)
13. Valves, switches and interconnecting piping.

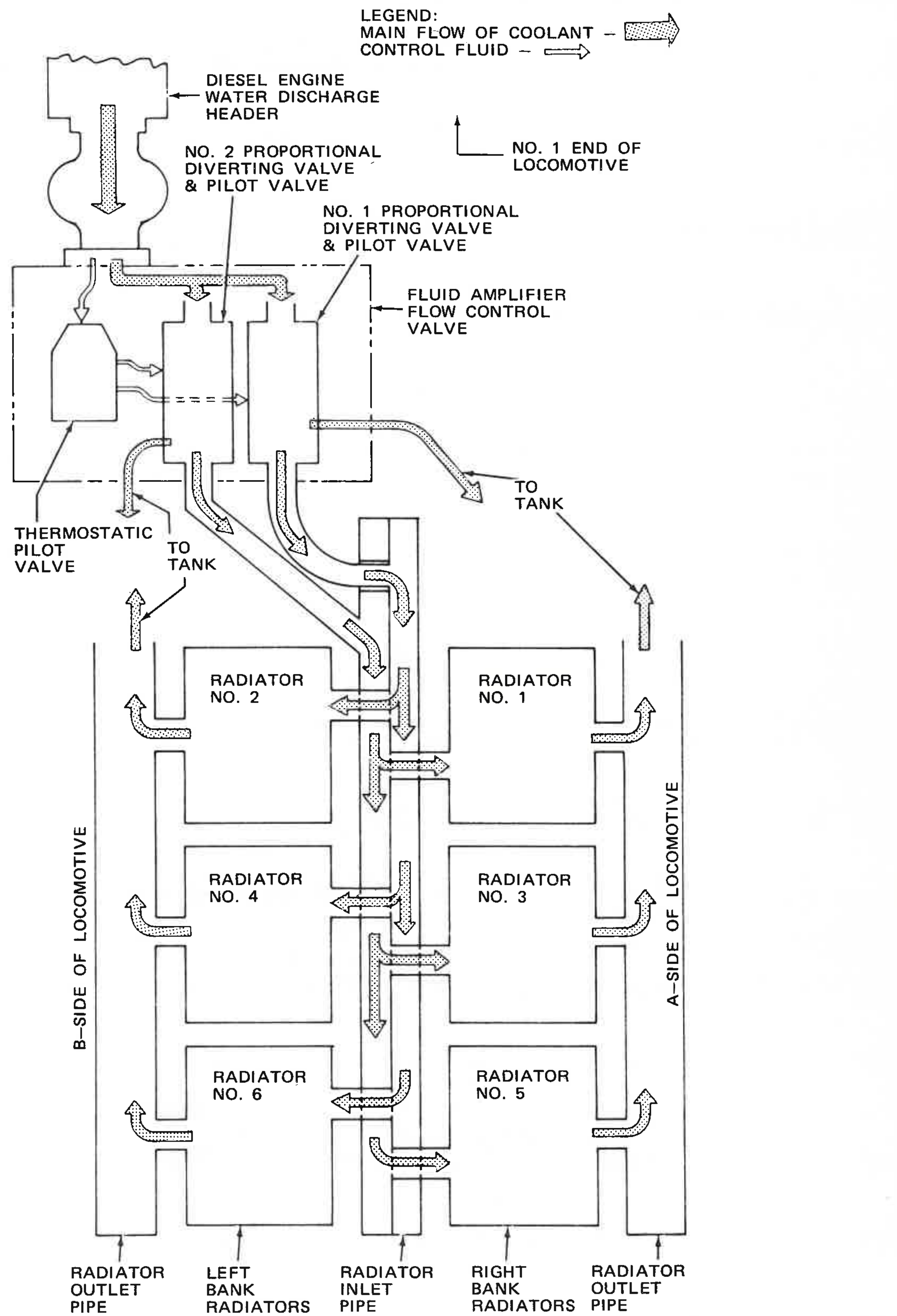

FIG. X-3. WATER FLOW, DIAGRAMMATIC VIEW.

FIG. X-3, E-19651

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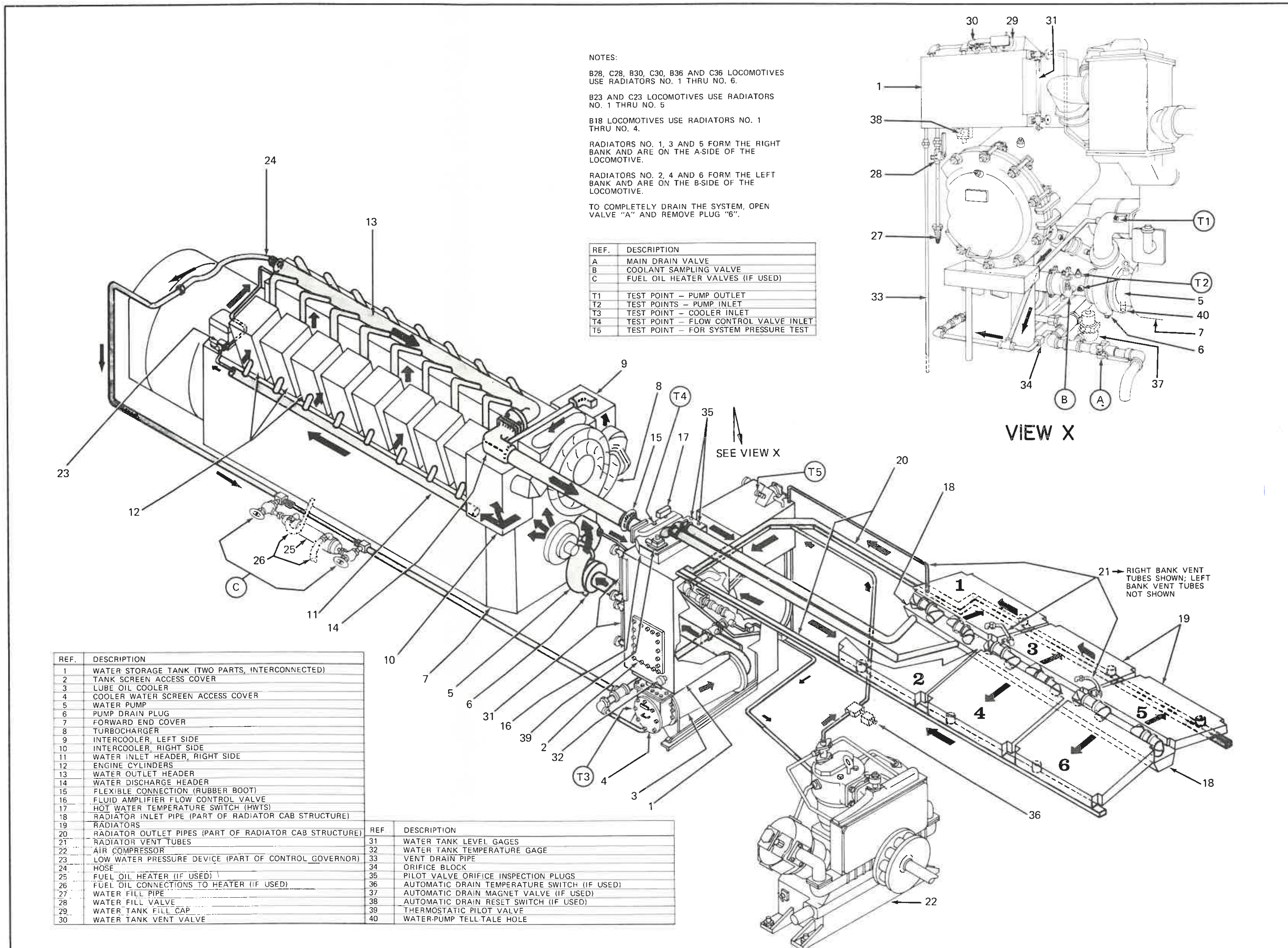

NOTES:

B28, C28, B30, C30, B36 AND C36 LOCOMOTIVES USE RADIATORS NO. 1 THRU NO. 6.

B23 AND C23 LOCOMOTIVES USE RADIATORS NO. 1 THRU NO. 5

B18 LOCOMOTIVES USE RADIATORS NO. 1 THRU NO. 4.

RADIATORS NO. 1, 3 AND 5 FORM THE RIGHT BANK AND ARE ON THE A-SIDE OF THE LOCOMOTIVE.

RADIATORS NO. 2, 4 AND 6 FORM THE LEFT BANK AND ARE ON THE B-SIDE OF THE LOCOMOTIVE.

TO COMPLETELY DRAIN THE SYSTEM, OPEN VALVE "A" AND REMOVE PLUG "6".

REF.	DESCRIPTION
A	MAIN DRAIN VALVE
B	COOLANT SAMPLING VALVE
C	FUEL OIL HEATER VALVES (IF USED)
T1	TEST POINT – PUMP OUTLET
T2	TEST POINTS – PUMP INLET
T3	TEST POINT – COOLER INLET
T4	TEST POINT – FLOW CONTROL VALVE INLET
T5	TEST POINT – FOR SYSTEM PRESSURE TEST

REF.	DESCRIPTION
1	WATER STORAGE TANK (TWO PARTS, INTERCONNECTED)
2	TANK SCREEN ACCESS COVER
3	LUBE OIL COOLER
4	COOLER WATER SCREEN ACCESS COVER
5	WATER PUMP
6	PUMP DRAIN PLUG
7	FORWARD END COVER
8	TURBOCHARGER
9	INTERCOOLER, LEFT SIDE
10	INTERCOOLER, RIGHT SIDE
11	WATER INLET HEADER, RIGHT SIDE
12	ENGINE CYLINDERS
13	WATER OUTLET HEADER
14	WATER DISCHARGE HEADER
15	FLEXIBLE CONNECTION (RUBBER BOOT)
16	FLUID AMPLIFIER FLOW CONTROL VALVE
17	HOT WATER TEMPERATURE SWITCH (HWTS)
18	RADIATOR INLET PIPE (PART OF RADIATOR CAB STRUCTURE)
19	RADIATORS
20	RADIATOR OUTLET PIPES (PART OF RADIATOR CAB STRUCTURE)
21	RADIATOR VENT TUBES
22	AIR COMPRESSOR
23	LOW WATER PRESSURE DEVICE (PART OF CONTROL GOVERNOR)
24	HOSE
25	FUEL OIL HEATER (IF USED)
26	FUEL OIL CONNECTIONS TO HEATER (IF USED)
27	WATER FILL PIPE
28	WATER FILL VALVE
29	WATER TANK FILL CAP
30	WATER TANK VENT VALVE

REF	DESCRIPTION
31	WATER TANK LEVEL GAGES
32	WATER TANK TEMPERATURE GAGE
33	VENT DRAIN PIPE
34	ORIFICE BLOCK
35	PILOT VALVE ORIFICE INSPECTION PLUGS
36	AUTOMATIC DRAIN TEMPERATURE SWITCH (IF USED)
37	AUTOMATIC DRAIN MAGNET VALVE (IF USED)
38	AUTOMATIC DRAIN RESET SWITCH (IF USED)
39	THERMOSTATIC PILOT VALVE
40	WATER-PUMP TELL-TALE HOLE

FIG. X-4. COOLING WATER SYSTEM.

FIG. X-4, E-24366

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SYSTEM OPERATION

The cooling water system is a pressurized, dry-radiator type system. The system, when in operation, must be tight and free of all leakage so pressure can be maintained. The dry-radiator system is one having no coolant in the radiator sections when the engine is shut down and when the coolant temperature is in the lower range of operation; when the coolant temperature goes into the medium and higher ranges of operation, coolant is diverted into the radiator sections for cool-down. This feature is mandatory when the ambient temperature is subfreezing, since the radiator sections are outside the zone of heat generated by the diesel engine.

Water leaving the storage tank is drawn downward through vertical tubes in the lubricating-oil cooler and is then piped to the suction side of the engine-driven centrifugal water pump.

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

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

Each cylinder contains a liner whose outer surface is machined to form two annular water bands. Water from the water inlet headers, coming through the jacket wall, is distributed around the liner by the lower waterband. It then passes through the 1/8-in. annular space, formed by the distribution dam on the outside diameter of the liner and the inside diameter of the jacket, into the upper water band. From the upper water band, it continues into the head through a large number of holes drilled in the upper liner wall.

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

The turbocharger, located at the forward-end of the engine, receives its cooling water through two openings in the top surface of the forward-end cover. These openings are aligned with openings in the base of the turbocharger bracket, or with the turbocharger feet directly. Mating connections are sealed by O-rings.

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

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

The fluid-amplifier flow-control valve regulates the temperature of the system by routing the water flow from the engine as follows:

1. Directly to the water storage tank – when minimum engine cooling is required
2. To the left-bank radiator sections – when partial cooling is required
3. To all radiator sections – when full engine cooling is required.

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

FLUID AMPLIFIER

The hot coolant leaves the diesel engine, Fig. X-3, and enters the inlet port of the fluid-amplifier flow-control valve. Inside the valve housing the coolant divides into three paths; a small quantity called the control fluid passes into the thermostatic pilot valve; the main flow of coolant divides into two parallel systems.

A small portion of the coolant (the control fluid) is sensed by a thermostat in the thermostatic pilot valve. The thermostatic pilot valve controls the flow of the control fluid, which in turn, thru transverse jets and fluidic action, diverts the main flow of coolant to the tank and/or radiators. The control of the large, main flow of coolant by a small, control flow, or the amplification of the small, control flow, gives the term "fluid amplifier."

The paths of the two parallel flow systems, depending on the coolant temperature and the thermostatic pilot valve are:

1. Thru the inboard (No. 1) proportional diverting valve and pilot valve, then to the tank and/or left-bank radiators.

2. Thru the outboard (No. 2) proportional diverting valve and pilot valve, then to the tank and/or right-bank radiators.

FILLING AND DRAINING

Filling

Detailed instructions for filling the water tank are mounted on the water tank.

Draining

To completely drain the system, open Valve A and remove pump drain plug, Fig. X-4 (Item 6).

EQUIPMENT AND ENGINE AIR SYSTEMS

EQUIPMENT AIR SYSTEM

Air, Fig. X-5, enters the equipment blower compartment (forward of the engine compartment on six-axle locomotives) thru V-screens on both sides of the locomotive. The blower forces this air into the main air duct, which extends almost the full length of the locomotive and is formed by the two main sills, the top platform deck and bottom plates that join the bottom portions of the two main sills.

NOTE: *The four-axle locomotive has the blower in the rear of the locomotive.*

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Pressurized air flows both forward and to the rear of the blower inside the main air duct. This air flows thru plastic air cleaners located in the duct, then to the traction motors, alternator (or traction generator), auxiliary generators, control compartment, rectifier panel, operating cab and to extended range dynamic-braking compartment (if used).

The discharge air from the alternator pressurizes the engine cab, and thereby excludes outside dirty air from this area. Some of the pressurized engine cab air, escaping around the outside of the exhaust stack, helps to direct the exhaust gases up and away from the locomotive. The balance of the engine cab air passes thru the air-compressor drive shaft tunnel to the air-compressor intake filters.

Each air cleaner is comprised of 54 individual tubes. Each tube acts as a miniature, cyclonic dirt separator. Incoming air enters the vanes in the tubes, causing the air to swirl. Dirt particles, being heavy, go to the outside and eventually leave the far end of the outer tube. The cleaned air swirling in the central portion is discharged out of the cleaner. The bleed air carries the dirt out of the cleaner.

Openings at the bottom of each panel permit the separated dirt and bleed air to escape. It is continuously discharged from the locomotive through outlets beneath the underframe.

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

ENGINE AIR SYSTEM

The engine air-cleaner system is located between the engine cab and radiator cab. Ambient air enters the locomotive through a screened air inlet (which contains three plastic air cleaners) located just above the platform walkway on each side of the locomotive. The cleaned air is collected in the cleaned air plenum and is delivered up through the secondary paper air filters to the inlet of the turbocharger.

Dirty bleed air is discharged out of two holes on the end of each primary cleaner into an air duct. The bleed air then is discharged out the stack, utilizing an exhaust stack-aspirator. A check valve prevents engine exhaust gases from entering the cleaned-air system through the bleed-air duct.

Two safety or protective devices insure that an adequate supply of air is delivered to the engine for combustion. These devices are:

1. A service indicator, which indicates when the air cleaner system needs servicing.

2. A pressure switch that returns the engine to idle, actuates the trainline alarm, and illuminates the ENGINE AIR FILTER light on the engine control panel. This prevents diesel engine operation with plugged air filters.

FIG. X-5, E-15055B

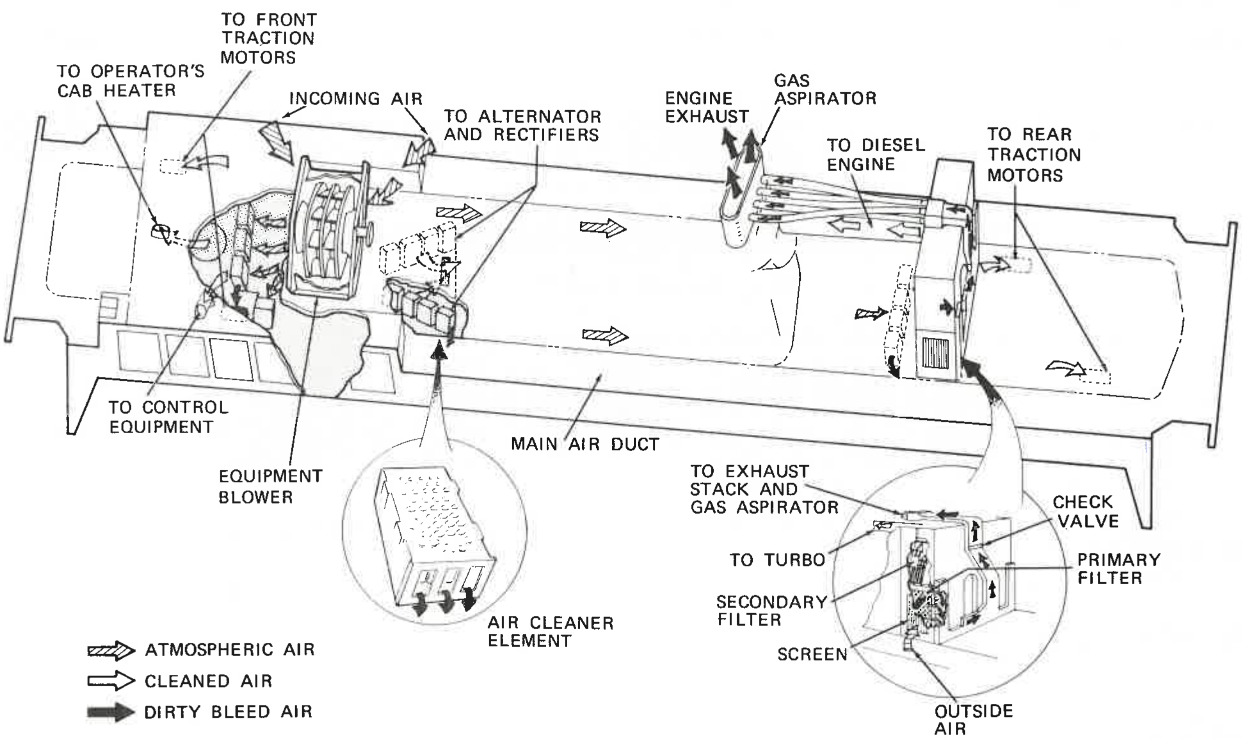

FIG. X-5. EQUIPMENT AND ENGINE AIR SYSTEMS (SIX-AXLE LOCOMOTIVE).

TRANSPORTATION SYSTEMS BUSINESS DIVISION

ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

LOAD TESTING

CONTENTS

INTRODUCTION

This section provides information on load testing the Series-7 diesel-electric locomotives. It is divided into two parts:

1. Self Loading on dynamic braking resistor grids
2. Connected to external loading unit, like 17EM99.

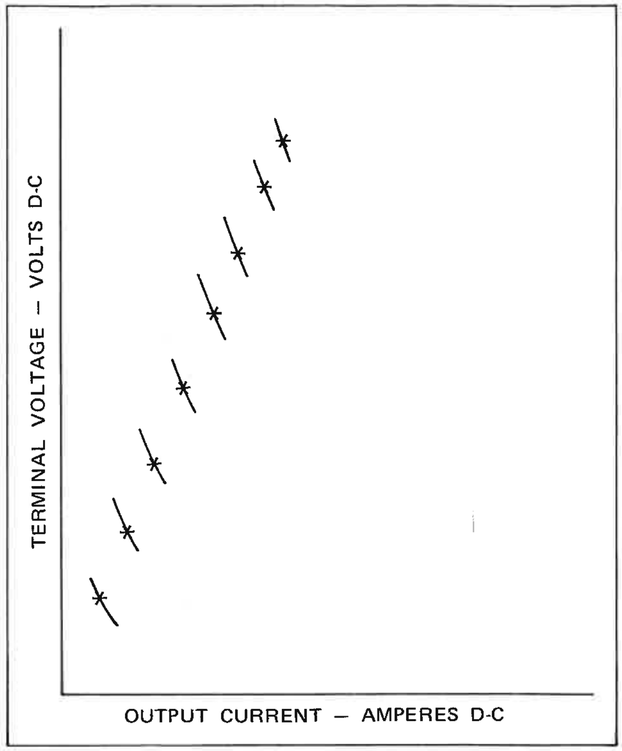

FIG. XI-1. NOTCH SPREAD ALONG SELF-LOADING RESISTANCE LINE.

Each of the loading methods has certain advantages as listed here for comparison.

Self Loading

1. This is a very quick way to check locomotive output (engine horsepower). Very little set-up time is required, and a 0-10 vdc meter is the only test equipment needed.

FIG. XI-1, E-25390

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GENERAL ELECTRIC

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2. An excellent means of testing nearly all of the systems on the locomotive. Although it is done at a single value of resistance, Fig. XI-1, it will give the output for each of the eight Throttle notch positions.
3. It can be accomplished almost anywhere on railroad property, but preferably not inside a building since this could overheat the sprinkler system and cause other problems. During summer the hot engine alarm may ring on the locomotive.
4. The engine itself will not be running at its correct operating point and may not put out normal horsepower due to action of the temperature derater in the overspeed link. Also it will not run at normal intake manifold and water jacket temperatures.
5. Horsepower measurements will not be as accurate as by the other method due to the use of portable meters. Current is seldom measured because of the time required to install a shunt.

External Loading Unit

1. Horsepower can be measured with great precision and high accuracy. Accuracies of 1 percent are not unusual since better meters are normally provided in loading units at permanent load box stations.
2. Operation can be continuous due to absence of the hot engine alarm system.
3. The engine is running under normal temperature conditions.
4. While on a loading unit, there is an opportunity to select several resistance values and thus test most of the excitation curve, Fig. XI-2.
5. During load testing, Power Matching can be set or checked.

SELF LOADING

DESCRIPTION

A diesel-electric locomotive with this feature can be isolated while in a multiple-unit consist and using its dynamic braking resistors for an electrical load, can have its own power output, engine speeds and excitation system checked in each of the eight throttle notches. This can be done without uncoupling the locomotive from the others, and in a very short period of time.

Results of the test will quickly determine if the locomotive is suitable for continued service, if repairable or if it should be shopped for a serious malfunction.

A locomotive is equipped with the self-loading feature if it has a Self-Load light on the Engine Control (EC) panel,

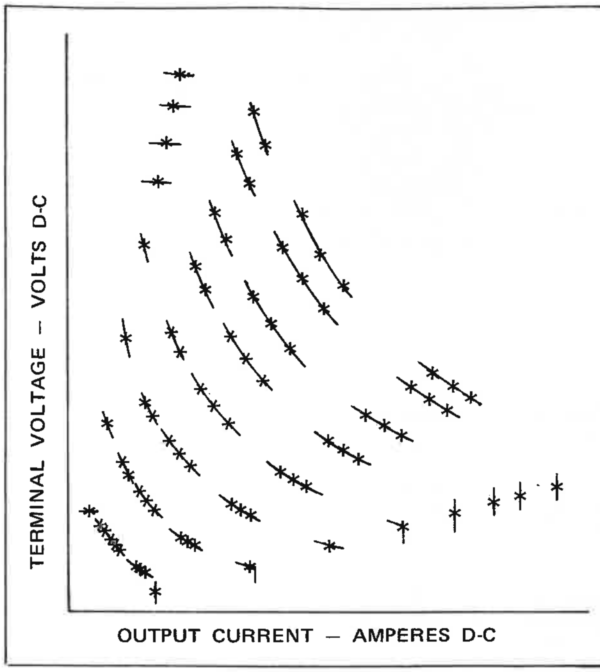

FIG. XI-2. NOTCH SPREAD ALONG TEN RESISTANCE LINES OF EM99 LOADING UNIT.

FIG. XI-2, E-25391

Fig. XI-3, and the Load Box Toggle Switch (LBTS) located at top left center of upper control compartment. The switch is mounted on an instruction plate, like Fig. XI-4, for the C30-7 model locomotive. Instructions plates for other models are the same except for values in Table XI-I.

CAUTION: *Prolonged testing with ambient temperatures above 65 F could damage equipment due to excessive heat.*

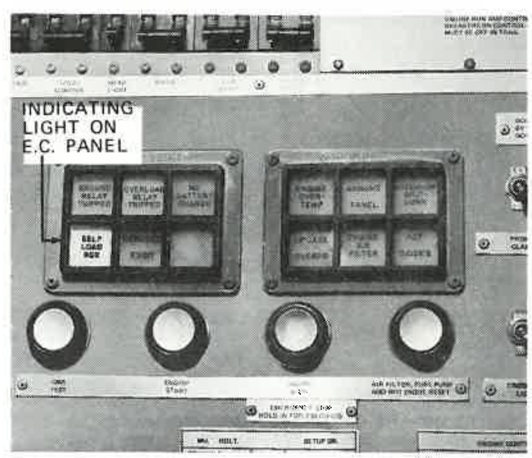

FIG. XI-3. LOCATION OF SELF-LOAD BOX LIGHT ON ENGINE CONTROL PANEL.

FIG. XI-3, E-25392

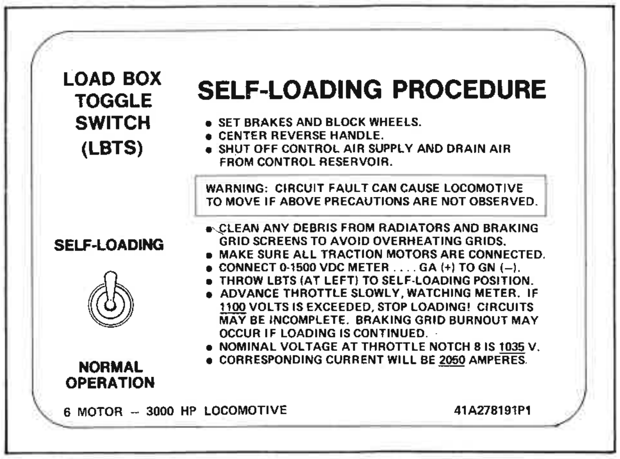

FIG. XI-4. TYPICAL SELF-LOADING TOGGLE SWITCH INSTRUCTION PLATE.

FIG. XI-4, E-25393

TABLE XI-I, INSTRUCTION PLATE VALUES

Model	First	Second	Third
B18-7	1100	980	1300
B23-7	1200	1110	1470
C23-7	1190	1110	1440
B28-7	1280	1225	1500
C28-7	1060	990	1950
B30-7	1320	1280	1660
C30-7	1100	1035	2050
B36-7	1300	1210	2120
C36-7	1240	1140	2260

TEST EQUIPMENT

One to three 0-10 vdc digital voltmeters.

PREPARATION FOR TEST

A locomotive to be self loaded is electrically isolated from the other locomotives if in a consist of multiple locomotives (MU). This is done by uncoupling the 27-point MU jumpers at each end of the locomotive under test. The air brakes must be properly set to prevent possible movement during the test. Individual locomotives should also have the wheels chocked or blocked.

To prevent application of power to the traction motor circuits, CLOSE air supply cock at control air NS-1 reducing valve and OPEN the control air reservoir drain cock (or insert insulation between main contacts of S and P contactors).

Since some of the motor fields are in the circuit during self loading, do not test with damaged traction motors, a traction motor cut-out or other defects in the power circuits.

Before starting test, check all radiator cab intake screens and underside of radiators to be sure they are clear and free of debris, to insure proper cooling.

The loadmeter on operator's console is bypassed during self loading, so an external ammeter with shunt may be desired. If so, connect the shunt in series with the ACCR reactor, keeping the ACCR in the circuit.

The air for cooling the braking grids also passes up through the radiators that cool the water. If the ambient temperature gets too high, the Hot Water alarm will ring after the heated air has raised the water temperature.

LOAD TESTING

On Series-7 locomotives with the CHEC excitation system, a quick verification of horsepower output can be made using one digital voltmeter with a 0-10 vdc range. Voltage from Test Point on MP card (FD735, fourth position from the left) multiplied by the 300 kw/v calibration and 1.41 conversion factor (1000/746X0.95) gives a good indication of locomotive output.

This can be verified using readings of current from the ACCR 600 A/V test point on the face of the FL card (FD738 Filter Card, seventh position from the left), on the FL138 panel, Fig. XI-5, to any COMMON test point and voltage from the VCR/BCCR, MOTOR 150 V/V, BRAKE 100 A/V to any COMMON test point. For ease of comparison, the output curves, Figs. XI-7 to XI-15, include scales for actual values and for the 0-10 v meter readings. These two readings, can be plotted on the output curve directly.

To convert the meter readings to actual values, multiply the indications by 600 and 150 respectively (the numbers printed beside the test points). These values can be plotted on the output curve using actual values for voltage and current.

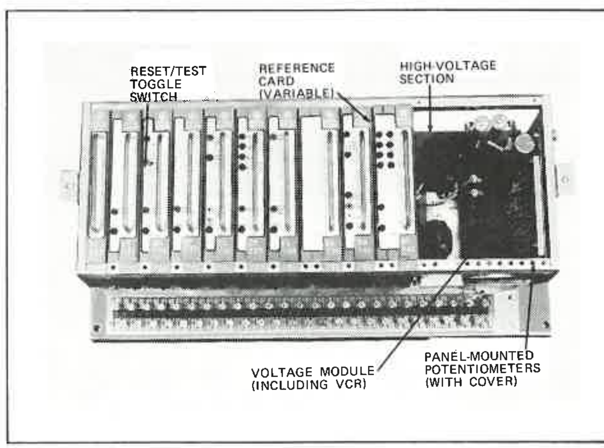

FIG. XI-5. FL138 CHEC EXCITATION PANEL WITH HIGH-VOLTAGE SECTION EXPOSED.

FIG. XI-5, E-20343

XI

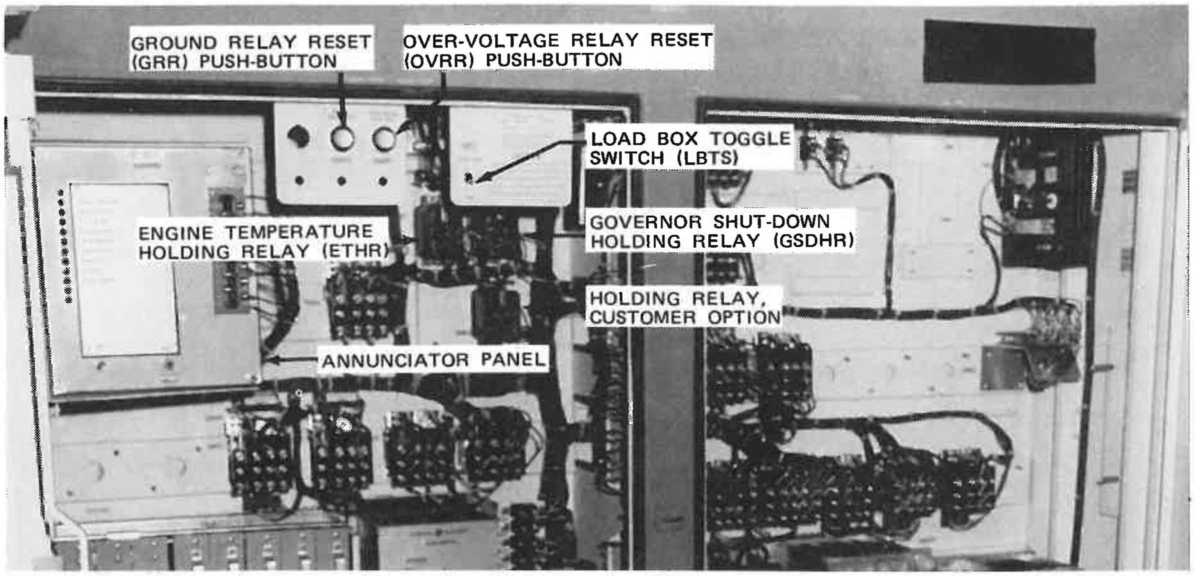

FIG. XI-6, E-25039

FIG. XI-6. LOCATION OF SELF-LOADING TOGGLE SWITCH (LBTS) AND INSTRUCTION PANEL.

With the Throttle handle in the OFF position and the Reverse handle in FORWARD, the engine idling (at operating temperature), snap the Load Box Toggle Switch (LBTS, located in the upper control compartment) to the SELF LOAD position, Fig. XI-6. The light on the EC panel should now light, Fig. XI-3.

The Throttle handle can then be moved to each of the eight notch positions. Engine speed for each notch is the same as for normal motoring. Output in each throttle position can be compared with the corresponding point on the curve to verify the locomotive output. This is done by plotting each of the meter readings taken for a particular throttle position on the appropriate curve for the model locomotive being tested, Figs. XI-7 thru XI-15.

NOTE: *If points do not plot along resistance line shown, refer to schematic diagram for locomotive being tested. Verify the combined resistance – it could be different than the one shown.*

TROUBLE-SHOOTING LOW OUTPUT LOCOMOTIVES

Further diagnosis of reasons for partial output can then be undertaken in Tables XI-II and XI-III.

RESTORING LOCOMOTIVE FOR SERVICE

1. Move Toggle switch LBTS to RUN position
2. Remove all test equipment and restore all circuits to normal which may have been modified for the test.

EXTERNAL LOADING

DESCRIPTION

A load test should be performed periodically to assure the locomotive power plant is producing rated horsepower, especially after a major overhaul of power plant or replacement of equipment.

This instruction is a guide for checking the output of a power plant using the EM99 Loading Unit. The load test may be applied to adjust the output of an overhauled engine or to determine the condition of an engine while in service on a locomotive. A tabulation of accumulated test data can aid in determining the effectiveness of overhaul work on a rebuilt engine and guide maintenance work to improve engine performance.

This instruction assumes an ungrounded resistor-blower type loading unit will be used. However, this does not prohibit the use of any other type loading device or unit, since the test preparations, connections and procedure will be similar.

XI

TABLE XI-II, E-25422

XI

TABLE XI-II, LOW HORSEPOWER OUTPUT – POSSIBLE CAUSES:

Item	Problem	Possible Cause	Correction
ELECTRICAL ITEMS			
1E	Low Control Voltage	Voltage regulator failure	Reset rheostat, replace or repair panel
2E	Low Voltage Power Supplies on CHEC Panel +15 and –15 vdc	Faulty FD740, "RG" Card	Replace or repair FD740 card
3E	Reduced Excitation Mode of Operation. LED ON on FD734 card	Any defect causing continuous turn on of FT card False Turbo Signal Wheelslip Signal	Correct fault, move switch to RESET position
		Defective FT card	Replace or repair FD733 card
4E	Low Excitation Operation	Inaccurate test meters	Reset with calibrated meters
		Traction motors cut-out	Reset switch
		High lube-oil temperature	Check oil cooler operation
		FD738 Filter card out of calibration	Replace card
		ORS Engine Governor Solenoid energized in error	Fix circuit
		Extraneous signal on H Terminal of CHEC Panel	Check Speed Event or Wheelslip Panel outputs. (Should be zero volts at standstill.)
		Bad CMR "ACCR" reactor	Replace reactor
5E	Low Alternator Output	Power Limit switch in NOTCH 7 Position (400-600 hp low in Notch 8 only).	Reset switch to NORMAL
		Running single phase	Check each phase voltage
		Filter card FD738 out of calibration for ACCR or VCR	Replace card, check ACCR or VCR
MECHANICAL ITEMS			
1M	Poor Combustion	Incorrect pump timing	Retime engine
		Incorrect valve tappet clearance	Readjust to proper clearances
		Air leaking from intake manifolds or elbows (turbo to intercooler)	Replace O-rings, bent or broken manifold sections
		Racks not set properly	Readjust all injection pump racks to same correct setting
		Carbon build-up in cylinder inlet ports	Remove air inlet manifolds and clean ports
		Fuel has low heating value	Submit sample for lab. test
		Faulty fuel injectors	Replace bad injectors
2M	Overspeed Derator Link Expanded	High ambient temperature	Clean intercoolers (air side and/or water side)
		High manifold temperature	Clean intercoolers (air side and/or water side)
		Low oil pressure	Faulty pump or regulator in Overspeed Governor
3M	Low Fuel-Oil Pressure	Plugged filter elements	Replace elements
		Plugged strainer	Clean strainer
		Regulator valve set low	Recalibrate valve
		Suction pipe admitting air	Tighten fittings or replace tubing, pipes or hoses
4M*	Engine Control Governor Modulating	Low lube-oil pressure	Correct cause of low pressure
		Low water pressure	Correct cause of low pressure
5M	Low Turbocharger Speed	Cold lube oil	Let system warm up
		Bearing problem	Replace turbocharger
		Carbon build-up	Replace turbocharger
6M	Engine Control Governor Malfunction	Air leak in tube to manifold	Replace or mend tube
		Air sensor malfunction	Replace governor
		Load control pilot valve unbalanced at 0.344 in. with air OK	Replace governor
		Binding fuel linkage	Clean, free up and lubricate

*When Provided

TABLE XI-III, EXHAUST SMOKE ANALYSIS

Item	Indication	Possible Cause	Correction
1	Black Smoke Puffs	One or more defective injectors	Recondition or change the defective injector.
		Fuel pump rack is stuck	Free the rack or change the pump.
		Fuel pump rack is set too high	Locate the high rack and readjust.
		Fuel pump rack is out of time	Adjust timing.
		Worn or damaged turbocharger	Repair or replace turbocharger.
		Broken or leaking manifold pipes	Repair or replace the manifold.
		Engine speed is bogging down	Check the engine operation and circuits for fault.
		Turbocharger surging	Inlet ports partially blocked or turbocharger misassembled (nozzle ring and diffuser). Clean cylinder inlet ports if dirty.
		Turbocharger rotor is stuck	Replace turbocharger.
2	White Smoke Puffs	Fuel pump is out of time	Adjust timing.
		Cylinder with valves burned or stuck open	Replace cylinder.
		Engine is too cold	Wait until engine warms up.
		Cylinder with low compression	Replace cylinder.
		Fuel system is air bound	Bleed the fuel system.
3	Blue Smoke and Oil Out the Stack	Failed turbocharger bearings and seals	Replace turbocharger.
		Worn or broken piston rings	Replace rings.
		Cracked piston crown	Replace piston and rings.
		Scored liner	Replace cylinder and rings.
		Prolonged operation at IDLE	Load engine and condition should clear up.
4	Steady Smoke	Worn or leaking injectors	Change injectors.
		Late pump timing on all cylinders	Time the injection pumps.
5	Water Out Stack	Cylinder seal leaks or cracked turbocharger	Locate and correct.
6	"Blow" in Exhaust System	Broken exhaust manifold section	Repair or replace manifold or manifold section.
		Valve tappet clearance is insufficient	Readjust valve tappets.
		Cylinder valve is stuck open	Replace cylinder.
		Cylinder valve seat is "guttered"	Replace cylinder.

TABLE XI-III, E-25423

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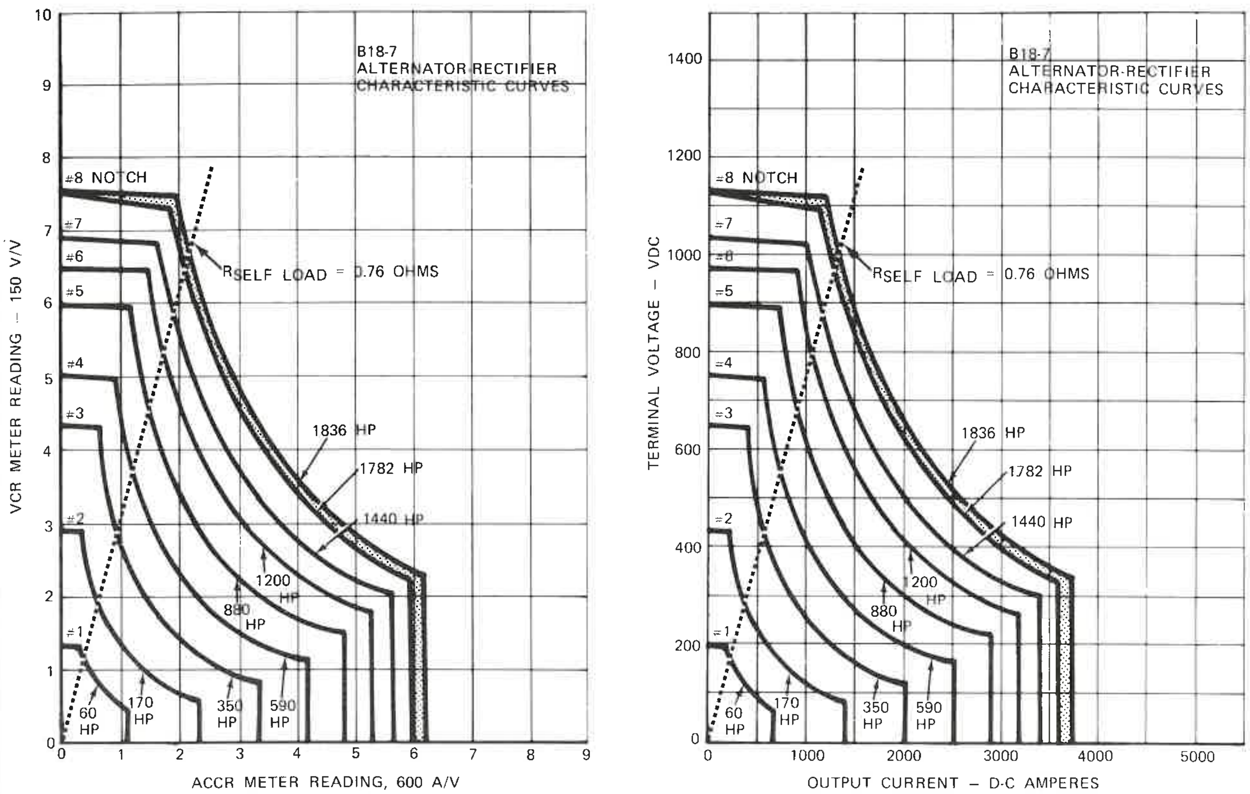
WARNING: *To protect against fatal injury from electrical shock, DO NOT proceed with load test until both the frame of the loading device and the locomotive are properly grounded.*

TEST EQUIPMENT AND SPECIAL TOOLS

	Part No.
Loading device with connecting cables and meters, recently calibrated to ± 1/4 percent accuracy; either a Loading Unit like an EM99 or a water box arrangement	5EM99D1
Ammeter with calibrated shunt (If meter on loading device not accurate)	0-6000 adc
Voltmeter (If meter on loading device not accurate)	0-1500 vdc
Voltmeter	0-150 vdc
Tachometer, 0-1500 rpm	2X2795
Overspeed Test Lever	147X2016

FIG. XI-7, E-25355



AVERAGE READINGS FOR SELF LOADING A B18-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.76 OHMS RESISTANCE.

	LEFT CURVE			RIGHT CURVE			
NOTCH	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	2.17	6.60	4.29	1300	990	1285	1815
7	1.93	5.87	3.40	1160	880	1020	1440
6	1.77	5.37	2.84	1060	805	855	1205
5	1.49	4.53	2.03	895	680	610	860
4	1.22	3.70	1.35	730	555	405	570
3	0.93	2.83	0.79	560	425	240	335
2	0.60	1.83	0.33	360	275	100	140
1	0.38	1.13	0.13	225	170	40	55

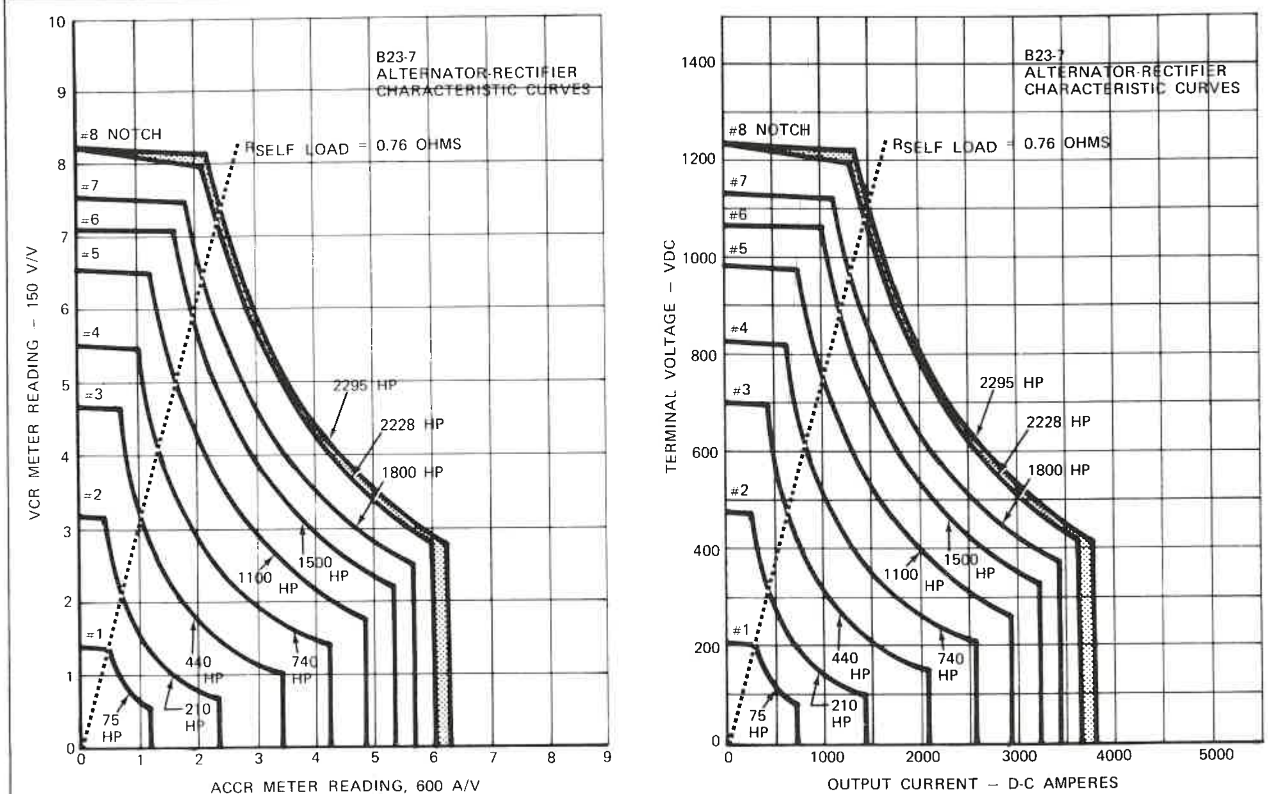
FIG. XI-7. SELF LOADING A B18-7.

XI

PREPARATIONS FOR TEST

1. Chock or block the wheels during test to prevent possible locomotive movement.
2. Disable the Power Matching feature during the load test (if locomotive is so equipped) by lifting wire from Terminal L and applying jumper between Terminals EXP-L and EXP-M on FL138 excitation panel.
3. If desired to unload air compressor for duration of test, jumper +75 vdc to coil of magnet valve. This keeps compressor from loading, which would cause extra load on the engine.
4. Load Test connections – refer to the locomotive Schematic and Connection Diagrams.

   a. Disconnect all the traction motor cables at the positive terminal at the power rectifier panels. Do not disconnect the small control wire, GA, since it is required to control the excitation system. Connect the positive cables of the loading device in place of the motor cables just removed,



AVERAGE READINGS FOR SELF LOADING A B23-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.76 OHMS RESISTANCE.

	LEFT CURVE			RIGHT CURVE			
NOTCH	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	2.52	7.37	5.57	1515	1105	1672	2360
7	2.13	6.50	4.17	1280	975	1250	1765
6	1.98	6.00	3.55	1185	900	1065	1505
5	1.66	5.03	2.50	995	755	750	1060
4	1.35	4.10	1.65	810	615	495	705
3	1.01	3.07	0.93	605	460	280	395
2	0.68	2.07	0.42	410	310	125	180
1	0.43	1.30	0.24	260	195	50	70

FIG. XI-8, E-25356

FIG. XI-8. SELF LOADING A B23-7.

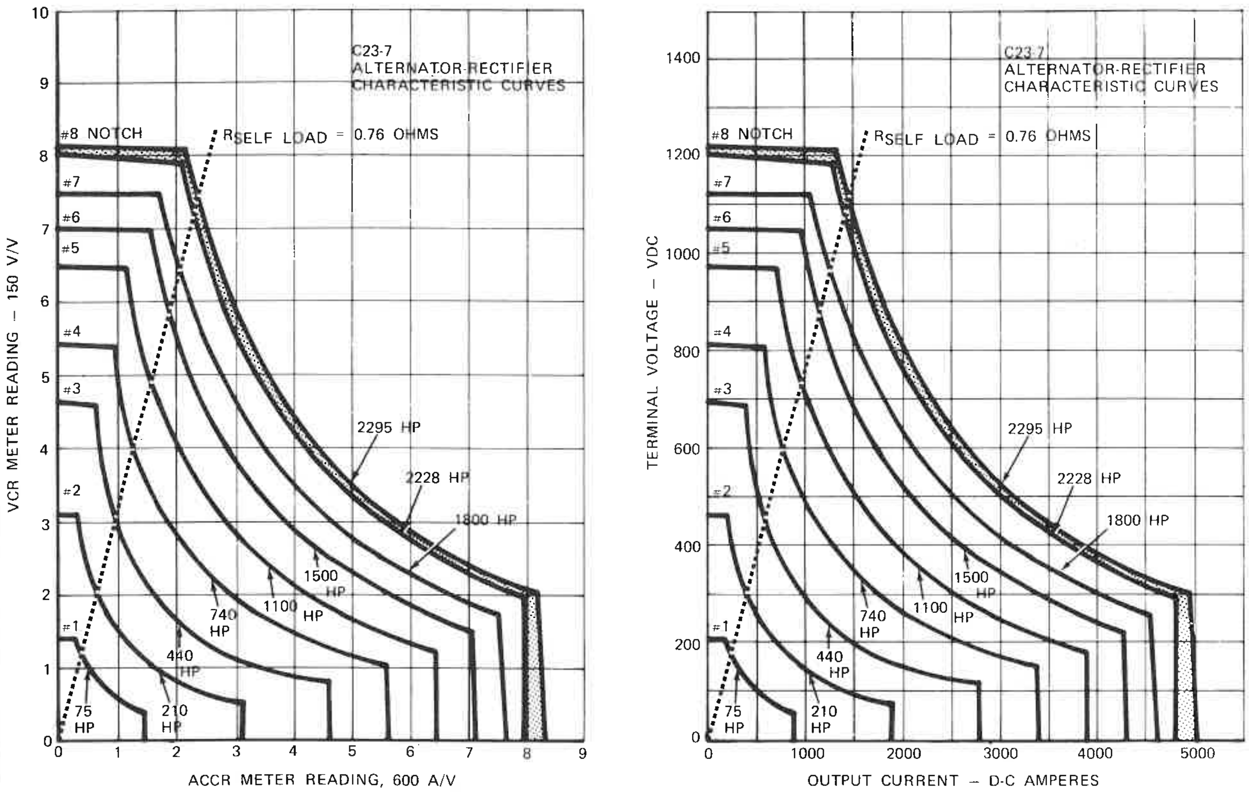
XI

Fig. XI-16. Assure the load test cables are of sufficient size to safely handle the maximum load current used in the test. Thoroughly insulate the cable lugs removed above so no contact can be made at anytime during the test.

NOTE: *When connecting cable or wire lugs, be sure the lugs have flat, clean mating surfaces and be sure the correct size and quantity of hardware is used to properly make the connection. Apply joint compound (T&B M-53, No. 21059 or GE 41A204944P1). This will prevent "hot spots" at the connections and prevent loss of power.*

b. Disconnect and insulate all the traction motor cables at the current reactor, ACCR in the lower compartment, Fig. XI-17. All load current must pass through ACCR during the test. Do not disconnect the small GN wire from the load test circuit. Connect the negative cables of the loading device to the negative end of the reactor, to assure the load current passes thru the reactor during the load test. Include a current-measuring shunt in the negative cables to the loading device if an accurate loadmeter is not built into the loading unit.

FIG. XI-9, E-25357



AVERAGE READINGS FOR SELF LOADING A C23-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.76 OHMS RESISTANCE.

	LEFT CURVE			RIGHT CURVE			
NOTCH	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	2.43	7.40	5.40	1460	1110	1620	2285
7	2.15	6.53	4.21	1290	980	1264	1785
6	1.97	6.00	3.56	1185	900	1065	1505
5	1.64	5.00	3.48	985	750	740	1045
4	1.36	4.13	1.68	815	620	505	715
3	1.03	3.13	0.97	620	470	290	410
2	0.68	2.06	0.59	410	310	125	180
1	0.44	1.33	0.18	265	200	55	75

FIG. XI-9. SELF LOADING A C23-7.

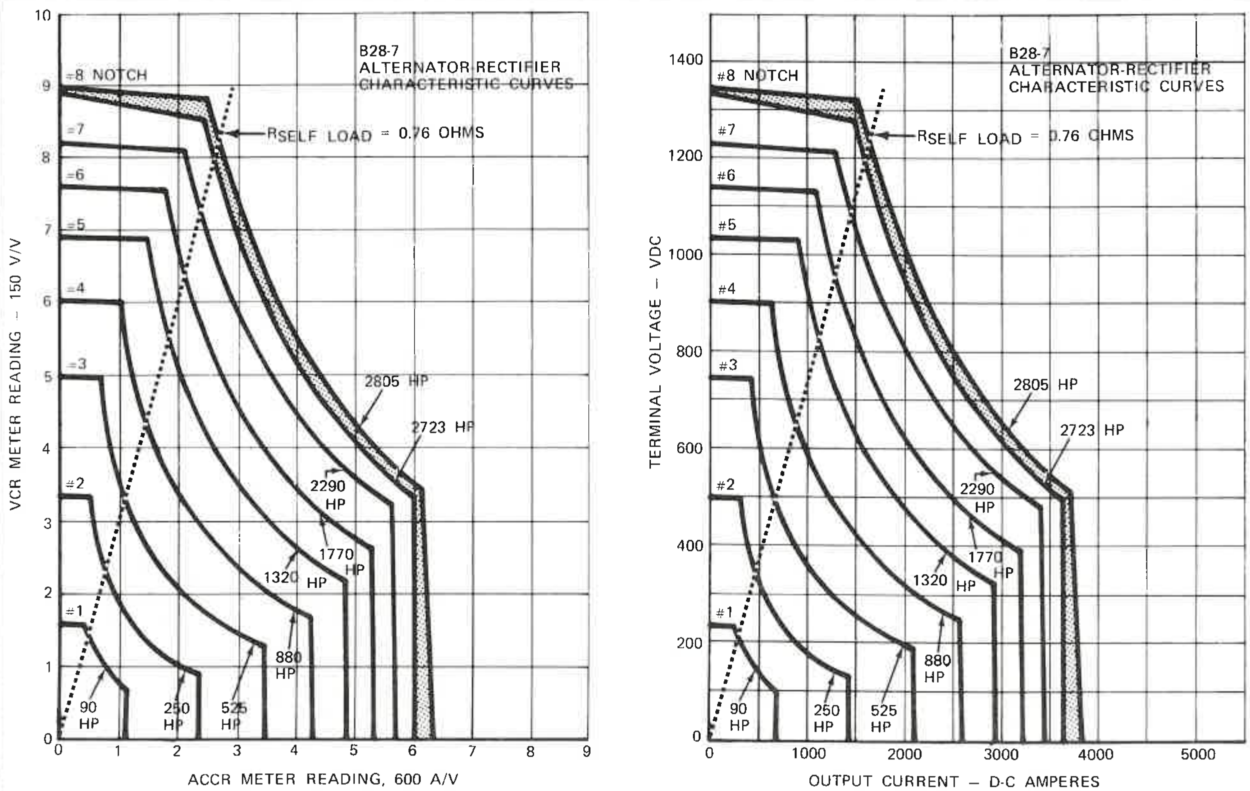
WARNING: *Proper precautions must be taken to protect personnel from possible contact with the high-voltage meter wiring. Suggest all meters be enclosed in a large box with clear plastic protective cover.*

c. If there is no accurate voltmeter in the loading device, connect a 0-1500 vdc voltmeter across the power rectifiers at Terminals GA to GN. It is important the cables to and from the loading device be of sufficient size and quantity to keep the voltage drop thru the cables at a minimum.

NOTE: *It is important that all meters used in load-testing be accurate and calibrated quarterly. The accuracy of the meter calibration will determine the precision of the horsepower calculation. Digital-type meters are recommended, due to their retention of calibration; however, do not apply them at voltages in excess of their rating, and always unplug them from wayside charging during usage.*

d. Connect a 0-150 vdc voltmeter at the Reverse Current Diode Panel, 17FM203, from cathode side to 4 wire (or N wire) of the battery-charging

XI



AVERAGE READINGS FOR SELF LOADING A B28-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.76 OHMS RESISTANCE.

NOTCH	LEFT CURVE			RIGHT CURVE			
	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	2.69	8.17	6.57	1610	1225	1970	2785
7	2.41	7.33	5.30	1445	1100	1590	2245
6	2.10	6.40	4.05	1265	960	1215	1715
5	1.83	5.57	3.06	1100	835	920	1295
4	1.42	4.33	1.85	855	650	555	785
3	1.10	3.33	1.10	660	500	330	465
2	0.77	2.33	0.54	460	350	161	225
1	0.47	1.43	0.20	285	215	60	85

FIG. XI-10, E-25358

FIG. XI-10. SELF LOADING A B28-7.

XI

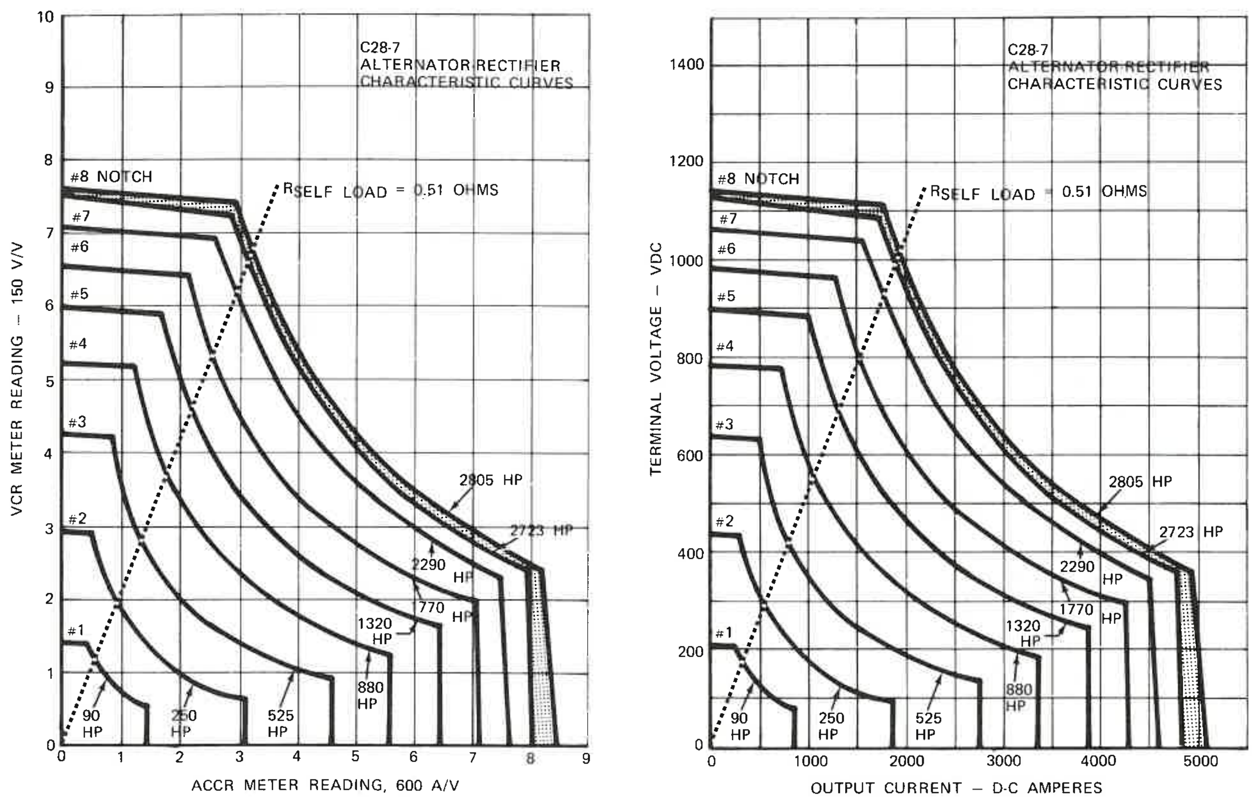
circuit. This meter will read charging volts. Do not attempt to read battery volts across the blades of the battery switch or across the voltage regulator.

e. Install a 0-1500 rpm tachometer-generator, Tool 2X2795, with matching digital meter, to the engine. Apply the tachometer-generator at the 1/2-in. pipe plug opening behind the overspeed governor, on the right side of the engine, Fig. XI-18.

NOTE: *A hand tachometer with extension can be used by applying it at the same location.*

f. Shut off air supply to NS-1 Control Air reducing valve. Drain control air reservoir to prevent any possible operation of contactors during the test or remove and insulate the battery power wire, EF, from the EC switch to the reverser and GR to GOLR interlock, to eliminate control power from all the power contactors.

5. If a corrected horsepower check is to be made, measure the fuel temperature in the fuel line to the engine (between the secondary fuel filter and the header). Read the ambient air temperature and barometric pressure just before and after horsepower



AVERAGE READINGS FOR SELF LOADING A C28-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.51 OHMS RESISTANCE.

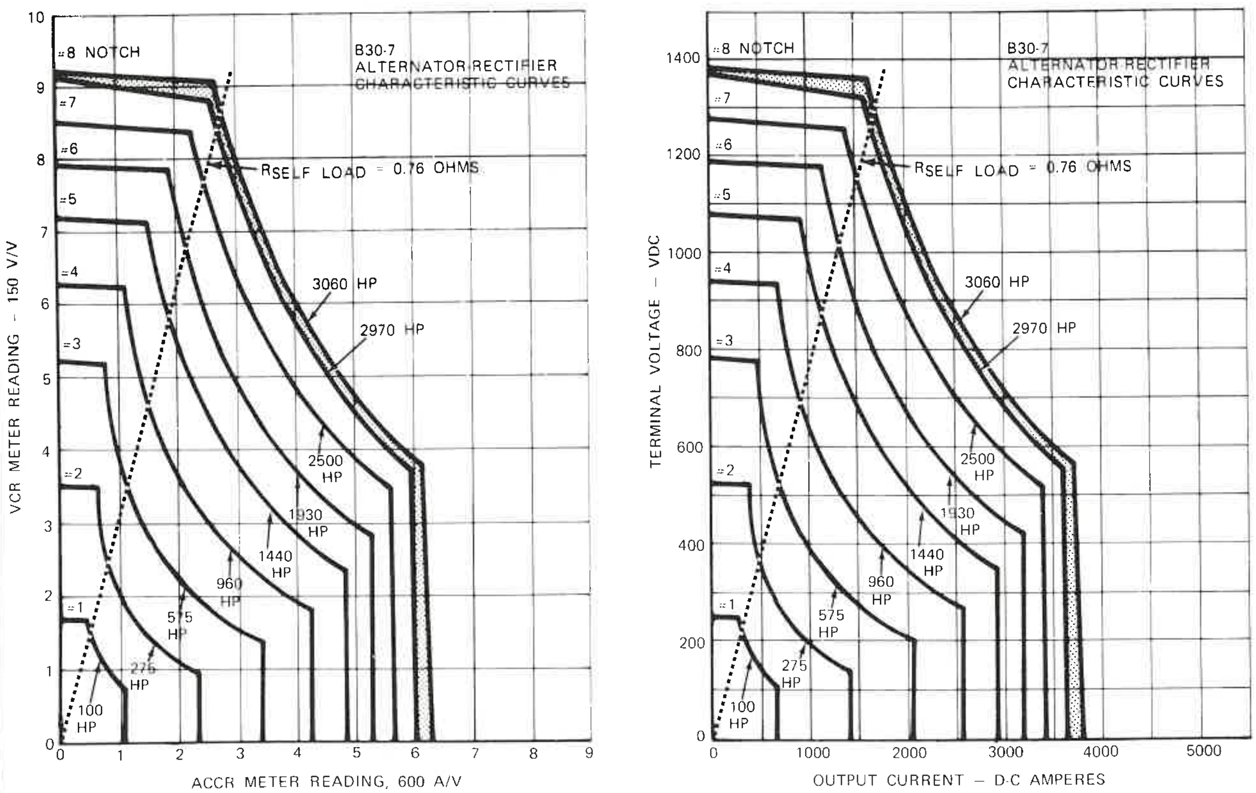
	LEFT CURVE			RIGHT CURVE			
NOTCH	ACCR CARD 7	VCR CARD 7	POWER CARD 7	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	3.30	6.73	6.67	1980	1010	2000	2820
7	3.02	6.17	5.60	1815	925	1680	2370
6	2.63	5.37	4.24	1580	805	1270	1795
5	2.29	4.67	3.20	1370	700	960	1355
4	1.83	3.73	2.05	1100	560	615	870
3	1.39	2.83	1.18	835	425	355	500
2	0.98	2.00	0.59	590	300	175	250
1	0.57	1.17	0.20	345	175	60	85

FIG. XI-11. SELF LOADING A C28-7.

check of the load test. If accurate barometer is not available, use the elevation of the test site. See CALCULATING GROSS ENGINE OUTPUT in Load Testing Instructions under Section ET-2 of Maintenance Manuals.

Power Plant Operation

1. Check the engine for proper level of cooling water, lubricating oil, fuel oil and governor oil, so the load test can be completed without stopping.
2. Check the level of the lubricating oil in the air compressor, traction generator gear unit and radiator fan gear unit.
3. Check the fuel linkage system on the engine to see that it is properly lubricated and operates freely. Also check output pressure of the fuel oil pump. It should be 40 psi.
4. Check all rotating apparatus for loose or broken brushes and any foreign material. Correct any unsatisfactory condition found, before proceeding.



AVERAGE READINGS FOR SELF LOADING A B30-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.76 OHMS RESISTANCE.

NOTCH	LEFT CURVE			RIGHT CURVE			
	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	2.74	8.33	6.85	1660	1280	2125	3000
7	2.48	7.53	5.59	1485	1130	1680	2370
6	2.17	6.60	4.29	1300	990	1285	1815
5	1.88	5.70	3.21	1125	855	960	1355
4	1.50	4.57	2.06	900	685	615	870
3	1.14	3.47	1.19	685	520	355	505
2	0.80	2.43	0.58	480	365	175	245
1	0.49	1.50	0.22	295	225	65	95

FIG. XI-12, E-25360

FIG. XI-12. SELF LOADING A B30-7.

XI

5. Check that no warning devices are tripped, such as the engine air filter indicator. Remove the air supply hose to the Overspeed and Fuel Control Device (Overspeed Link under engine control governor) at the device, and plug the hose fitting.

6. Preset the loading device so the highest resistance is in the circuit prior to starting the engine. Then check that the circuit thru the loading device is OPEN during engine starting to minimize drain on the battery.

7. Start the engine. If the engine has been overhauled, follow the break-in procedure as listed in publication found in Section DE-15 of Maintenance Manuals. Check for system leaks or any sign of distress. Correct any faults before proceeding.

8. Turn off all nonessential auxiliary loads like lights, electric cab heaters and water coolers; also batteries are to be fully charged. Derater link must not be derating. Fuel strainer and fuel filters must be clean.

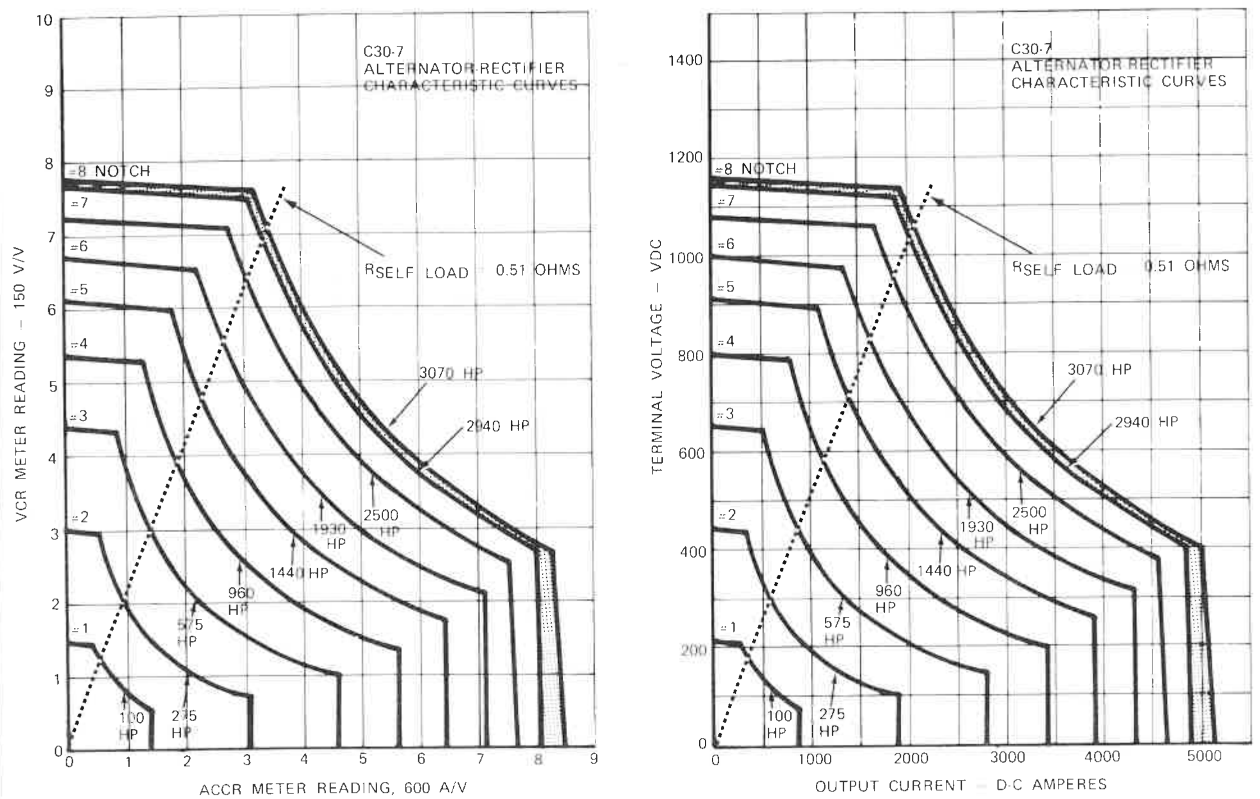


FIG. XI-13, E-25361

AVERAGE READINGS FOR SELF LOADING A C30-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.51 OHMS RESISTANCE.

	LEFT CURVE			RIGHT CURVE			
NOTCH	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	3.38	6.90	7.00	2050	1035	2125	3000
7	3.09	6.30	5.84	1855	945	1755	2475
6	2.68	5.47	4.40	1610	820	1320	1865
5	2.32	4.73	3.29	1390	710	985	1390
4	1.88	3.83	2.16	1125	575	645	915
3	1.44	2.93	1.27	865	440	380	535
2	0.98	2.00	0.59	590	300	175	250
1	0.60	1.23	0.22	365	185	70	95

FIG. XI-13. SELF LOADING A C30-7.

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9. Check Power Limit switch on operator's console to be sure it is in the NORMAL (Notch 8), NOT the NOTCH 7 position.

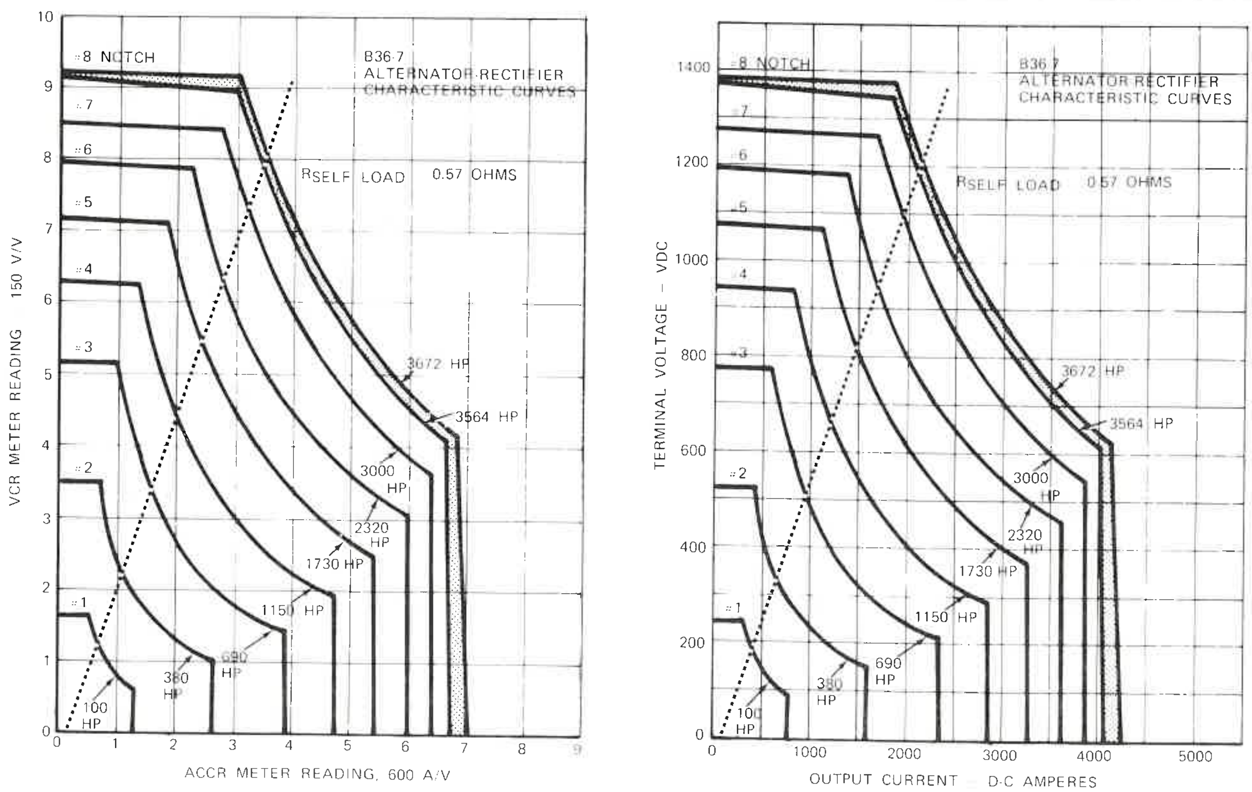
Voltage Regulator Check

Before proceeding with the load test, check the voltage regulator for proper regulation at between 73.5 and 74.5 volts at both IDLE and FULL engine speeds. Read the voltmeter installed in the battery-charging circuit.

If correction is needed, loosen the locknut on the potentiometer on face of regulator panel, either FH-20 or FH-23, and turn the adjustment screw to obtain proper voltage; then, again tighten the locknut.

Engine Speed Check

Run the engine in Notch 3 or 4 until the water temperature is 65 C (150 F) or above. Check the engine for proper crankshaft speeds in all notches, and refer to the Engine Control Governor instructions if any adjustment is necessary. The tachometer should read 1553-1568 rpm for a 1045-1050 rpm engine speed.



AVERAGE READINGS FOR SELF LOADING A B36-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.57 OHMS RESISTANCE.

	LEFT CURVE ABOVE			RIGHT CURVE ABOVE			
NOTCH	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP P
8	3.53	8.07	8.57	2120	1210	2565	3620
7	3.23	7.37	7.15	1940	1105	2145	3025
6	2.81	6.40	5.40	1685	960	1620	2285
5	2.42	5.53	4.03	1455	830	1210	1705
4	1.96	4.47	2.63	1175	670	790	1110
3	1.52	3.47	1.58	915	520	475	670
2	1.02	2.33	0.72	615	350	215	305
1	0.58	1.33	0.23	350	200	70	100

FIG. XI-14. SELF LOADING A B36-7.

FIG. XI-14, E-25362

XI

Engine Overspeed Check

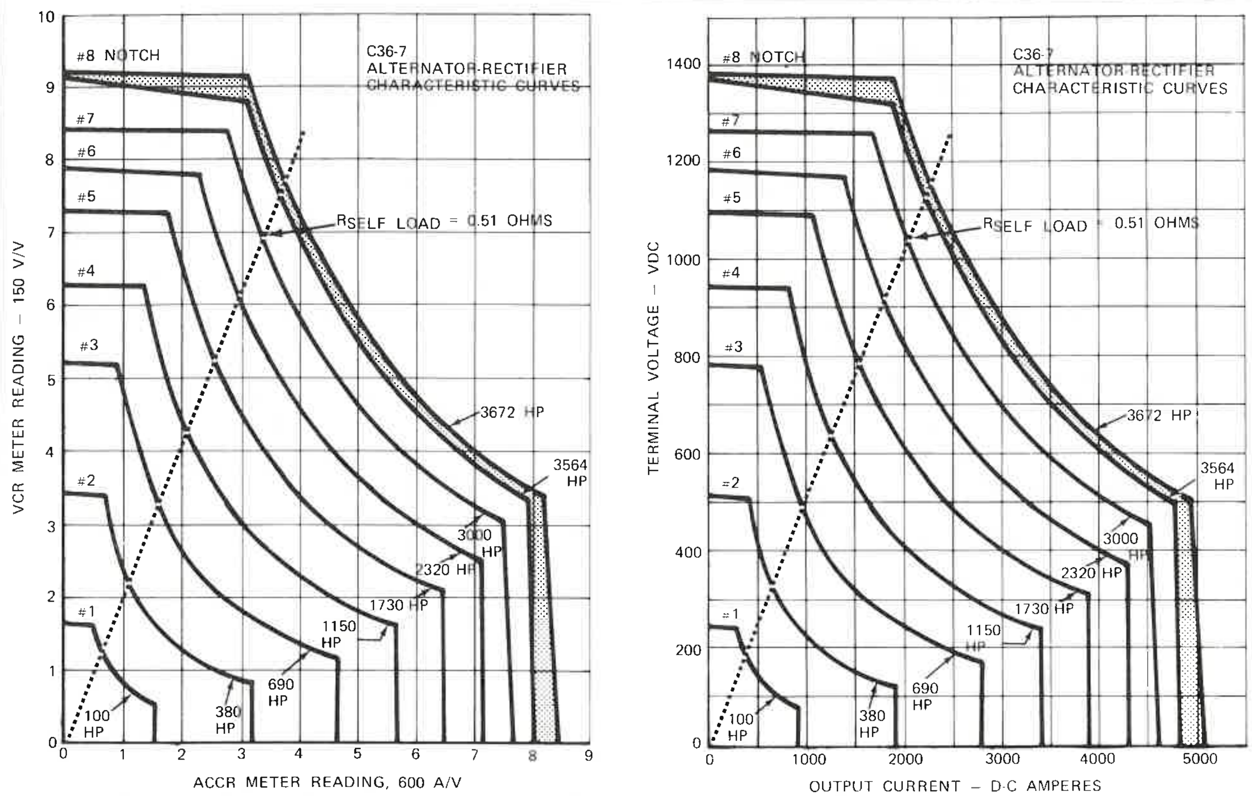
With the engine heated to normal operating temperature, run it in IDLE and no-load. Place the special overspeed test lever tool, 147X2016, under the outer cup of the overspeed link, Fig. XI-19. The recess on the back fits over the head of the clamp bolt of the fuel arm connected to the bottom of the link. This is the pivot point for the test lever.

Press down on the end of the tool to raise both the overspeed link and the governor power piston output shaft. This extends the racks and increases the engine speed. When the trip point of the overspeed governor is reached, it dumps the oil pressure to the link. The link is then permitted to extend and return the racks to the shutdown position. Read the engine speed on the digital meter at the moment the overspeed link extends.

LOAD TESTING

NOTE: *Load Test according to local railroad safety regulations.*

FIG. XI-15, E-25363



AVERAGE READINGS FOR SELF LOADING A C36-7 LOCOMOTIVE ON ITS DYNAMIC BRAKING GRIDS OF 0.51 OHMS RESISTANCE.

	LEFT CURVE			RIGHT CURVE			
NOTCH	ACCR CARD 7	VCR CARD 7	POWER CARD 4	CURRENT AMPERES	VOLTAGE VOLTS	POWER KW	POWER HP
8	3.76	7.67	8.65	2255	1150	2595	3660
7	3.40	6.93	7.07	2040	1040	2120	2990
6	2.96	6.03	5.37	1775	905	1610	2275
5	2.57	5.23	4.03	1540	785	1210	1710
4	2.09	4.27	2.68	1255	640	805	1135
3	1.62	3.30	1.60	970	495	480	680
2	1.08	2.20	0.72	650	330	215	305
1	0.63	1.30	0.25	380	195	75	105

FIG. XI-15. SELF LOADING A C36-7.

Open-Circuit Voltage Check

With the engine at normal operating temperature, above 65 C (150 F), proceed as follows:

1. Move the Braking handle to OFF, and the Reverse handle to FORWARD or REVERSE position. Move EC (Engine Control) switch to RUN, then close the GF circuit breaker.

> **WARNING:** *Electric shock can cause serious or fatal injury. To avoid such injury, personnel must observe proper precautions.*

2. Set the loading device on OPEN CIRCUIT.
3. Close the Control circuit breaker on the EC panel, and move the Throttle handle to Notch 4. Observe that the test voltmeter has been properly connected, giving a positive reading. This step checks the voltage at a lower notch to assure the excitation system is operating properly and that it will not produce an excessive voltage in Notch 8 which could severely damage the equipment.
4. Gradually advance the Throttle handle to Notch 8 while checking the open-circuit voltage for each

XI

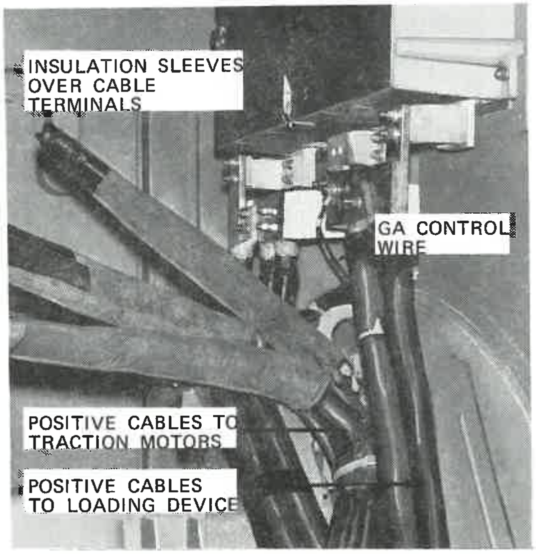


FIG. XI-16. SUBSTITUTION OF LOADING CABLE AT POSITIVE TERMINAL OF POWER RECTIFIERS.

FIG. XI-16, E-22784

notch. Never allow the voltage to exceed that given at No-Load on the Characteristic Curve, Figs. XI-24 thru XI-32. A small change in the open-circuit Notch 8 voltage can be made by resetting the VL (third potentiometer under right end cover of the CHEC panel). Otherwise proceed to the Current Limit Check, making any required adjustment to CL8 (Potentiometer 4), then repeat the open-circuit voltage check.

5. With the air compressor running unloaded, read the voltmeter across the power rectifiers. The open-circuit voltage should plot between the limits shown on the appropriate Characteristic Curve. This is at the zero current, or the left end, of the curve. See Figs. XI-24 thru XI-32 for the proper model of locomotive being tested.

6. Return the Throttle handle to the IDLE position.

Current Limit Check

1. With loading unit set for minimum resistance, advance the Throttle handle to Notch 4. With the air

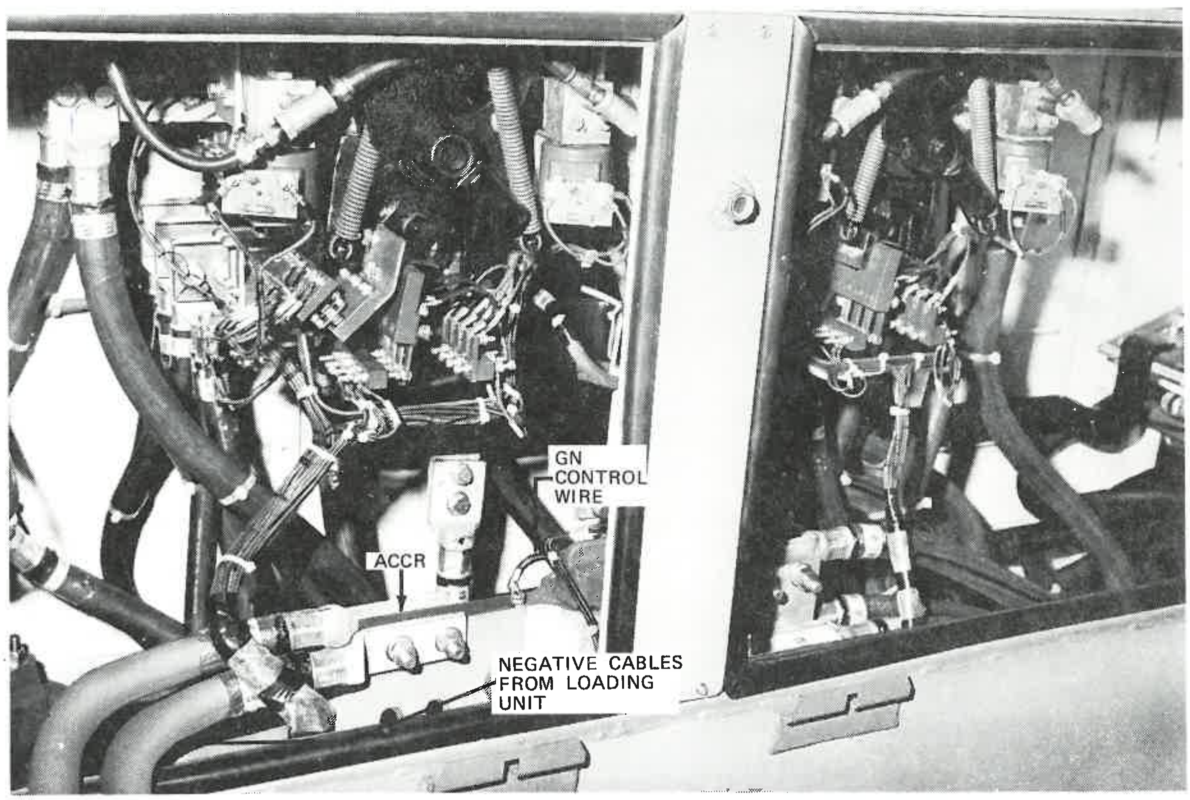


FIG. XI-17. SUBSTITUTION OF LOADING CABLES AT NEGATIVE TERMINAL ON ACCR.

FIG. XI-17, E-25398

XI

FIG. XI-18, E-20949

FIG. XI-18. MEASURING ENGINE SPEED AT TACHOMETER DRIVE FITTING ON GOVERNOR DRIVE GEAR BOX.

compressor running unloaded, take voltage and current readings and plot the point on the appropriate load curve, Figs. XI-24 thru XI-32.

CAUTION: *Do not hold high current loads any longer than necessary to protect the equipment against possible high temperature damage developed by the high current.*

2. Gradually advance the Throttle handle to Notch 8, while watching the ammeter to be sure the limit shown on the curve is not overrun. Read the meters and plot the point on the nearly vertical right end of the curve. The point should fall between the curve limits, in line with the point plotted for Notch 4 and the origin, or left corner, of the curve.

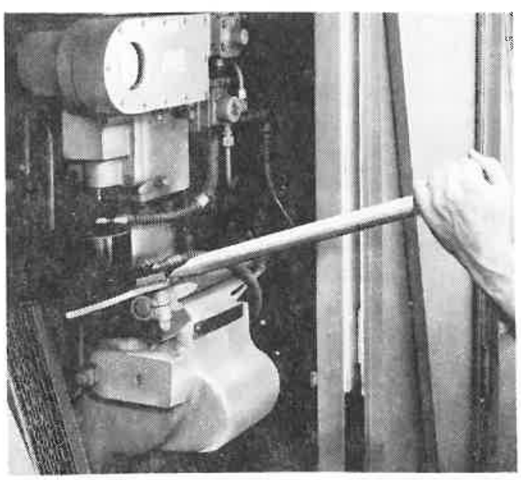


FIG. XI-19, E-22576

FIG. XI-19. INCREASING ENGINE SPEED WITH SPECIAL OVERSPEED TEST LEVER TOOL.

3. If an adjustment is required, adjust the rheostat to give a current value which will fall within the limits of the curve and on the resistance line being used. This line should cross the curve somewhere below the lower right "corner point." Check that the LCP (Load Control Potentiometer) brush arm on the engine control governor is operating at the 5:30 o'clock or "Max. Field" position.
4. Return the Throttle handle to the IDLE position.
5. If the rheostat was adjusted, repeat the open-circuit voltage check to determine it is still within the curve limits, since any adjustment may have changed the envelope or size of the whole curve.

Output Curve Check

NOTE: *The curved portion of the Load Curves is the constant horsepower section, and the resistance steps on the loading device must be selected to get points in this section.*

Select a resistance step on the loading device, move the Throttle handle to Notch 8, plot the point on the appropriate curve then return the handle to IDLE.

Make another selection of resistance on the loading unit and repeat. Thus, a number of points can be checked in this manner, however, only at the resistance values available on the loading device being used.

CAUTION: *Do not hold high-current loads any longer than necessary to protect the equipment against possible damage due to high temperatures developed by the high current.*

Refer to FL138 excitation panel instructions for additional information on the proper operation of the LCP (Load Control Potentiometer) in the engine control governor. With near standard test conditions the indicator should not go to less than about 4:30 o'clock (from the "Max. Field" position of 5:30) at any time during the horsepower curve check. If it does go to a lower value, refer to the excitation panel instructions for possible causes and corrections.

The curves, Figs. XI-24 thru XI-32, are based on standard 1-2-3-4-5-6-7-8 engine speeds, with Power Matching disconnected. Also the Steps 1-10 resistance lines are for an

EM99 Loading Unit. Other resistances can be used and values plotted on same curves if found necessary to load on some other device. The EM99 step resistances are given in heading of table for each curve, Figs. XI-24 thru XI-32.

SETTING POWER MATCHING

Description

The Power Match feature is required to protect the traction motors of some locomotives, when working in multiple with older units, to prevent damage to or reduce the life of the motors. This feature works during the first step of transition, being bypassed in any others. Thus only high current or slow speed operation of the locomotive is modified.

If all locomotives dispatched in a consist were of the same model, with same gearing and wheel size or have corresponding short-time ratings, Power Matching would not be necessary. However a consist of locomotives is seldom made up of units with similar ratings, whether of the same manufacturer or of different manufacturers.

Any locomotive operating continuously or for long periods of time at a speed lower than its CONTINUOUS RATING, needs this feature as a protective device. Unless the high horsepower locomotive is the lead unit (the one the operating crew is riding) the crew is unaware of traction motor overloading until it slips or smokes excessively. The crew may be watching a loadmeter with much less restrictive time limits.

NOTE: *Normally locomotives with this protection are derated, with a corresponding loss in available horsepower for train starting and slow speed operation. This applies even when operating alone or with others of the same model. The settings for Power Matching are variable. Thus it is important to have it readjusted whenever the type of locomotives causing the problem and determining the setting are transferred to another territory or retired from service.*

XI

When properly set, Power Matching will protect the traction motors from overheating their insulation and thus shortening their useful life. It reduces the current thru the motors to be compatible with the ratings of the motors on the other locomotives operating in multiple with it.

NOTE: *Do not confuse Power Matching with Power Limit. This is a Toggle switch on the operator's console with Notch 7 and NORMAL positions. It is provided for use on the lead locomotive to condition the rail for the trailing locomotives, permitting a higher average of tractive effort over the grades and thus a higher speed than otherwise possible.*

Power Matching is also known as Performance Control as applied on competitors locomotives.

A periodic survey should be conducted of all locomotives working together in a given territory to determine if there has been a change in the restriction on all pooled power. It could allow the amount of Power Matching to be adjusted to utilize more of the available power (or eliminate Power Matching altogether) on each locomotive, at the lower speeds.

As an example of the application of Power Matching, assume Locomotive No. 1 is an older unit with a continuous rating Point C1 on Speed-Tractive Effort Curve, Fig. XI-20-A. A second, higher horsepower Locomotive No. 2 with a different continuous rating point, C2, is shown on the same curve. Since the two locomotives are coupled together they must pull the train at the same speed and without Power Matching No. 2 would normally operate at Point A when Locomotive No. 1 is at continuous rating. This is at a current exceeding its continuous current rating. When transposed to the Alternator-Rectifier Characteristic Curves, Fig. XI-20-B, the Points A, C1 and C2 might be located as in Fig. XI-20-C.

Point B is determined at the same speed as C1 but the same tractive effort (same current for like motors and gearings) as C2. It transposes as a point on a reduced horsepower output curve of Fig. XI-20-D, say 3000 hp. During train acceleration the Power Matching on Locomotive No. 2 would then cut in at D, follow the reduced output curve to B, then transfer back to the full horsepower curve at C2, continuing along that curve. Remember this reduction is not made after transition when coming back along the full horsepower curve the next time.

Point C2 is referred to as the KNEE and line B-D as the LEVEL for setting Power Matching, Fig. XI-22.

Adjusting Power Matching

The CHEC excitation panel, FL138, has two adjustments for Power Matching located under the high voltage cover at the right end of the panel along with six other panel-mounted 20-turn potentiometers. The lower two potentiometers, Numbers 7 and 8, set the KNEE and the LEVEL for Power Matching. All adjustments are done with a very small insulated screwdriver, Fig. XI-21.

See Fig. XI-22 for details on adjustments. CW reduces both settings while CCW increases them.

There are no standard settings for Power Matching. Each railroad determines the proper setting for each type locomotive in each territory. Be sure to follow the latest railroad instruction when checking or changing the setting.

FIG. XI-20, E-25395

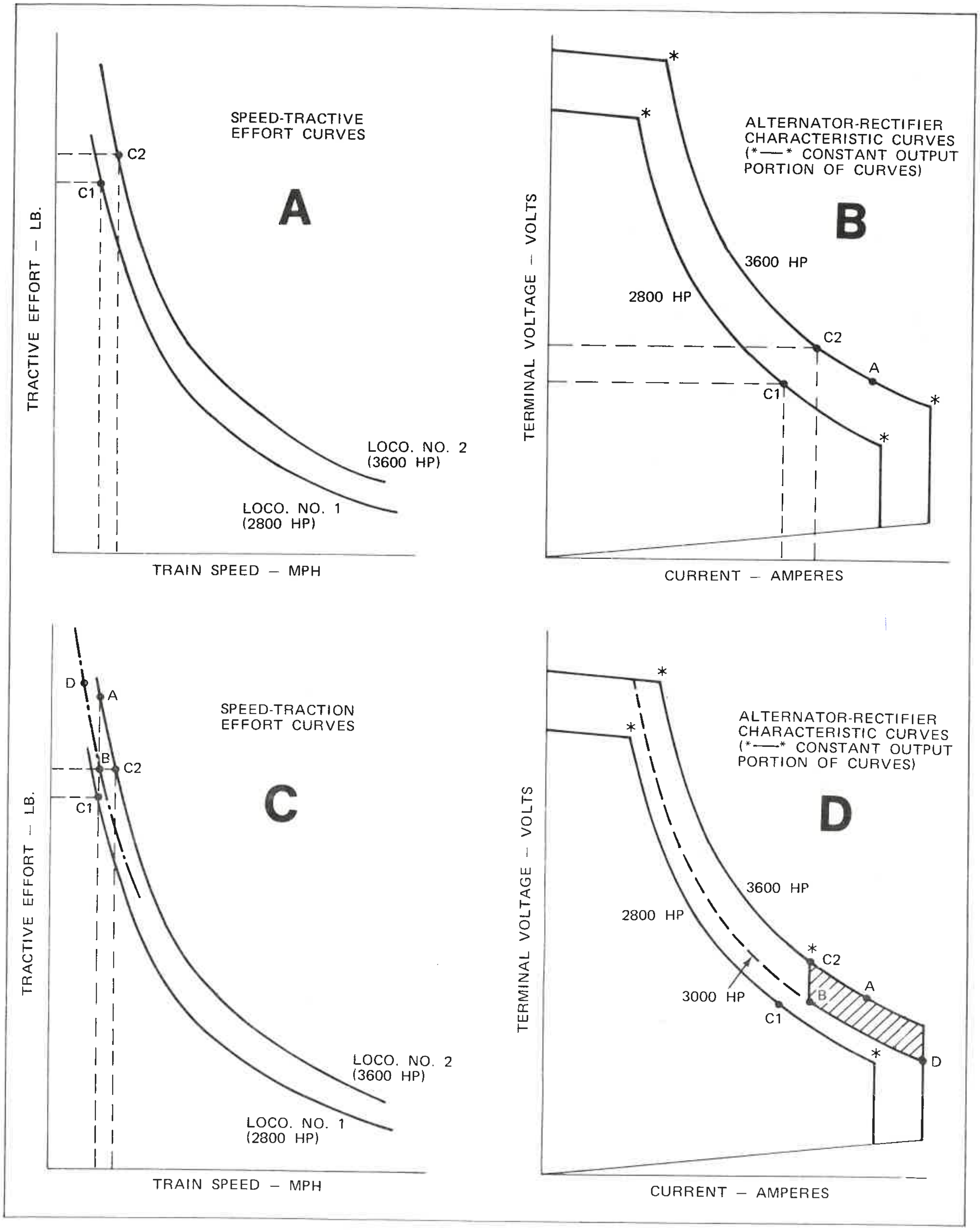


FIG. XI-20. DETERMINING SETTINGS FOR POWER MATCHING.

XI

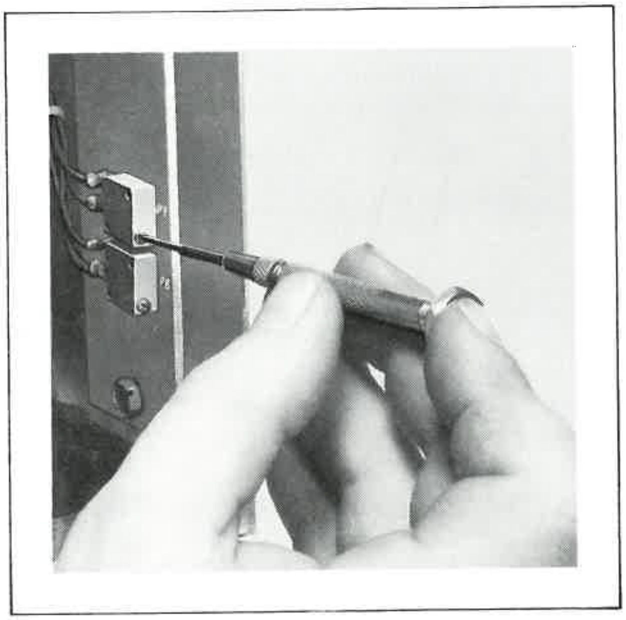


FIG. XI-21. ADJUSTMENT OF POWER MATCHING KNEE.

Procedure for Setting Power Matching

While connected to the loading unit, activate the Power Matching feature by removing the jumper between Terminals EXP-L and EXP-M on the FL138 CHEC excitation panel.

Set the loading unit on any of the steps for which the resistance line will cross either the D-B or B-C2 line as on Fig. XI-23. Then gradually increase the Throttle handle to Notch 8. Read the voltage and current. These should plot on the Characteristic Curve at the intersection of the Power Matching lines and the Step resistance lines. If not, the LEVEL or the KNEE should be adjusted.

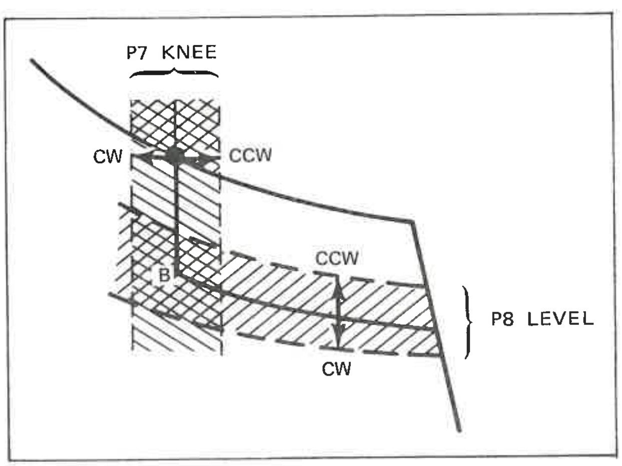


FIG. XI-22. P7 KNEE AND P8 LEVEL ADJUSTMENT DETAILS.

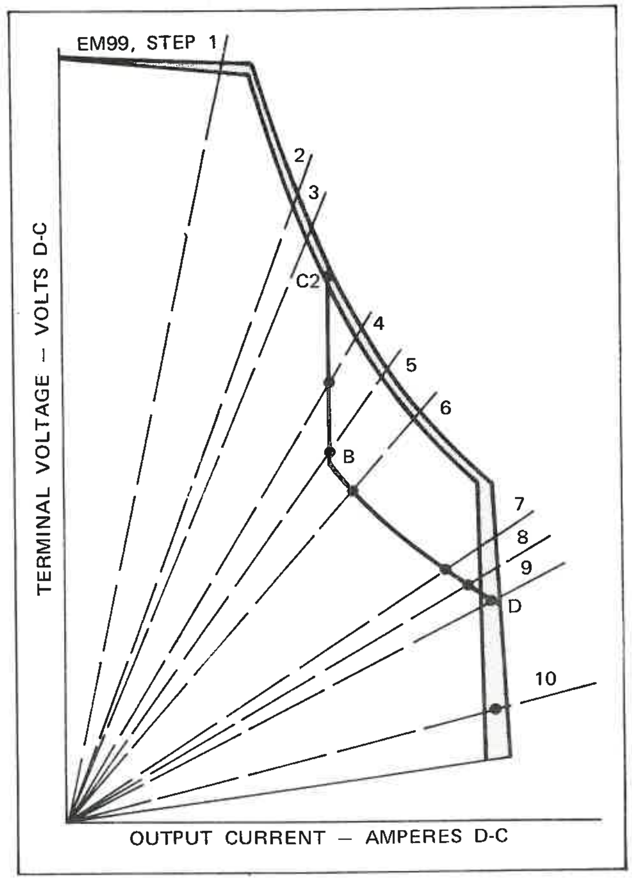


FIG. XI-23. SETTING POWER MATCHING WHILE ON AN EM99 LOADING UNIT.

NOTE: *When an adjustment is made along one resistance line, check it along the other lines.*

Once the KNEE and LEVEL have been properly set and recorded, the test equipment can be removed and locomotive made ready for revenue service.

RESTORING LOCOMOTIVE FOR SERVICE

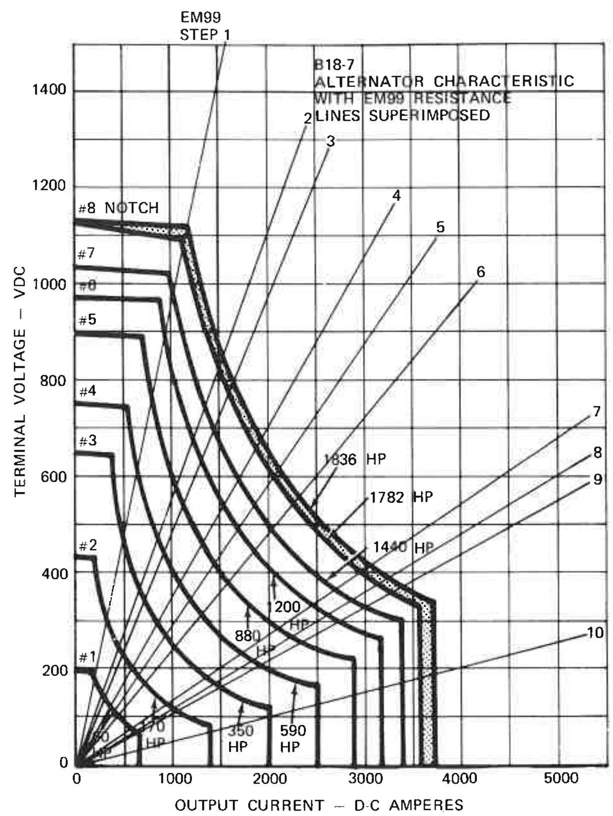
1. Remove all test equipment.
2. Disconnect all external wires and cables.
3. Restore all circuits back to normal, including Power Matching if applied.
4. Open NS-1 reducing valve and close the control air drain cock if previously set to prevent locomotive movement. Restore air compressor control to normal.
5. Replace all covers and plugs in their proper location.
6. Remove chocks or blocks used to prevent locomotive movement.

FIG. XI-21, E-25396

FIG. XI-22, E-25397

FIG. XI-23, E-25394

FIG. XI-24, E-25364



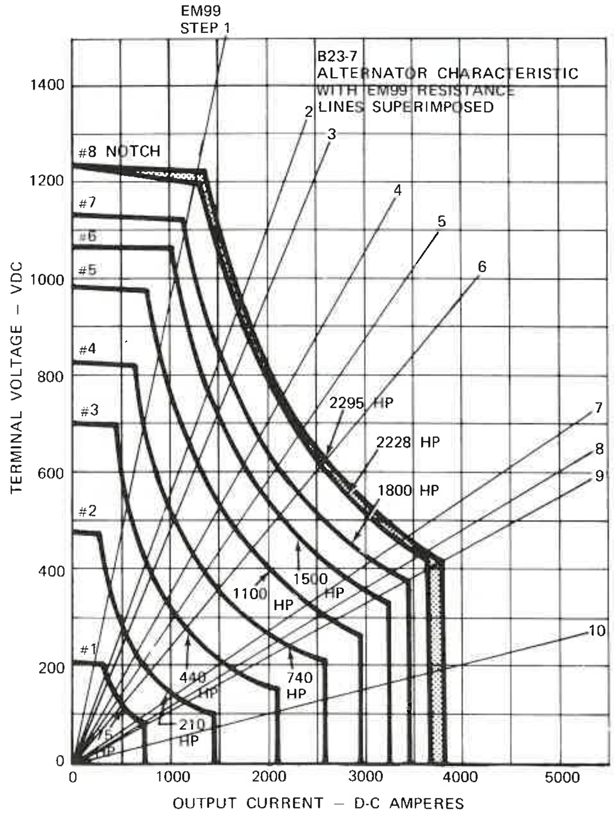
AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1145	1110	1540	840	1620	785	1915	665	2085	605
7	1015	985	1365	745	1435	695	1700	590	1860	540
6	930	900	1245	680	1320	640	1555	540	1705	495
5	785	760	1055	575	1105	535	1310	455	1430	415
4	640	620	860	470	905	440	1080	375	1170	340
3	490	475	660	360	700	340	835	290	915	265
2	310	300	440	240	475	230	560	195	620	180
1	195	190	275	150	290	140	345	120	380	110

Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	2295	555	3020	405	3180	385	3320	365	3655	190
7	2045	495	2725	365	2850	345	3000	330	3365	175
6	1860	450	2465	330	2605	315	2730	300	3175	165
5	1570	380	2125	285	2235	270	2320	255	2885	150
4	1300	315	1715	230	1820	220	1910	210	2500	130
3	1010	245	1345	180	1405	170	1455	160	2020	105
2	680	165	935	125	990	120	1000	110	1440	75
1	415	100	560	75	580	70	590	65	675	35

FIG. XI-24. LOADING B18-7 ON EM99 LOADING UNIT.

XI



AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1250	1210	1720	940	1805	875	2145	745	2330	675
7	1130	1095	1530	835	1610	780	1915	665	2090	605
6	1050	1015	1400	765	1475	715	1745	605	1895	550
5	875	850	1180	645	1250	605	1500	520	1620	470
4	715	695	970	530	1020	495	1210	420	1330	385
3	540	520	725	395	765	370	920	320	1015	295
2	360	350	495	270	525	255	635	220	690	200
1	210	205	310	170	330	160	390	135	430	125

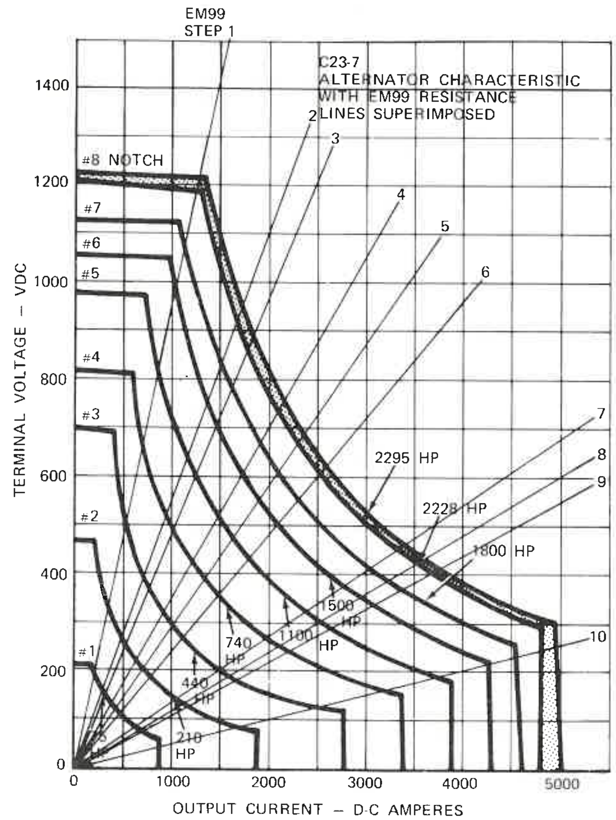
Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	2560	620	3360	450	3510	425	3635	400	3655	190
7	2295	555	3060	410	3225	390	3365	370	3365	175
6	2085	505	2800	375	2935	355	3090	340	3175	165
5	1795	435	2390	320	2520	305	2635	290	2885	150
4	1465	355	1980	265	2065	250	2180	240	2500	130
3	1115	270	1490	200	1570	190	1680	185	2020	105
2	765	185	1045	140	1075	130	1135	125	1345	70
1	475	115	635	85	660	80	680	75	675	35

FIG. XI-25. LOADING B23-7 ON EM99 LOADING UNIT.

FIG. XI-25, E-25365

XI

FIG. XI-26, E-25366



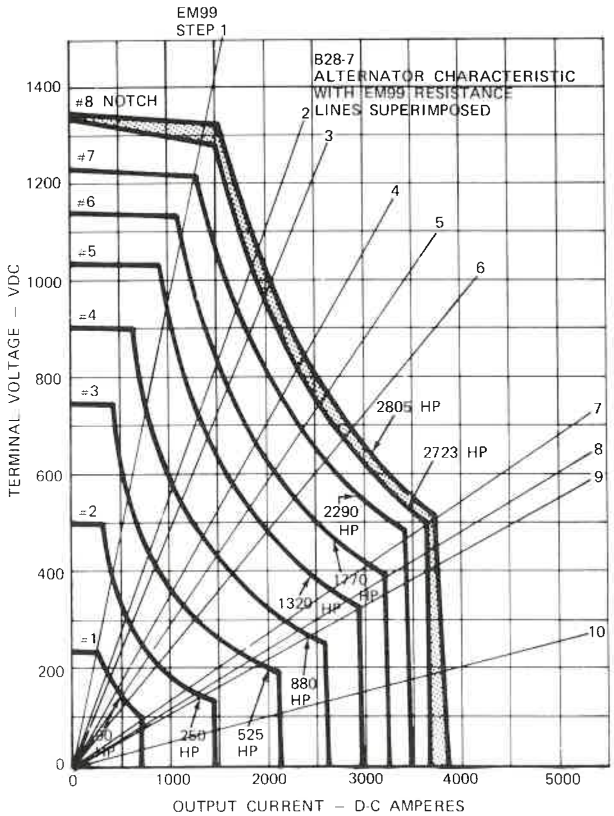
AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1250	1210	1720	940	1815	880	2145	745	2345	680
7	1140	1105	1520	830	1610	780	1915	665	2105	610
6	1050	1020	1400	765	1475	715	1745	605	1895	550
5	875	850	1180	645	1250	605	1485	515	1640	475
4	710	690	960	525	1020	495	1225	425	1345	390
3	545	530	725	395	765	370	920	320	1015	295
2	360	350	520	285	525	255	635	220	705	205
1	210	205	310	170	330	160	405	140	395	115

Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	2560	620	3395	455	3555	430	3730	410	4810	250
7	2295	555	3060	410	3225	390	3365	370	4425	230
6	2085	505	2875	385	2935	355	3045	335	4135	215
5	1795	435	2425	325	2520	305	2635	290	3655	190
4	1465	355	2015	270	2065	250	2180	240	3075	160
3	1115	270	1495	200	1570	190	1680	185	2405	125
2	785	190	1045	140	1075	130	1180	130	1635	85
1	475	115	635	85	660	80	680	75	865	45

FIG. XI-26. LOADING C23-7 ON EM99 LOADING UNIT.

XI



AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1340	1300	1925	1050	1990	965	2375	825	2585	750
7	1250	1215	1730	945	1825	885	2160	750	2380	690
6	1140	1105	1500	820	1590	770	1875	650	2050	595
5	985	955	1320	720	1390	675	1645	570	1795	520
4	770	745	860	570	1105	535	1325	460	1450	420
3	580	565	795	435	845	410	1010	350	1120	325
2	410	400	550	300	600	290	705	245	775	225
1	225	220	350	190	370	180	445	155	485	140

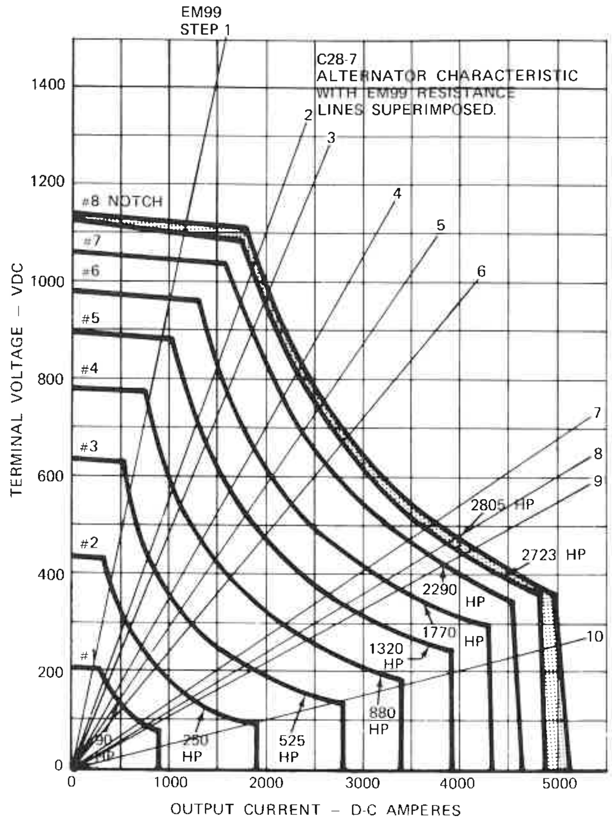
Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	2810	680	3655	490	3635	440	3635	400	3655	190
7	2605	630	3395	455	3390	410	3365	370	3365	175
6	2250	545	3060	410	3180	385	3180	350	3270	170
5	1985	480	2650	355	2770	335	2865	315	2885	150
4	1610	390	2165	290	2270	275	2365	260	2500	130
3	1240	300	1715	230	1820	220	1865	205	2115	110
2	850	205	1195	160	1240	150	1090	120	1345	70
1	540	130	670	90	660	80	635	70	770	40

FIG. XI-27. LOADING B28-7 ON EM99 LOADING UNIT.

FIG. XI-27, E-25367

XI

FIG. XI-28, E-25368



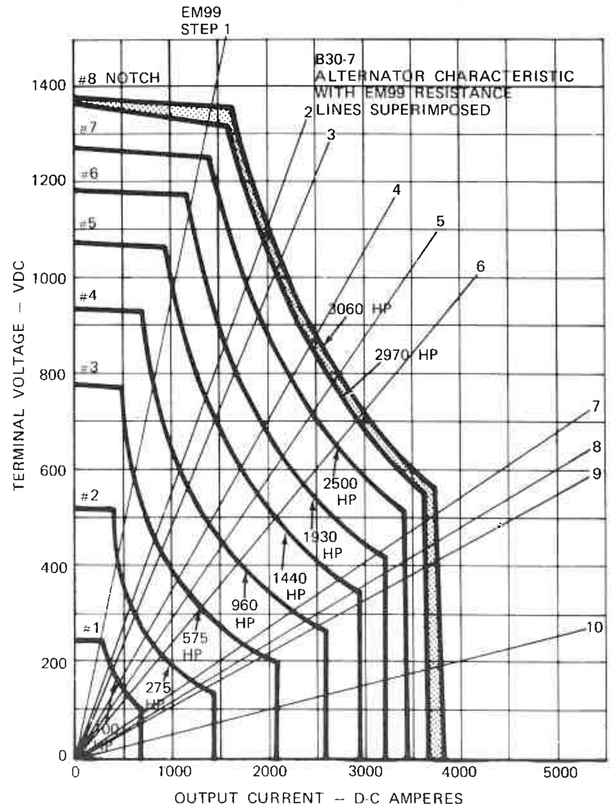
AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1145	1110	1905	1040	2010	975	2375	825	2585	750
7	1080	1050	1740	950	1835	890	2160	750	2380	690
6	1000	970	1520	830	1600	775	1885	655	2070	600
5	910	885	1320	720	1380	670	1640	570	1795	520
4	785	760	1060	580	1125	545	1340	465	1465	425
3	580	565	795	435	845	410	1010	350	1120	325
2	400	390	570	310	600	290	720	250	795	230
1	215	210	340	185	350	170	430	150	465	135

Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	2830	685	3730	500	3925	475	4090	450	5000	260
7	2605	630	3505	470	3680	445	3820	420	4615	240
6	2250	545	3060	410	3180	385	3365	370	4325	225
5	1960	475	2725	365	2770	335	2910	320	3940	205
4	1610	390	2165	290	2275	275	2410	265	3460	180
3	1240	300	1680	225	1775	215	1820	200	2690	140
2	870	210	1120	150	1240	150	1275	140	1925	100
1	515	125	710	95	745	90	775	85	962	50

FIG. XI-28. LOADING C28-7 ON EM99 LOADING UNIT.

XI



AVERAGE METER READINGS USING EM99 LOADING UNIT

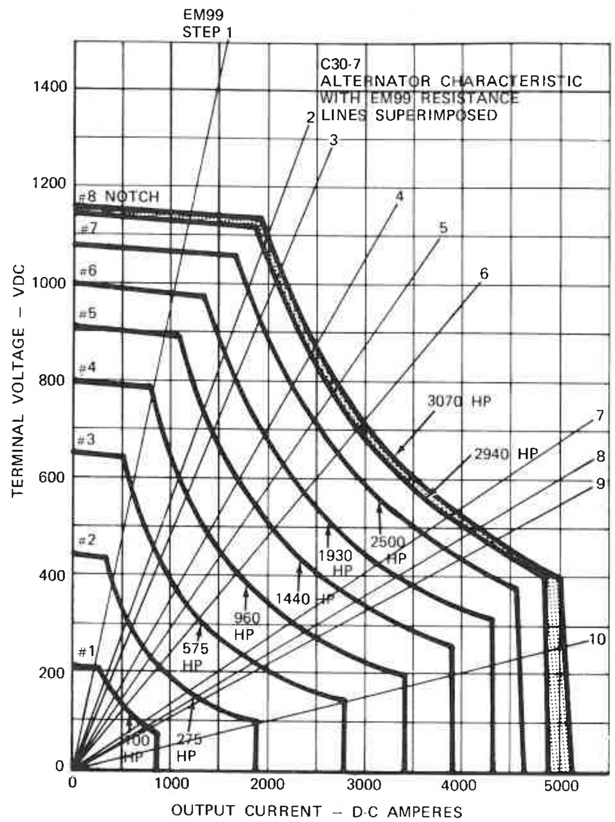
Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1380	1340	2000	1090	2105	1020	2480	860	2705	785
7	1290	1250	1815	990	1910	925	2260	785	2465	715
6	1185	1150	1575	860	1650	800	1960	680	2140	620
5	1015	985	1365	745	1445	700	1700	590	1860	540
4	815	790	1275	695	1155	560	1385	480	1515	440
3	615	595	835	455	885	430	1065	370	1170	340
2	440	425	575	315	610	295	720	250	895	260
1	260	250	365	200	380	185	460	160	500	145

Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	2935	710	3695	495	3635	440	3680	405	3655	190
7	2705	655	3435	460	3390	410	3365	370	3365	175
6	2355	570	3170	425	3180	385	3180	350	3175	165
5	2045	495	2760	370	2890	350	2910	320	2885	150
4	1675	405	2275	305	2395	290	2500	275	2595	135
3	1280	310	1790	240	1860	225	1955	215	2115	110
2	890	215	1195	160	1280	155	1365	150	1440	75
1	560	135	670	90	660	80	635	70	675	35

FIG. XI-29, E-25369

FIG. XI-29. LOADING B30-7 ON EM99 LOADING UNIT.

FIG. XI-30, E-25370

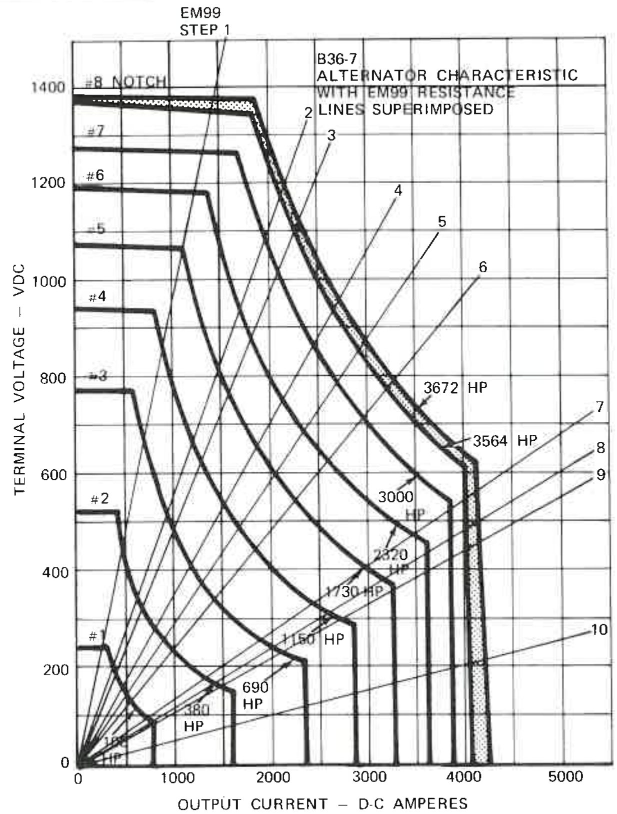


AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1170	1135	1985	1085	2080	1010	2480	860	2690	780
7	1075	1045	1575	860	1650	800	1960	680	2140	620
6	945	915	1265	690	1320	640	1570	545	1705	495
5	760	740	1015	555	1070	520	1285	445	1380	400
4	590	575	795	435	845	410	1010	350	1105	320
3	485	470	650	355	690	335	820	285	895	260
2	400	390	530	290	555	270	665	230	725	210
1	175	170	310	170	350	170	445	155	480	140

Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	2955	715	3920	525	4050	490	4270	470	4810	250
7	2355	570	3170	425	3305	400	3545	390	4515	235
6	1880	455	2535	340	2645	320	2775	305	4040	210
5	1530	370	2050	275	2150	260	2225	245	3270	170
4	1200	290	1640	220	1695	205	1775	195	2595	135
3	990	240	1345	180	1365	165	1455	160	2115	110
2	805	195	1080	145	1115	135	1180	130	1730	90
1	540	130	745	100	745	90	775	85	865	45

FIG. XI-30. LOADING C30-7 ON EM99 LOADING UNIT.



AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1410	1370	2180	1190	2310	1120	2725	945	2965	860
7	1315	1275	1990	1085	2095	1015	2480	860	2690	780
6	1225	1190	1730	945	1825	885	2160	750	2380	690
5	1110	1075	1490	815	1580	765	1875	650	2050	595
4	895	870	1210	660	1280	620	1525	530	1670	485
3	690	670	935	510	990	480	1180	410	1275	370
2	470	455	630	345	670	325	790	275	860	250
1	260	250	365	200	380	185	460	160	485	140

Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	3265	790	4105	550	4010	485	4000	440	4040	210
7	2955	715	3880	520	3800	460	3820	420	3845	200
6	2605	630	3510	470	3555	430	3545	390	3560	185
5	2250	545	3020	405	3140	380	3180	350	3175	165
4	1840	445	2465	330	2560	310	2725	300	2790	145
3	1405	340	1940	260	1985	240	2090	230	2305	120
2	950	230	1345	180	1365	165	1455	160	1540	80
1	535	130	745	100	745	90	725	80	770	40

FIG. XI-31. LOADING B36-7 ON EM99 LOADING UNIT.

FIG. XI-31, E-25371

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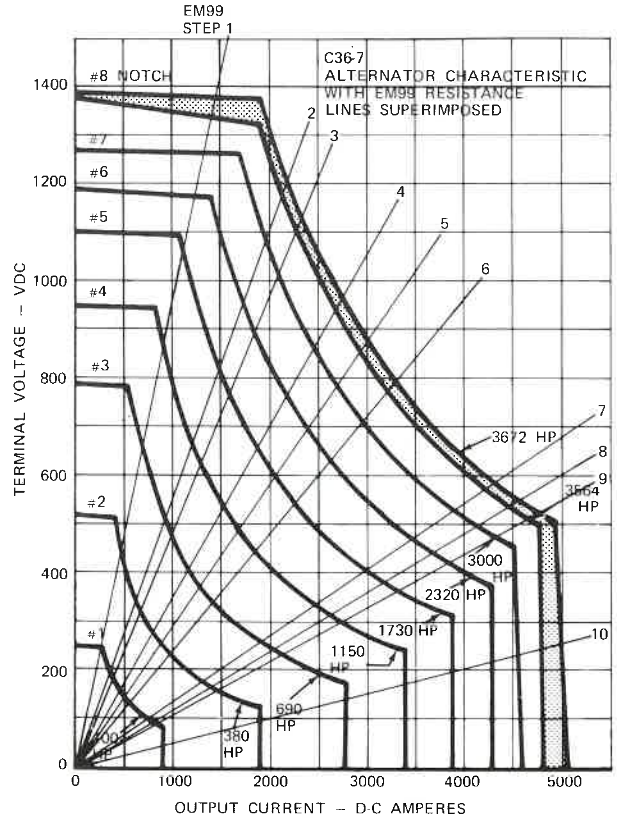
FIG. XI-32, E-25372



AVERAGE METER READINGS USING EM99 LOADING UNIT

Notch	Step 1 0.970 Ohm		Step 2 0.546 Ohm		Step 3 0.485 Ohm		Step 4 0.347 Ohm		Step 5 0.290 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	1390	1350	2190	1195	2310	1120	2740	950	2960	860
7	1300	1260	1980	1085	2090	1015	2480	860	2700	780
6	1215	1180	1720	940	1820	880	2160	750	2360	685
5	1100	1080	1480	810	1580	760	1870	650	2050	595
4	885	860	1200	660	1280	620	1530	530	1670	485
3	680	660	930	510	1000	485	1170	405	1290	375
2	465	450	610	335	660	320	780	270	860	250
1	260	250	350	190	370	180	450	155	500	145

Notch	Step 6 0.242 Ohm		Step 7 0.134 Ohm		Step 8 0.121 Ohm		Step 9 0.110 Ohm		Step 10 0.052 Ohm	
	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts	Amps.	Volts
8	3230	780	4300	575	4540	550	4730	520	4880	255
7	2950	715	3950	530	4140	500	4350	480	4570	238
6	2590	625	3500	470	3660	445	3870	425	4300	220
5	2240	540	3000	400	3160	380	3330	365	3900	200
4	1820	440	2470	330	2600	315	2740	300	3400	175
3	1400	340	1900	255	2020	245	2150	235	2800	145
2	950	230	1300	175	1360	165	1430	158	1900	98
1	540	130	740	100	780	95	820	90	900	46

FIG. XI-32. LOADING C36-7 ON EM99 LOADING UNIT.

XI

NOTES:

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NOTES:

XI

TRANSPORTATION SYSTEMS BUSINESS DIVISION
ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

INSTRUCTIONS

TROUBLE-SHOOTING

CONTENTS

FIG. XII-1, E-24459

INTRODUCTION

This section presents trouble-shooting procedure as an aid for correcting locomotive problems to keep the locomotives "on the line." It lists some of the troubles which may occur, along with most probable causes and corrections which will restore normal working order.

The information contained in this guide deals with those problems which could be corrected on the road or at a terminal, with a minimum of time and repair equipment.

Certain problems are related to visual and audible warning indications received by the operator. Causes of some of these indications are common operating failures normal to operation of a road locomotive, yet easily overlooked.

These correction procedures should be performed by qualified personnel having a working knowledge of the overall locomotive systems. Familiarity with the necessary test equipment required to perform these tests and adjustment procedures is also necessary.

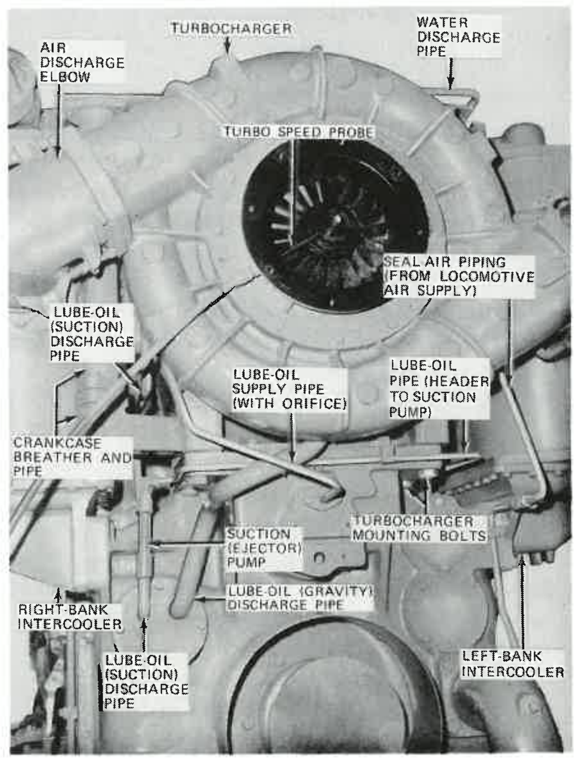

FIG. XII-1. TURBO DETAILS, COMPRESSOR END.

These instructions are intended for the general guidance of assigned personnel. The suggested corrections are stated briefly to enable an experienced maintainer to rapidly scan the lists and pinpoint the necessary correction for a specific trouble. They are not intended to provide an exhaustive treatment of safety precautions or procedures for any individual, experienced or inexperienced, with regard to installation, removal, operation, maintenance or repair of the equipment. In all instances local safety rules should

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GENERAL ELECTRIC

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prevail. Input power should be removed before making changes or connections to all electrical equipment, and air pressure should be released or isolated before changing pneumatic connections.

Before any adjustments are made, proper trouble-shooting should be performed to isolate the problem and identify the need for adjustment.

Adjustment of assemblies or components not covered within this publication may be found in the instructions specifically published for such assemblies or components. For more detailed information on any condition or repair procedure, refer to the locomotive Maintenance Manual.

TROUBLE-SHOOTING PROCEDURE

Trouble-shooting is the process of locating a malfunction and correcting it. Basically, trouble-shooting consists of performing the following steps:

1. Recognizing that a problem exists
2. Analyzing the problem
3. Isolating the problem to a particular system or circuit
4. Further isolating the problem to a particular component or device
5. Making the necessary replacement, repairs or adjustments to place the unit back into proper operation.

Familiarity with the locomotive system schematic diagram and the overall locomotive system operations is required for rapid, logical trouble-shooting.

It is assumed, when trouble-shooting printed circuit cards, maintenance personnel will substitute "good" (spare) cards for suspected malfunctioning cards as a means to isolate the problem to an individual card.

It is assumed that failed and defective cards and devices will be replaced with new or repaired-tested equipment.

Before applying power for trouble-shooting, maintenance personnel should perform a check for wiring faults or grounds.

This section does not cover all malfunction possibilities. It is written to suggest specific functional system tests to aid in trouble isolation and, also, procedures for system adjustments.

SAFETY NOTICE

WARNING: *Electrical shock can cause serious or fatal injury. Proper precautions should be observed by personnel performing the trouble-shooting and adjustments.*

WARNING: *Before removing or dismantling any pneumatic component or pipe joint, the locomotive must be safely parked, and the component or pipe joint must either be isolated by the use of an appropriate cut-out cock, or all air pressure on the locomotive must be vented. Failure to comply with this warning notice could result in physical injury.*

WARNING: *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

CAUTION: *Power should be removed when pulling or replacing electronic cards, to prevent electrical damage to the cards and their contacts in the panel.*

The General Electric Company has made every effort to provide safeguards for all its equipment to reduce hazards to a minimum. However, success in accident prevention can be achieved only through the cooperation of every person conducting these trouble-shooting and adjustment procedures. The most effective methods of preventing accidents during testing of electrical equipment are alertness, caution and safe habits.

In general, the following rules apply:

1. Areas involved in test operations shall be conspicuously identified with suitable warnings.
2. Do not inspect any high-voltage compartment (or compartment identified with a warning sign) when locomotive is energized.
3. Do not remove any component card or device when locomotive is energized.
4. Do not touch motors, switches, protective barriers or other electrical apparatus without being fully instructed as to their use.
5. All circuits not known to be "dead" are to be considered "alive and dangerous" at all times.
6. Air and/or handbrakes on the locomotive must be applied or wheels blocked at all times, except when locomotive movement is required.

TROUBLE-SHOOTING GUIDE

The following procedures are not all-conclusive and should not be used as a substitute for normal railroad trouble-shooting procedures. These procedures are a general guide to be used in addition to the normal railroad trouble-shooting procedures as a further aid to the maintainer. It should also be noted that an overall visual inspection and check procedure is not included but is covered in Section II, "Inspections and Checks."

PRELIMINARY CHECK (ENGINE SHUT DOWN)

When a unit is sitting on the incoming track ready to be brought into the shop, check the following:

1. All available engineer's reports for trouble
2. Check line-of-road reports for reported troubles
3. Check past work reports on the unit for repeats
4. Then go to the unit.

   a. If the engine is shut down on arrival, check the Annunciator Panel and the two holding relays, Engine Temperature Holding Relay (ETHR) and Governor Shut Down Holding Relay (GSDHR), for lit indicator lights and check all safety shutdown devices. Close the battery switch if it is open. If any indicator lights are lit or safety shutdown devices are found tripped, determine the reason and correct. If no lights are lit and none of the devices are found tripped, make a thorough crankcase inspection in all doors looking for dripping water, broken cylinder skirts, scored liners, traces of fine metallic particles on internal surfaces and ledges of the crankcase or signs of heat on any of the main or rod bearing caps. If any of these conditions are found, not only the appropriate repairs on these items may be necessary, it will also require checking items such as the following:

      1) Lube-oil pump bearing housing for signs of heat
      2) Oil in the crankcase for water and/or viscosity out of limits
      3) Water level in the sight glass on the water tank
      4) Fuel pressure by starting fuel pump.

   b. Remove the cylinder valve covers and inspect each cylinder for broken or stuck valves, broken rocker levers or push rods, loose or missing tappet nuts, loose valve keepers, loose locknuts or any unusual condition that may be evident.

   c. If nothing is found up to this point, open the cylinder relief valves and manually bar the engine over two complete revolutions. While barring over, look for water coming out of the relief valves, listen for unusual noises, and "feel" for any binding in the engine. If nothing is observed up to this point, close the cylinder relief valves and carefully try to crank the engine. Do not try to help the engine to start by moving the layshaft manually.

NOTE: *If an engine does not fire within sixty seconds and fuel pump racks do not come out to 11-13 mm while cranking, it probably is not going to start. To avoid running the battery down, do not continue cranking the engine. If permitted by railroad rules, pull the racks on two (only) injection pumps out to "full rack" while cranking. If the engine still does not start, leave it dead and proceed to investigate the possible cause.*

5. Table XII-I lists the most common causes of engine cranking problems and engine shutdown problems. Table XII-II presents a more detailed listing of engine component malfunctions, electrical malfunctions and locomotive systems malfunctions including some "one time only" occurrences. It should be noted that in some cases in Table XII-II, more than one shut-down device is shown as being activated for a particular cause. Although two devices may be activated, only one is required for engine shutdown.

   Also, it should be noted that the POSSIBLE CAUSE column in Table XII-I lists the causes in descending order of probability. Thus, the first cause listed is the most probable cause of the problem and the last cause listed is the least probable cause.

PRELIMINARY CHECK (ENGINE RUNNING)

If the locomotive arrives with the engine running at idle, check the following:

Operator's Cab

1. Engine lube-oil pressure should be 20 psi (minimum).
2. Fuel-oil pressure should be 40 psi (minimum).

TABLE XII-I, ENGINE TROUBLES

Problem	Possible Cause	Correction
ENGINE WON'T START		
Fuel pump won't run.	GSDHR is tripped.	Reset after analysis of fault.
	COP is tripped.	Reset after analysis of fault; see Crankcase Overpressure tripped under Engine Shutdown Devices.
	Shutdown signal has been sent to engine.	Check all other devices including contacts on Emergency fuel shut-off and Engine Stop push-buttons.
Engine won't crank (contactors don't operate).	Fuel pump is not operating.	Reset after analysis of fault.
	Barring Over Switch (BOS) is open.	Replace cover on barring over drive or connect cable.
Engine won't crank (contactors operate).	Start circuit is malfunctioning.	Check brushes and commutators in auxiliary generator and exciter; check cables and start circuit. Also, check for 74 vdc battery voltage.
Engine won't start (governor gap is greater than 1 in.).	Stop signal is being sent to governor.	Move Throttle handle from SHUTDOWN to IDLE position to clear stop signal to the governor speed solenoid (DV).
	One or more engine shutdown devices tripped.	Determine which device(s) is tripped and the cause. See Engine Shutdown Devices.
Engine won't start (governor gap is approximately 3/4 in.; rack setting is less than 10 mm).	Overspeed system malfunction.	Reset if tripped. Check overspeed governor output pressure during cranking. Pressure should not be less than 95 psi. If pressure is less than 95 psi, replace overspeed link and/or governor regulating valve.
	Mis-adjusted overspeed governor.	Adjust overspeed governor.
Engine won't start (governor gap is approximately 3/4 in.; rack setting is 11 to 13 mm.).	Fuel supply low, problem with fuel line or very low fuel pressure.	Check fuel supply and fuel line. If needed, add fuel. Determine and correct the cause of low fuel pressure.
	Timing is incorrect.	Reset timing.
	Cranking speed is too slow.	Check battery condition.
ENGINE SHUTDOWN DEVICES		
Low Oil Pressure (LOP) tripped. (This is an automatic reset.) **NOTE:** *GSDHR will also be tripped. Reset after analysis of fault.*	Low oil level.	Add oil.
	Dirty oil filters.	Replace filters.
	Open filter tank drain-back valve (C).	Close valve.
	Dirty lube-oil cooler (oil side).	Replace cooler tube bundle.
	Dirt in crankcase oil strainer or loose cover.	Replace strainer; secure cover.
	Faulty lube-oil relief valve.	Replace valve.
	Dirty fuel filter or strainer.	Replace filter or strainer.
	Failed (slipping) bonded pump drive.	Replace bonded pump drive.
	Hot oil because of low viscosity.	Determine and correct the cause of low viscosity such as dirty oil filters, dirty lube-oil coolers, and dirty crankcase oil strainer.
	Failed oil pump.	Replace oil pump. Also, examine engine bearing caps and housings for signs of excessive heat; investigate and correct cause.

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TABLE XII-I (Cont'd.)

Problem	Possible Cause	Correction
	Excessively worn engine bearings.	During crankcase inspection look for evidence of bearing metal on all crankcase ledges. Carefully inspect bearing caps for signs of distress.
	Worn governor drive gear box shaft bearings.	Replace bearings.
	Wrong dipstick.	Replace with proper dipstick and recheck oil level.
	During cold weather, oil in the dead-end pipe to the governor's low lube-oil pressure device becomes very thick.	Modify the dead-end piping to bypass. (See GEMS, Volume V, Issue 2 dated Sept. 30, 1977.)
	Defective diaphragm in governor.	Replace diaphragm.
Low Water Pressure (LWP) tripped. (This is an automatic reset.)	Low water level.	Add water. Also, inspect locomotive cooling system for leaks. Remember that the radiators on General Electric locomotives are dry unless the water temperature is high enough to send water to the radiators (with engine running). Inspect the crankcase for cylinder water leaks; check for water in oil.
	Boiling water at pump inlet.	Check for low water level or malfunctioning thermostat (pellet).
	Cooling system not pressurized.	Examine the fill cap for a good gasket, good fit to the fill pipe, and for proper application of the fill cap. Also, check for cracked water tank or sight glass.
	Dirty lube-oil cooler (water side).	Replace cooler tube bundle.
	Lube-oil cooler water inlet screen is plugged.	Remove debris and clean screen.
	Dirty fuel filter or strainer.	Replace filter or strainer.
	Failed (slipping) bonded pump drive.	Replace bonded pump drive.
	Defective diaphragm in the governor pressure switch.	Check for water leakage at the low water pressure switch on the governor; replace diaphragm.
Crankcase Overpressure (COP) tripped.	Oil level too high.	Pull the dipstick and check for oil level being too high. Perform test to check for presence of water in crankcase. Excess level in crankcase may be caused by cylinder seals leaking water. Make a crankcase inspection to look for water dripping from either the inside of the cylinder bore (top seal leak) or from the bottom outside part of the cylinder skirt (lower liner seal leak).
	Cylinder blow-by.	Perform blow-by test to detect defective cylinder or piston; replace defective component(s).
	Plugged or inverted crankcase breather screen.	Clean screen; check for proper installation.
	COP switch out of calibration.	Recalibrate switch.
	Defective switch.	Replace switch.

TABLE XII-I (Cont'd.)

Problem	Possible Cause	Correction
OTHER ENGINE TROUBLES		
Hot engine.	Severe cooling water system-related problem.	Check cooling water system; see items listed under Low Water Pressure (LWP) Tripped. If no fault is found with the cooling water system, tests the LOTS switch. It may not be indicating that a high lube-oil temperature has occurred.
	Failed fan drive.	Check that fan is running. On a General Electric locomotive, the fan always runs while the engine is running.
	Dirty radiator air passages.	Clean radiators.
	Plugged air inlet screens.	Clean screens.
	Dirty lube-oil cooler (either side).	Replace cooler tube bundle.
Engine Overspeed (O/S) tripped.	Stuck control rack linkage.	Remove governor link pin and check control linkage for binding.
	Defective overspeed governor or set too low.	Replace overspeed governor, or reset in place on engine. Overspeed should be set for 1150 engine rpm (1708 rpm at tach drive).
	Injection fuel pump racks stuck open.	Reset racks or reduce linkage binding.
	Defective engine governor.	Replace governor.
Low fuel pressure.	No fuel.	Check fuel in tank; add fuel.
	Dirty fuel strainer.	Clean strainer.
	Suction leak in line.	Locate leak and repair.
	Dirty fuel filter.	Clean filter.
	Defective fuel transfer pump motor.	Replace motor.
	Regulating valve set too low.	Reset valve to 40 psi.
	Relief (safety) valve leaks.	Replace valve.
	Relief (safety) valve set too low.	Reset valve to 75 psi.
Fuel dilution.	Defective nozzle.	Pop-test each cylinder to check for weak and/or not firing cylinder. Repair or replace nozzle.
	Defective fuel injection pump.	Replace fuel pump.
	Cold engine.	Replace thermostat. Clean orifices in pilot valve.

3. All circuit breakers on Engine Control Panel closed or "ON."
4. No indicating lights lit or alarm bells ringing.
5. Battery switch closed.
6. Operator's control console switches set-up for proper operation.
7. Air brakes set-up for proper operation.
8. All air pressure gages at normal.
9. Power Limit (7th Notch) Switch in NORMAL OPERATION position.
10. Reverse handle in NEUTRAL position.
11. Generator Field switch in OFF position.
12. Pop-test all cylinders, and listen carefully for any unusual noises coming from the engine.

Engine Room

1. Sides of engine for fuel, oil or water leaks.

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TABLE XII-II, SUMMARY – CAUSES FOR ENGINE SHUTDOWN

Item	Cause	Result: Low Oil Pressure (LOP)	Low Water Pressure (LWP)	Crankcase Over-Pressure (COP)	Engine Over-Speed (O/S)	Fuel Problem (Fuel)	None
ENGINE							
1.	Low oil level	X					
2.	Failed bearing/bearings	X					
3.	Lube-oil pump failed	X					
4.	Overspeed governor low output pressure	X	X				
5.	Overspeed link failed	X	X				
6.	Low oil diaphragm failed	X					
7.	Low water diaphragm failed		X				
8.	Low engine speeds	X	X				
9.	Stuck racks	X	X		X		
10.	Defective load pot	X	X				
11.	Engine bog due to sticky fuel linkage	X	X				
12.	Low lube-oil viscosity (fuel dilution)	X					
13.	Bonded-rubber pump drive sheared	X	X				
14.	Pipe plug missing from cavity in top of forward-end cover	X		X			
15.	Plugged crankcase breather			X			
16.	Crankcase breather screen inverted (large mesh up)			X			
17.	Broken crankcase eductor			X			
18.	High oil level			X			
19.	Water pump failed		X				
20.	Wrench on layshaft				X		
21.	Failed governor drive						X
22.	Faulty governor	X	X				
23.	Engine overspeed (true overspeed)				X		
24.	False engine overspeed (cover or adjustment screw loose)				X		
25.	Fuel-injection pump rack or fuel linkage stuck	X	X		X		
26.	Faulty overspeed governor				X		
27.	Failed turbocharger	X	X				
28.	Plugged intercoolers	X	X				
29.	Inlet port carbon	X	X				
30.	Cracked piston			X			
31.	Stuck rings or scored liners			X			
32.	Dry piston rings (after extended shutdown)			X			
33.	Cracked piston crown			X			
34.	Wrong piston rings applied			X			
35.	Cylinder water leaks (into crankcase causing oil level to be too high)			X			
ELECTRICAL							
1.	Dynamic braking for long period and at high ambient temperature	X					
2.	Engine won't crank						X
3.	Faulty COP switch			X			

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TABLE XII-II (Cont'd.)

Item	Cause	Result: Low Oil Pressure (LOP)	Low Water Pressure (LWP)	Crankcase Over-Pressure (COP)	Engine Over-Speed (O/S)	Fuel Problem (Fuel)	None
ELECTRICAL (Cont'd.)							
4.	GSDHR tripped						X
5.	Intermittent fuel cut-off switch or ENGINE STOP push-button						X
6.	Emergency shutdown on throttle						X
7.	ENGINE STOP push-button has been pressed						X
8.	Excessive excitation	X	X				
9.	Control grounds	X	X				X
10.	Transition transients	X	X				
11.	Fuel pump relay coil failed						X
12.	Fuel pump motor failed	X	X				
LOCOMOTIVE SYSTEMS							
1.	Blocked oil pan strainer	X					
2.	Cover off oil pan strainer or defective cover gasket	X					
3.	Filter drain-back valve (C) open	X					
4.	Plugged lube-oil cooler (oil side)	X					
5.	Plugged lube-oil cooler (water side)	X	X				
6.	Low water level		X				
7.	Water-tank fill cap missing or loose fit or defective		X				
8.	Water storage tank: defective baffle or splitter, blocked screens, cracks in tank		X				
9.	Water leak		X				
10.	Hot water (causes hot and low viscosity oil)	X					
11.	Relief lube-oil valve set too low	X					
12.	Plugged fuel filter	X	X				
13.	Plugged engine air filters	X	X				
14.	Lube-oil level too high			X			
15.	Wrong lube-oil dipstick	X		X			
16.	Blocked breather pipe at the exhaust stack			X			
17.	Air blow down (at lube-oil filter change)			X			
18.	Leak in oil line between O/S governor and link				X		
19.	Fuel tank empty					X	
20.	Low or no fuel pressure	X	X			X	
21.	Excessive leakage in fuel suction line or in seal of fuel transfer pump	X	X			X	
22.	Ice in fuel tank or fuel strainer, or waxed-up fuel strainer					X	
23.	Plugged lube-oil filter	X					
24.	Wrong exhaust stack			X			
25.	Broken oil pipe	X					
26.	Hot oil	X					
27.	Low or no radiator cooling (dirty radiator, fan stopped, etc.)	X	X				

2. Oil level (at or near full mark).

3. Water temperature gage (150 to 170 F).

4. The water sight level glass (at approximately 170 F, water should be near HIGH at IDLE mark).

5. Water pump for seal leak (check for water drip onto platform).

6. Water fill (pressure) cap is in place.

7. Air compressor for oil leaks.

8. The radiator fan is turning.

9. Dynamic braking grids for burned or open ribbons and broken insulators or barriers.

PRELIMINARY CHECK (COLD WEATHER)

The following checks should be performed to help prevent cold weather trouble and possible road shutdown. These checks are in addition to the normal railroad checks and procedures for cold weather service.

1. Assure there are no breaks in the traction motor air ducts that would permit moisture to enter.

2. Assure there are no breaks in the seals on the control compartment doors that would permit moisture to enter.

3. Assure winter/summer doors are in proper position.

4. Assure fuel heater (if installed) is operating properly.

5. Assure proper oil (for cold weather service) is used in the governor (5W-30 or 10W-30 depending on railroad cold weather service requirement).

6. Assure fuel filters are clean.

7. Assure fuel strainer is clean.

NOTE: *The fuel oil pressure gage must indicate 25 psi minimum in Notch 8 when checked on self-load or the Load Box. If not, recheck cleanliness of fuel filters and strainer.*

8. Assure horsepower is proper for each notch. There should be no engine bogging. If governor modulation occurs, check lube-oil filters for cleanliness. If dirty, replace filters. If horsepower is low, check engine rpm. Also, assure rpm at IDLE is correct. See Note below.

NOTE: *Low idle speed will cause road shutdown when returning to IDLE. Correct speed is 450 rpm; tach drive is 668 rpm.*

9. Assure battery is in good condition and is fully charged.

10. Assure voltage regulator is operating properly (74 vdc at IDLE).

11. If permitted by railroad rules, add alcohol to fuel tank to prevent freezing (usually one gallon of alcohol per 1000 gallons of fuel).

12. If engine cranks without starting, check the overspeed link. The overspeed governor pressure may reach 200 psi. If the link becomes fully compressed at a greater psi than 120 or does not fully compress, replace the overspeed link. If the pressure is less than 95 psi, replace overspeed governor regulating valve.

NOTE: *Oil pressure during cranking (without manual rack assist) should not be less than 95 psi or less than 175 psi when engine reaches IDLE speed. An oil pressure of 200 psi, or higher, is considered standard. (See GEMS, Volume III, Issue 4 dated December 10, 1974.)*

NOTE: *If the equipment has been properly maintained and the above 12 steps have been performed satisfactorily, a single man start from the operator's cab will be possible.*

ENGINE RUN CHECK

After the Preliminary Check(s) have been completed and if everything appears to be normal up to this point, proceed with the following:

1. Run the engine up to the eighth Throttle notch (no load) and read all gages for normal settings. Return the Throttle handle to IDLE.

2. If everything still appears to be normal, set locomotive brakes, set-up for power, open throttle to Notch 1 and check that loadmeter reads up scale to normal Notch 1 current (approximately 300 amps.). Return the Throttle handle to IDLE.

If reasonably sure that there are no malfunctions with the engine, proceed with the electrical and locomotive systems checks.

TABLE XII-III, EXHAUST SMOKE ANALYSIS

Indication	Possible Cause	Correction
Black smoke puffs.	One or more defective injectors.	Recondition or change the defective injector.
	Fuel pump rack is stuck.	Free the rack or change the pump.
	Fuel pump rack is set too high.	Locate the high rack and readjust.
	Fuel pump is out of time.	Adjust timing.
	Worn or damaged turbocharger.	Repair or replace the turbocharger.
	Broken or leaking manifold pipes.	Repair or replace the manifold.
	Engine speed is bogging down.	Check the engine operation and circuits for fault.
	Turbocharger is surging.	Inlet ports partially blocked or turbo misassembled (check nozzle ring and diffuser). Clean inlet ports, if dirty.
	Turbocharger rotor is stuck.	Replace turbocharger.
White smoke puffs.	Fuel pump is out of time.	Adjust timing.
	Cylinder with valves burned or stuck open.	Replace cylinder.
	Engine is too cold.	Wait until engine warms up.
	Cylinder with low compression.	Replace cylinder.
	Fuel system is air bound.	Bleed the fuel system.
Blue smoke exhaust and oil out the stack.	Failed turbocharger bearings and seals.	Replace turbocharger.
	Worn or broken piston rings.	Replace rings.
	Cracked piston crown.	Replace piston and rings.
	Scored liner.	Replace cylinder and rings.
	Prolong operation of the engine at IDLE.	Load engine and condition should clear-up.
Steady smoky exhaust stream.	Worn or leaking injectors.	Change the injectors.
	Late pump timing on all cylinders.	Time the engine pumps.
Water out of stack.	Cylinder seal leaks, cracked turbo, etc.	Locate and correct.
"Blow" in exhaust system.	Broken exhaust manifold section.	Repair or replace the manifold or manifold section.
	Valve tappet clearance is insufficient.	Readjust.
	Cylinder valve is stuck open.	Replace cylinder.
	Cylinder valve seat is "guttered."	Replace cylinder.

LOADING UNIT OR SELF-LOAD CHECK

It is assumed all controls and devices are properly set and an inspection of items such as water level, oil levels and battery voltage, have been performed.

NOTE: *For detailed instructions, refer to Section XI of this composite manual.*

Start engine, run at IDLE and check:

1. Lube-oil pressure (25-35 psi with water at normal temperature).
2. Fuel pressure (approximately 40 psi).
3. Smoke from stack (Table XII-III).
4. Sound from engine such as heavy pound, rap, knock or clatter (audible indicators of trouble).
5. Pop-test cylinders and observe exhaust for smoke (Table XII-III).
6. Voltage regulator volts (73.5-74.5 vdc).
7. Water, fuel and oil leaks.
8. Governor oil for proper level and cleanliness.
9. Rack readings of fuel injector pumps.

Slowly move Throttle handle to Notch 8 and check:

1. Lube-oil pressure (90-115 psi, or higher if oil is cold).
2. Fuel pressure (25-36 psi).
3. Turbo air pressure (20-32 psi; pressure will vary with atmospheric pressure and temperature).
4. Water temperature (170-180 F).
5. Engine air filter service indicator not tripped.
6. Brake cylinder pressure (45 psi minimum).
7. Cycling of air compressor.
8. Exhaust smoke (Table XII-III).
9. Air flow out of radiators (no debris or dirt in air passages).
10. Air manifold leaks including turbo elbows.
11. Exhaust manifold leaks.
12. Water tank sight glass for traces of oil or carbon.
13. Governor load pot position (at maximum field).
14. Power, voltage and current from CHEC Panel test points to check loading and excitation.

Move Throttle handle to IDLE, then move it to Notch 8 and observe:

1. Exhaust smoke (Table XII-III).
2. Time required for full horsepower.
3. Engine speed stability (hunting).

Move Throttle handle to IDLE and then perform engine shutdown procedure.

HORSEPOWER TROUBLE

No Horsepower (Engine Running)

Open throttle to see that engine responds, contactors pick-up, and loadmeter indicates up-scale. If engine does not respond to notch speeds, check engine controls to ensure that all breakers and switches are in proper operating position. Also, check the output of the voltage regulator panel for 74 vdc battery charging voltage.

Shut the engine down:

1. Inspect throttle control wiring for continuity
2. Check that governor solenoids are operating properly
3. Check that governor plug is properly seated.

If the engine responded to the throttle but no load, shut the engine down and check:

1. Exciter brushes
2. Alternator slip ring brushes, or generator brushes
3. Control air pressure
4. Contactor and relay sequence
5. Assure Generator Field, Control and Excitation breakers are closed.

Then crank the engine and, under no load condition, check the output from the alternator/rectifier circuit (GA and GN wires) with the engine at IDLE and at Notch 1 thru Notch 8 positions.

NOTE: *Refer to the Rectifiers, Exciter, and Alternator sections of the applicable locomotive schematic for location of test points to measure GA/GN voltage. A 1500 vdc meter is needed for this test. Voltage readings at Notch 8, no load, will vary from 1200 vdc to 1500 vdc depending on model of locomotive. Refer to Load Testing, Section XI, for voltages for each model of locomotive.*

Excitation panel cards:

A quick check here involves setting locomotive up to load and open throttle to Notch 1. With a voltmeter check signal from throttle stand, governor, etc., through the excitation system until the signal is lost; then go back one step and find the trouble.

Low Horsepower (Engine Running)

Check:

1. Power Limit switch is in NORMAL position.
2. Motor cut-out switch for "ALL-IN" position
3. Engine is not smoking and sounds normal
4. Reduced excitation indicator light on EC panel and on Annunciator Panel is not lit.

Shut the engine down:

1. Check that rack linkage is not binding

2. Visually inspect engine for evident defects (manifold leaks, disconnected fuel pump control links, etc.)

3. Check paper air filter "Red Flags" for dirty air filters.

Start the engine and advance throttle to about one-half speed (no load) and check:

1. That overspeed link is fully compressed

2. Turbo discharge piping and fitting and the intake manifold for leaks (you will be able to feel and, perhaps, see or hear them)

3. Remove plug from bottom of the turbo-compressor casing and feel that the air is pulsing out of the hole with no oil or water present – if okay, replace plug – if not, further investigation of the turbo will be necessary.

With the engine running top speed (no load), check fuel pressure (assuming the gage is not defective). If there is more than a three pound difference between IDLE and top speed readings, the engine is probably not receiving sufficient fuel under load conditions. Determine why; e.g., dirty fuel filter or strainer, low regulator settings, etc.

If the problem develops between 20 to 30 mph, check transition settings with test set.

If nothing is found up to this point, the unit should be connected to the load box or self-load for further checks. Refer to Load Testing, Section XI. One thing to remember is that under load conditions:

1. If the load pot is below maximum field, the problem is usually mechanical

2. If at maximum field, the problem is usually electrical

3. If the horsepower is high, there may be both mechanical and electrical problems.

XII

TURBOCHARGER TROUBLE

General

When mounted in the locomotive, the turbocharger, Fig. XII-1, is a difficult piece of equipment to check quickly and qualify for continued service. The turbocharger is frequently judged to be faulty on the basis of operating crew reports or on the basis of symptoms noted while the locomotive is being operated during the inspection process. While the symptom noted may identify a defective turbocharger, it has frequently happened that the same symptom applies to other faults on a locomotive, so many turbochargers are replaced unnecessarily. Refer to Table XII-IV for examples of symptoms showing multiple faults.

Inspection On Locomotive

The preferred method of qualifying a turbocharger for continued service is to observe it (and its effects) while load-testing the locomotive. Load-testing (refer to Load Testing, Section XI) should only be performed after first establishing the following items are functioning and correct:

1. Fuel pump racks – correctly set and equal
2. Fuel pumps – properly timed
3. Fuel-injection pumps and nozzles – all must function
4. Air-intake and exhaust manifolds – free of leakage
5. Valve tappet clearance – correctly set
6. Fuel filter and engine air filters – cannot be plugged
7. Fuel linkage – free moving
8. Excitation circuits – must be in good order and capable of being adjusted.

When under FULL LOAD and in Notch 8, observe turbocharger air pressure, color of exhaust gases, governor load pot action, and check the turbocharger for oil and water leakage and mechanical distress. Use Table XII-IV to identify a faulty turbocharger or other locomotive component.

When it is not possible to load test the locomotive, perform the following turbocharger check, with the locomotive shut down:

1. Working down thru the stack, use a flashlight and a mirror positioned to observe the turbine-disk blades, Fig. XII-2. While observing the blades, use a hook tool, made from 1/8-in. diameter stainless steel, to lift and rotate rotor thru one complete revolution. Examine all blades for possible damage caused by foreign material, and check rotor for free rotation. Performing this operation will often break up carbon build-up (which causes reduced rotor speed) and allow continued use of the turbocharger.

2. Remove the clamps, flexible duct, and air duct from the compressor end of the turbocharger, Fig. XII-3. Manually turn the rotor, and note that rotor is free to rotate. Set up a dial indicator and move the rotor, as required, to check the axial and radial clearance.

TABLE XII-IV, TROUBLE-SHOOTING THE TURBOCHARGER

Crew Report Or Symptom	Actual Turbocharger Fault	Possible Cause Of Turbocharger Fault	Other Possible Locomotive Faults
Black smoke out stack (steady-state).	- Rotor not turning. - Rotor turning at reduced speed.	- Rotor damaged by foreign object - Excessive carbon build-up between turbine seal and disk - Failed bearings - Failure of rotor turbine disk or compressor wheel - Compressor wheel or turbine disk rubbing	- Injection pumps not properly timed - Faulty fuel injection pumps and/or nozzles - Excessive carbon build-up in air intake ports - Dirty intercoolers - Plugged engine air filters - Leakage in air-intake manifold - Faulty excitation circuit adjustments or components
Not loading or low on power.	- Rotor not turning. - Rotor turning at reduced speed.	- Rotor damaged by foreign object - Excessive carbon build-up between turbine seal and disk - Failed bearings - Failure of rotor turbine disk or compressor wheel - Compressor wheel or turbine disk rubbing	- Dirty or plugged fuel filter - Fuel pump racks set incorrectly - Valve tappet clearance set incorrectly - Leak in manifold line to governor - Also, see faults listed above for "Black smoke out stack"
Blue smoke, and oil, out stack.	- Failed bearings and/or seals.	- Pipe plug missing in upper cavity of forward-end cover - Wrong size orifice in lube-oil supply pipe - Rotor unbalance	- Worn or broken piston rings - Cracked piston (crown) - Scored liner
	- Seal air passage plugged with carbon. - Labyrinth in turbine-end seal plugged with carbon.	- Prolonged operation of engine in idle and lower speed notches	
Low turbocharger air pressure (At Notch 8, FULL LOAD).	- Rotor turning at, reduced speed.	- Excessive carbon build-up between seal and disk - Defective bearings - Compressor wheel or turbine disk rubbing	- Leakage at air discharge elbows or in air-intake manifolds - Leakage in exhaust manifold - Faulty gage - Also, see faults listed above for "Low on power"
Low turbocharger air pressure (At less than Notch 8, FULL LOAD).	Possibly, no fault. Turbocharger air pressure is not indicated until in Notch 6, and above, and under load. There is no indication when in dynamic braking.		

Refer to Data section and Torque Values section for limits.

> **WARNING:** *When using compressed air for cleaning purposes, an environment potentially hazardous to personnel in the immediate area is created. To prevent physical injury by flying debris, observe all Railroad and OSHA safety regulations.*

3. Check for plugged seal-air passages. Disconnect the seal-air pipes and apply shop air into the seal-air passages in the turbine casing. If passages are clear, the sound of escaping air will be heard at the stack outlet. This operation can often clear a partially-blocked passage.

4. Check visually for evidence of mechanical damage, excessive heat and water leaks.

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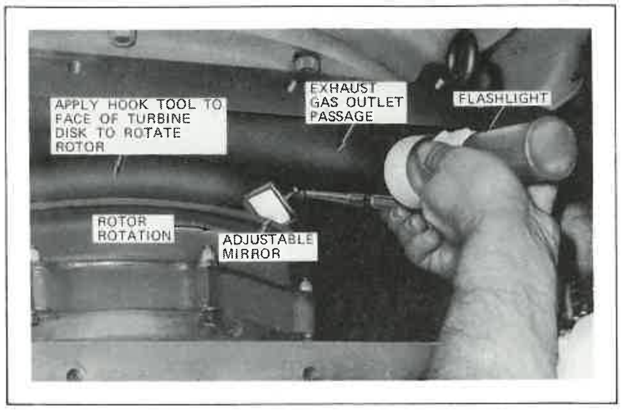

FIG. XII-2. INSPECTING TURBINE-BUCKET BLADES.

FIG. XII-2, E-23320

Data

	English	Metric
Weight, turbocharger	1470 lb.	667 kg
Rotor, end-play:		
New	0.013-0.021 in.	0,330-0,533 mm
Max. worn	0.025 in.	0,635 mm
Rotor, diametral clearance in bearings:		
New	0.003-0.0055 in.	0,076-0,140 mm
Max. worn	0.0065 in.	0,165 mm
Speed pick-up probe to cap, clearance	0.028-0.090 in.	0,711-2,286 mm
Oil-supply pressure, measured at turbine-casing inlet, with oil at normal operating temperature of 160-190 F (71-88 C),		
with engine at IDLE	10-20 psi	69-139 kPa
with engine at N8	15-40 psi	103-276 kPa

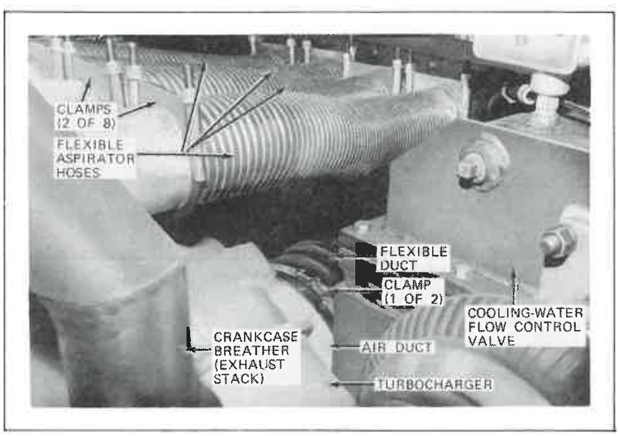

FIG. XII-3. TURBO INSTALLATION DETAILS, COMPRESSOR END.

FIG. XII-3, E-24460

Torque Values

	Lb.-Ft.	N·m
Bolts, turbocharger mounting	150-165	203-224
Bolts, stack clamping	55-60	75-81
Bolts, exhaust manifold to turbocharger	70-75	95-102
Nuts, stud-locking and ear-clamping, air-discharge elbows	55-60	75-81
Bolts, flange to intercooler	35-40	47-54

MODULATING CONTROL GOVERNOR TROUBLE

The modulating control governor is an electro-hydraulic device used to regulate speed and horsepower output of the diesel engine. It also includes a number of auxiliary devices such as a Water Pressure Switch (WPS) and an Oil Pressure Switch (OPS) to protect and provide the power plant with characteristics desirable for railway locomotive service.

These characteristics, devices and operational events are shown in Fig. XII-4. This figure consists of four tracking charts that show normal and abnormal operating events and what action should be taken to correct the abnormal events. The four tracking charts are:

1. Normal Conditions – Power
2. Engine Start
3. Normal Conditions – Dynamic Brake
4. Hot Engine Controls.

CHEC EXCITATION SYSTEM TROUBLE

The major component in the CHEC excitation system is the FL138 Excitation Panel. Therefore, emphasis has been placed on the trouble-shooting of the panel.

Table XII-V lists the ten cards in the panel and their function. The first nine cards are the same in all panels for the different models of General Electric locomotives. The tenth, or Reference Card, is different for each model of locomotive and for each model of the FL138 Excitation Panel (Table XII-VI).

NOTE: *The maintainer should not assume, for example, that all C30-7 Locomotives will have the same model of the FL138 panel and, thus, the same type of Reference Card. The model of the FL138 Panel installed on the C30-7 Locomotive depends on the type of turbocharger installed.*

CAUTION: *Power should be removed when pulling or replacing electronic cards, to prevent electrical damage to the cards or their contacts in the panel.*

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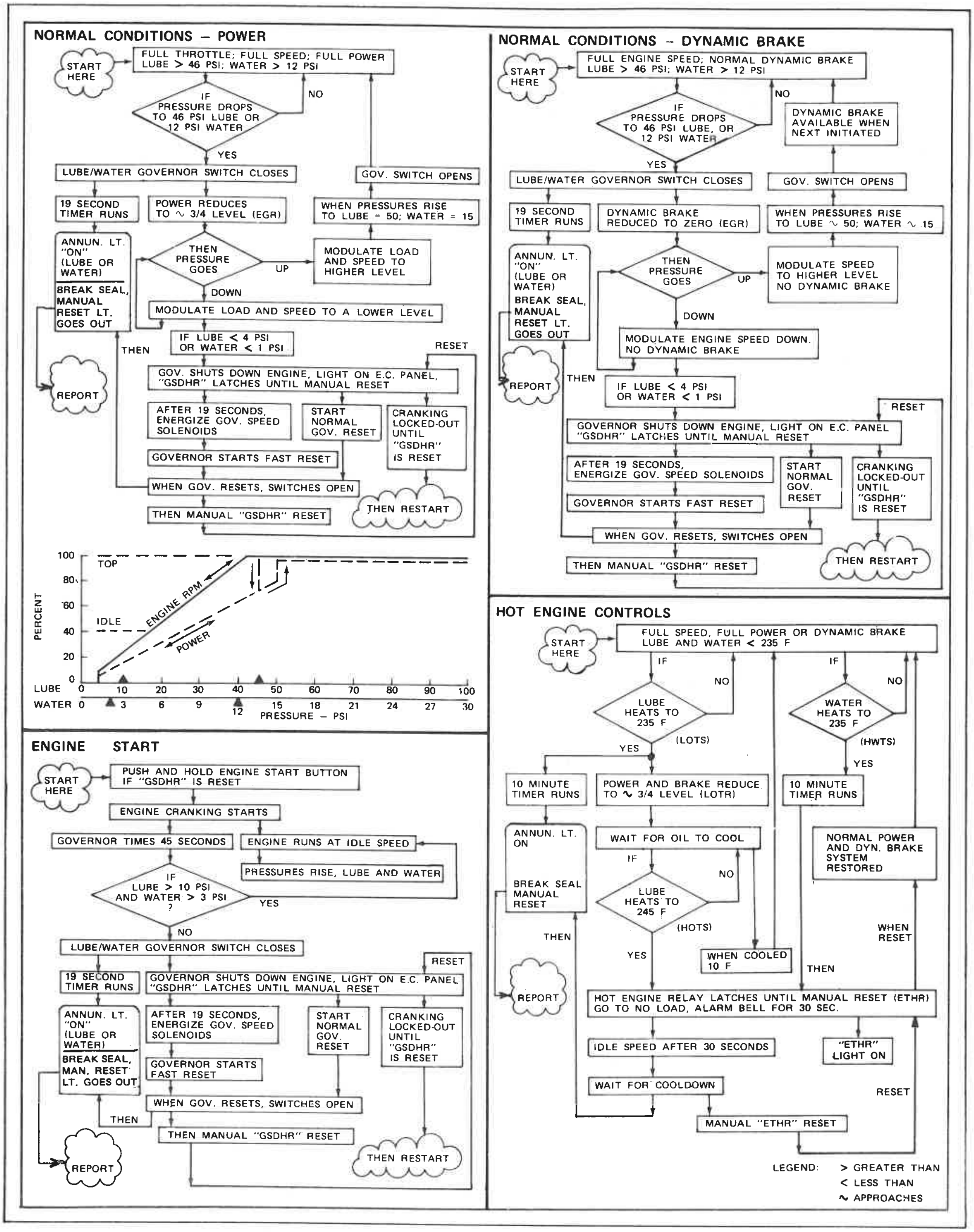

FIG. XII-4, E-24665

FIG. XII-4. ENGINE MODULATING GOVERNOR TRACKING CHARTS.

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TABLE XII-V, CARD DATA AND FUNCTION

Position (Left to Right)	Card Symbol	Card Title	Card No.	Card Function
1	TC	Test	FD732	Card reserves the left contact strip in panel for replacement by CHECKIT plug during system tests or checks. No components are mounted on it; however, it has interlock wiring, and must be in place unless CHECKIT is plugged in.
2	FT	Field Control*	FD733	Provides a variable current to the shunt field of the exciter (GY27).
3	MD	Modulator	FD734	Controls the variation in the shunt field current.
4	MP	Multiplier	FD735	Generates the power signal by multiplying the voltage and current signals supplied to it.
5	TS	Turbo Speed	FD736	Generates a signal proportional to turbo-rotor speed.
6	CP	Comparator	FD737	Determines which of the various signals will control the locomotive power output or the amount of dynamic braking effort developed.
7	FL	Filter	FD738	Smooths signals from ACCR, BCCR and VCR reactors and furnishes two signals to comparator card.
8	OS	Oscillator	FD739	Generates a 400 Hz signal to excite the three reactors (ACCR, VCR, BCCR) and supplies power to the RG card.
9	RG	Regulator	FD740	Supplies regulated positive and negative 15 volt power for certain cards and has four relays which repeat the Throttle command on MU trainline wires.
10	RF	Reference	FD–– (See Table XII-VI).	Presets the power, current and voltage limits for each Throttle notch, furnishes a power match signal when specified, and modifies turbo speed signal.

*The FD733 Card (FT) is sometimes referred to as the Field Transistor Card, Field Switch Card, or Field Control Card.

Table XII-VII presents a procedure for qualifying the locomotive for service. This procedure is a visual check which can be performed without test equipment.

It is suggested that the maintainer use a CHECKIT diagnostic analyzer for the convenient checking of the overall electrical excitation system. With the CHECKIT cord plug inserted in the FL138 panel in place of the FD732 Test Card (TC), the maintainer can observe the operation of the CHEC excitation system during normal locomotive road operation or during load testing. Detailed test instructions are included with the CHECKIT.

TABLE XII-VI
REFERENCE CARD ASSIGNMENTS

Locomotive Model	Reference Card	Panel Model
B18-7	FD894	17FL138K2
B23-7	FD867	17FL138H2
B23-7	FD897	17FL138T2
C23-7	FD868	17FL138J2
B28-7	FD895	17FL138L2
C28-7	FD896	17FL138M2
B30-7	FD862	17FL138B2
C30-7	FD741	17FL138A2
C30-7	FD1146	17FL138N2
C30-7	FD1202	17FL138X2
B33-7	FD864	17FL138D2
C33-7	FD863	17FL138C2
B36-7	FD866	17FL138F2
C36-7	FD865	17FL138E3

However, if a CHECKIT is not available, refer to Table XII-VIII. This table lists the trouble symptom and the possible cause. Substituting an "assumed good" card for a suspected malfunctioning card is the fastest method of trouble-shooting the panel. If the problem still cannot be resolved after checking the possible cause in Table XII-VIII, perform a load box check or, if the locomotive is so equipped, a self-load check. For detailed instructions, refer to Load Testing, Section XI.

Table XII-IX is presented as an additional aid to the maintainer. The table lists the test points on the cards in the FL138 CHEC Excitation Panel. These test points are color-coded as follows:

1. Black – Common
2. Blue – D-C signal voltage from measuring device
3. Orange – +15 vdc power supply
4. White – –15 vdc power supply
5. Brown – Throttle notch
6. Yellow – A-C, usually for oscilloscope use
7. Green – D-C reference voltage.

TABLE XII-VII, PROCEDURE FOR QUALIFYING LOCOMOTIVE FOR SERVICE

Step	Event	Engine Shutdown	Engine Running
1.	Check locomotive EC panel for a lit REDUCED EXCIT. indicating light. a. If lit, the locomotive is in the reduced excitation mode. Open the Control Compartment door and press the Toggle switch on the MD card to RESET. b. Indicating light will go out with operation of Reset Switch on MD card. c. To verify whether fault remains or has cleared, locomotive must be set for motoring, air brakes set, reverser thrown, GF in ON position, EC switch in RUN position and isolate all other units. d. Move Throttle handle to Notch 1, until unit starts to load. e. When indication of loading is observed on loadmeter of the locomotive, return Throttle handle to IDLE and note whether indicating light is now lit. If the light is not lit, the fault has been cleared. f. If indicator relights, go to the Control Compartment and check all cards for proper location and assure they are securely plugged in the panel.		X (Run)
2.	The two red LED lights on the RG card (FD740) should be ON when the +15 vdc and −15 vdc power supplies are functioning. If not, change out this and/or the OS card (FD739).	X	X (Start or Run)
3.	Move the Toggle switch on MD card (FD734) to TEST position to simulate a fault, causing the panel to go to the reduced excitation mode. The red LED on this card (Field Switch Light) should come on and stay lit until Toggle switch is moved to the RESET position. As the switch is moved, you should hear the EF relay operate.	X	X (Start or Run)
4.	Check terminals for loose connections and wires for charred or discolored insulation. Replace any damaged wires or hardware and tighten any loose connections. **CAUTION:** *The eight panel-mounted potentiometers are factory sealed and should not be tampered with, otherwise equipment may be damaged.*	X	X (Start)
5.	Check that cards are in their assigned locations and that card numbers agree with panel numbers.	X	X (Start or Run)
6.	Check that the RF (tenth) card is the proper one for the model of locomotive on which installed.	X	X (Start or Run)

CMR WHEELSLIP SYSTEM TROUBLE

Introduction

If a locomotive has a report of CMR wheelslip system trouble, this guide will assist in locating and correcting the problem. The guide consists of Table XII-X, Fig. XII-5, Fig. XII-6 and specific trouble-shooting procedures.

Table XII-X presents a listing of specific problems that are fairly common. If the system trouble is not specific or it cannot be located in Table XII-X, proceed to Fig. XII-5. This figure presents a programmed approach to trouble-shooting the problem. Observe the initial conditions specified in Step 1 of Fig. XII-5 and proceed step by step to isolate and correct the problem. When abnormal operation occurs, the horizontal line shown by the applicable step on Fig. XII-5 will reference a specific trouble-shooting procedure for restoring normal operation. Fig. XII-6 consists of a graph for plotting axle alternator output frequency or axle rpm versus train speed.

NOTE: *The Current Measuring Reactors (CMR's) used on Series-7 Locomotives are color-coded red or white (from two different vendors). These CMR's are mechanically and electrically interchangeable and may be mixed on any locomotive. The customer should not replace the red or white CMR's with any black CMR's that he may have in stock. These black CMR's are not electrically interchangeable with red or white ones.*

Procedures

A. Problems With Step 1

The problem is with transistor Q1. On a six-axle locomotive, replace the FD1154 Card located in the

TABLE XII-VIII
CHEC EXCITATION SYSTEM TROUBLE

Symptom	Possible Cause	
	Excitation Panel	External Circuits
No power in any notch.	RG, MD, FT, or RF card defective.	Open exciter shunt field circuit. Worn-out or broken exciter brushes. Governor plug not in place. GF, GFA open.
Very little power in any notch.	FT or TS card defective.	Open exciter shunt field circuit. No signal of turbo speed.
Less than normal power in most or all notches.	TS or MD card defective.	Fuel filter partially blocked or fuel suction leak (LCP will be at minimum). Low battery voltage. One magnet missing from turbo rotor.
Normal power and current in some notches; higher or lower than normal in others.	RF or RG card defective.	Open circuit in wires to coil of relays RLA, RLB, RLC, or RLD on RG card. Failure of these relays to operate properly.
Excessive current in all notches.	OS or CP card defective.	Open OVDR resistor. Open secondary in ACCR. Shorted VCR. No feedback from ACCR and/or VCR.
Load Control Potentiometer reads toward minimum field.	MP card defective.	
No or very low braking current.	CP card defective. Open P5 or P6 potentiometer in adjustment module.	Open feed wires to positive end of braking potentiometer. Open feed wire to EXP-AB terminal. Shorted RFC3 or AMC1 capacitor. Open motor field circuit. Open grid circuit (with CMR). Wrong CP2 contactor sequence.
Maximum braking in any handle position.		Open connection to negative end of braking potentiometer.
Braking current in red zone of loadmeter.	OS or CP card defective.	Open BCCR control winding.
Dynamic braking current hunts.	MD card defective.	Open circuit to L2 reactor in excitation panel

TABLE XII-VIII (Cont'd.)

Symptom	Possible Cause	
	Excitation Panel	External Circuits
Dynamic braking works in one direction of locomotive movement, but not in other.		Reverser not completely throwing, perhaps due to leaking air lines or defective magnet valves.

FL80 CMR Wheelslip Panel. On a four-axle locomotive, replace the FD1155 Card located in the FL84 CMR Wheelslip Panel.

Proceed to Fig. XII-5, Step 2.

B. Problems With Step 2

WSX relay is not picking-up. Look for grounds or short circuits. If none are found, replace WSX relay located on CMR wheelslip panel.

Proceed to Fig. XII-5, Step 3.

C. Problems With Step 4

At this point, several possible things could be the cause of the trouble. Therefore, it is necessary for further testing to determine where the fault is located.

1. Return the Throttle handle to IDLE, center the Reverse handle and place the Alternator (Generator) Field (GF) circuit breaker to OFF.

2. Equalize the wheelslip panel inputs from the CMR's by jumpering the following terminals together.

   a. On the FL80 Panel (six-axle locomotive), jumper terminals C-D-E-F-G-H.

   b. On the FL84 Panel (four-axle locomotive), jumper terminals C-D-E-F.

3. Pump-up the air brake system and set the locomotive brakes.

4. Place GF breaker to ON, move Reverse handle to FORWARD or REVERSE and advance Throttle handle to Notch 1.

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TABLE XII-IX, CHEC CARDS TEST POINTS

Card Symbol	Card No.	Test Point	Test Point Title	Remarks
TC	FD732	None		
FT	FD733	TP1	SWITCH OUTPUT	Measures Q4 output.
		TP2	COMMON	
MD	FD734	TP1	MODULATOR OUTPUT	
		TP2	COMMON	
MP	FD735	TP1	POWER 300 KW/VOLT	Negative voltage; see Note 1.
		TP2	COMMON	
TS	FD736	TP1	TURBO SENSOR	A-C voltage; turbo speed signal.
		TP2		
		TP3	TURBO 2150 RPM/V	
		TP4	COMMON	
		TP5	POWER REFERENCE	
		TP6	TURBO	
CP	FD737	TP1	I REFERENCE (MOTORING)	Alternator current.
		TP2	V REFERENCE (MOTORING)	Alternator voltage.
		TP3	GRID REFERENCE (BRAKING)	Braking grid current.
		TP4	FIELD REFERENCE (BRAKING)	Braking field current.
		TP5	MODULATOR BIAS	Comparison junction.
		TP6	COMMON	
FL	FD738	TP1	ACCR 600 A/V	Alternator current; see Note 2.
		TP2	VCR, BCCR, MOTORING 150 V/V BRAKE 100 A/V	Alternator volts; see Note 2; braking current.
		TP3	COMMON	
OS	FD739	None		
RG	FD740	TP1	+15 VDC	Regulated supply.
		TP2	−15 VDC	Regulated supply.
		TP3	COMMON	
		TP4		Not used.
		TP5	LOAD POT BRUSH ARM	Governor load pot voltage.
RF	(See Table XII-VI)	TP1	NOTCH 1	
		TP2	NOTCH 2	
		TP3	NOTCH 3	
		TP4	NOTCH 4	
		TP5	NOTCH 5	
		TP6	NOTCH 6	
		TP7	NOTCH 7	
		TP8	NOTCH 8	
		TP9	POWER	
		TP10	COMMON	

NOTE 1: *Horsepower into alternator for traction can be calculated as follows: TP1 volts x 424 = horsepower.*

NOTE 2: *Horsepower into alternator for traction can be calculated as follows:*

$$\frac{TP1\ volts \times TP2\ volts}{708} = horsepower.$$

NOTE 3: *All measurements are 15 vdc or less except FD736 Turbo Speed Card test points TP1 and TP2 which are a-c. Use 100,000 ohms per volt meter, or higher.*

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TABLE XII-X, CMR WHEELSLIP SYSTEM TROUBLE

Symptom	Possible Cause	Correction
At standstill, false wheelslip indication when Throttle handle is moved from IDLE to Notch 1.	Bad wiring at CMR.	Look for loose joints or connections, smoke, heat or other possible clues. Otherwise start with Step 4, Fig. XII-5.
	Wrong motor contactor sequence.	
	Slipped pinion.	
	Open circuit in traction motor.	
	High resistance connection in one of the power circuits.	
	Disconnected motor cable.	
Continuous wheelslip indication when speed reaches a little over one mph.	Locked traction motor.	Check motor rotation.
	Improper motor connections.	Check motor connections.
	Wrong gearing on one or more axles.	Check gearing.
	Wide variation in wheel diameter (more than 1 in.).	Compare wheel diameter.
	Compression bolts not removed from traction motor nose mounts.	Check for compression bolts. Otherwise start with Step 4, Fig. XII-5.
Continuous wheelslip indication at or above certain locomotive speed (usually 50 mph or higher).	Overspeed detection set too low (FD406 Card).	Start with Step 4, Fig. XII-5.
	Wide variation in wheel diameter (more than 1 in.).	Compare wheel diameter.
Continuous wheelslip indication during dynamic braking but not during motoring.	Open braking grid circuit.	Look for grid burned open or disconnected cable. Otherwise begin with Step 9, Fig. XII-5.
Brief wheelslip indication at transition.	Sensitivity set slightly too low. Contactor action is a little slow.	This is not an abnormal condition provided it does not get worse. If it does, start with Step 4, Fig. XII-5.
Brief wheelslip indication at low speeds while in dynamic braking.	Extended range braking contactors not coming in at the same time.	This is not abnormal provided it does not get worse. If it does, start with Step 4, Fig. XII-5.
Steady wheelslip indication at certain speed while in dynamic braking.	Extended range contactors did not operate properly.	Check contactors. Otherwise start with Step 9, Fig. XII-5.
No wheelslip indication with slips known to exist.	Current transformer (CT) failure WSX defective.	Start with Step 1, Fig. XII-5.

5. The FD406 Card located on the FL80 Panel (six-axle locomotive) and on the FL84 Panel (four-axle locomotive) has five test points numbered 1, 2, 3, 4 and Common. The FD408 Card located on the FL80 Panel (six-axle locomotive) has three test points numbered 5, 6 and Common.

   Check voltage between test points 1, 2, 3, 4 and Common on the FD406 Card (and 5, 6 and Common on the FD408 Card, if applicable) with a voltmeter. The meter scale should be selected to read d-c volts between 24 and 30 volts (4 volts for every 100 amperes on the loadmeter in the cab). The maximum difference should not exceed 3 volts, or 7 percent variation from highest to lowest.

6. Proceed with Case No. 1.

NOTE: *Several possible things could be the cause of the trouble. To simplify trouble-shooting, the fault situation has been presented in three "Cases": Case No. 1, Case No. 2 and Case No. 3.*

<u>Case No. 1</u>

If the CMR wheelslip system activates (WSL light is lit, sanding occurs and there is a reduction of excitation), then proceed to Case No. 2. If the CMR wheelslip system does not activate, the problem is localized to the external portion of the CMR system. Proceed with the following:

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FIG. XII-5, E-25410

STEP 1

INITIAL CONDITIONS:
1. ENGINE AT IDLE
2. REVERSE HANDLE CENTERED
3. GF BREAKER OFF

CMR WHEELSLIP SYSTEM OPERATES – CONTINUOUSLY → GO TO PROCEDURE A

NO CMR WHEELSLIP SYSTEM ACTIVATION ↓

STEP 2

JUMPER LEVEL TEST POINT ON FD1154 (OR 1155) CARD TO THE COMMON TEST POINT OF SAME CARD.

WSL DOES NOT COME ON → GO TO PROCEDURE B

WSL COMES ON (WSX IS GOOD) ↓

STEP 3

REMOVE JUMPER.

GO TO STEP 4.

STEP 4

1. PUMP UP LOCO. AIR BRAKE SYSTEM
2. SET BRAKES
3. PLACE GF BREAKER TO ON
4. MOVE REVERSE HANDLE TO FORWARD OR REVERSE
5. MOVE THROTTLE HANDLE TO NOTCH 1.

CMR WHEELSLIP SYSTEM OPERATES → GO TO PROCEDURE C

NO CMR WHEELSLIP SYSTEM ACTIVATION ↓

CAUTION: *TO AVOID MOTOR DAMAGE, DO NOT HOLD MOTOR CURRENT LONGER THAN 1 MINUTE.*

STEP 5

PLACE TEST TOGGLE SWITCH ON CMR PANEL TO TEST AND HOLD FOR 5 TO 10 SECONDS.

NO OR OTHER RESPONSE → GO TO PROCEDURE D

WSL FLASHES CONTINUOUSLY, SANDING OCCURS, AND LOADMETER DROPS TO LOWER LEVEL AS LONG AS SWITCH IS HELD. (LEVEL CIRCUIT IS GOOD.) ↓

STEP 6

1. RETURN THE THROTTLE HANDLE TO IDLE. CENTER THE REVERSE HANDLE; AND PLACE GF BREAKER TO OFF.
2. APPLY TEMPORARY JUMPER FROM THE WHEELSLIP PANEL TERMINAL BOARD TERMINALS:
   AP TO AR ON 6-AXLE LOCOMOTIVES
   AC TO AD ON 4-AXLE LOCOMOTIVES

   NOTE: *THE JUMPER NULLIFIES THE LEVEL CONNECTION IN THE EXCITER SHUNT FIELD CIRCUIT. RATE REMAINS.*

3. a. PUMP UP LOCO. AIR BRAKE SYSTEM
   b. SET BRAKES
   c. PLACE GF BREAKER TO ON
   d. MOVE REVERSE HANDLE TO FORWARD OR REVERSE
   e. MOVE THROTTLE HANDLE TO NOTCH 1
   f. WAIT FOR LOADMETER TO BECOME STEADY.

   CAUTION: *TO AVOID MOTOR DAMAGE, DO NOT HOLD MOTOR CURRENT LONGER THAN 1 MINUTE.*

   g. PLACE TEST TOGGLE SWITCH TO TEST AND HOLD FOR 5 TO 10 SECONDS.

NO REACTION OR RESPONSE, SAME AS FOR STEP 5 → GO TO PROCEDURE E

WSL FLASHES CONTINUOUSLY, SANDING OCCURS, AND LOADMETER DROPS TO A LOWER LEVEL, BUT NOT AS LOW AS IN STEP 5 WHEN JUMPER WAS OFF (Q3 AND RATE CIRCUIT ARE GOOD). ↓

STEP 6 CONTINUED AT TOP OF NEXT PAGE

FIG. XII-5. CMR WHEELSLIP SYSTEM FLOW CHART.

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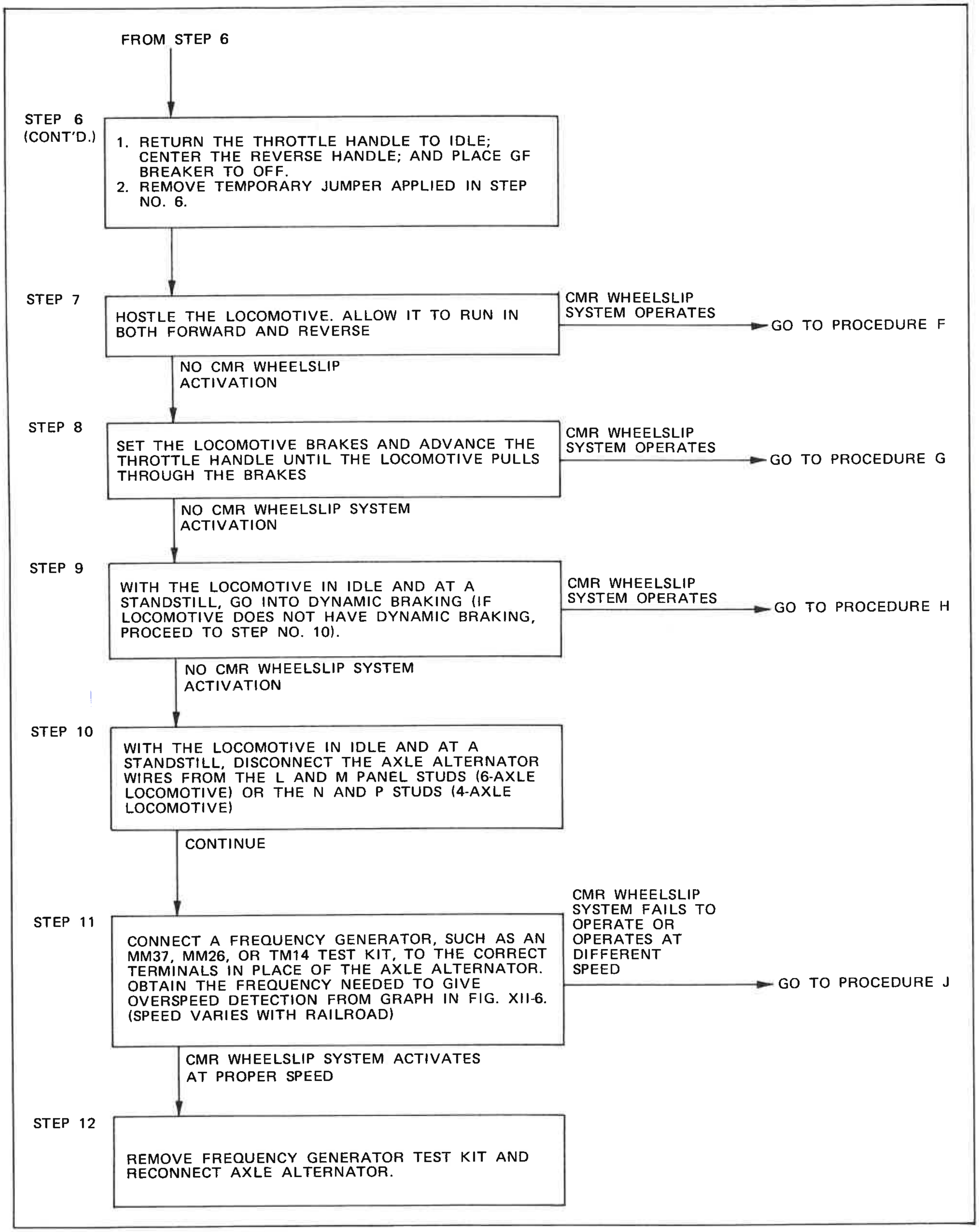

FIG. XII-5. CMR WHEELSLIP SYSTEM FLOW CHART (CONT'D.).

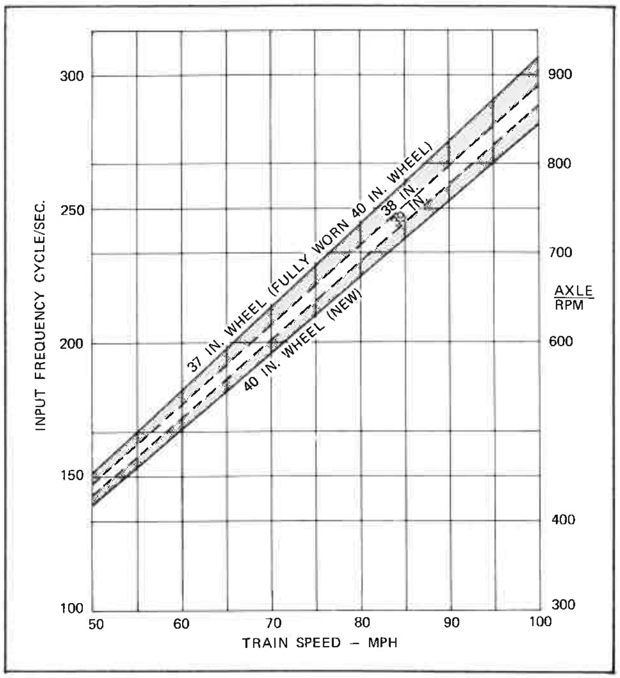

FIG. XII-6. AXLE ALTERNATOR OUTPUT FREQUENCY OR AXLE RPM VS. TRAIN SPEED.

1. Return Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.
2. Remove the jumpers from the panel terminals and then repeat Steps 4 and 5 of Procedure C, noting which test point gives the abnormal reading.
3. Return Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.
4. Using the locomotive schematic and the applicable CMR Wheelslip Panel schematic, trace the circuit containing the test point in question. Determine which wires on the panel terminal strip are in the same circuit as the test point.
5. Check the wiring to the CMR's by removing the wires from Terminals C, D, E, F, G and H on the CMR Wheelslip Panel (six-axle locomotive) or Terminals C, D, E and F (four-axle locomotive).
6. Using a Simpson 260 meter (or equivalent), measure the resistance between the wire and its corresponding terminal stud. If a different resistance is noted (as compared with the others), the problem is in that circuit. Replace the wires when finished.
7. Check for an open or shorted CMR. Compare resistance measurements with a CMR known to be good. Check the CMR terminals for dirt or conducting material. Clean terminals if necessary.
8. Check for loose bolted joints either in the traction motor connections within the motor itself, or in the accompanying busbars and cables. Look for signs of heat and/or smoke.
9. Check the motor contactor sequence operation. Assure all tips are operating and are in good condition. Also, carefully check the traction motor shunt connections.
10. Check for an open circuit within the traction motor. Check to see if a pinion has come off of a traction motor.
11. Check traction motor connections to assure motors will rotate in proper direction and that there are no locked axles.
12. Carefully inspect wheel sizes. If there is a difference of greater than one in. diameter between the largest and smallest wheels, the CMR wheelslip system will detect it. Change wheels, if necessary, to satisfy the tolerance.
13. Check to assure all traction motors have the same gearing. Also, check the nose mountings of the traction motors to assure they are firmly seated in the rubber mounts.
14. Check the CMR's are effectively shielded from nearby cables.

This is the end of Case No. 1. If the fault has not been corrected, proceed to Case No. 2. If the fault has been corrected, proceed to Fig. XII-5, Step 5.

Case No. 2

If the CMR wheelslip system activates and there is no significant voltage difference between the test points on the card(s), proceed to Case No. 3. If there is a significant voltage difference, the problem is most likely in the current measuring circuit (transformer(s) on the panel) or the voltage comparison circuit (FD409 or FD410 Card). Note the test point(s) giving the abnormal reading and then proceed with the following.

1. Return the Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.
2. Remove jumpers from panel terminals.

3. Assure all wires on the panel terminal strip are firmly fastened.

4. Using a Simpson 260 meter (or equivalent), check the winding continuity of the panel transformers. Especially check the transformer in the circuit with the abnormal reading.

5. Remove all the cards from the panel and visually check for burned or damaged components. Especially check the filter capacitors on the FD409 Card (six-axle locomotive) or the FD410 Card (four-axle locomotive). Also, check the plug connection pins on each card to assure they are not bent or broken. Replace any defective card.

6. Replace all the circuit cards in their proper slots and assure they are secured in the panel.

   This is the end of Case No. 2. If the fault has not been corrected, proceed to Case No. 3. If the fault has been corrected, proceed to Fig. XII-5, Step 5.

Case No. 3

The lack of a significant voltage difference indicates the problem is in one of the detection circuits (Level, Rate or Overspeed). Proceed with the following:

1. Return the Throttle handle to IDLE, center the Reverse handle and place GF breaker to OFF.

2. Remove jumpers from panel terminal.

3. Repeat Step 2 of Fig. XII-5 to double-check WSX relay is operating properly. If it is not, replace it.

4. If no faults have been found to this point, replace the FD1154 Card (six-axle locomotive) or the FD1155 Card (four-axle locomotive) with an "assumed good" card.

   Proceed to Fig. XII-5, Step 5.

D. Problems With Step 5

1. Return the Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.

2. Replace the FD1154 Card (six-axle locomotive) or the FD1155 Card (four-axle locomotive) with an "assumed good" card.

3. Perform the following:

   a. Pump up the air brake system and set the locomotive brakes.

   b. Place GF breaker to ON, move Reverse handle to FORWARD or REVERSE and advance Throttle handle to Notch 1.

   c. Wait for loadmeter to become steady.

CAUTION: *To avoid traction motor damage, do not hold motor current longer than one minute.*

4. Place test Toggle switch on the panel to TEST and hold for 5-10 seconds.

   a. If the WSL light flashes continuously, sanding occurs and the loadmeter drops to a lower level as long as the Toggle switch is held, proceed to Fig. XII-5, Step 6.

   b. If there is no response, proceed with the following:

      1) Shut down locomotive completely.

WARNING: *Do not proceed unless locomotive is dead. This avoids potentially dangerous voltages which could cause serious or fatal injury.*

      2) Check for open circuit condition in wiring between panel and current transformer.

      3) Check diode rectifier bridge 5BR1 which is located on the side of the panel.

      4) Restart the engine; observe standard railroad procedure and precautions.

      5) Perform the initial conditions of Step 1 of Fig. XII-5 and then return to Step 4 of Fig. XII-5.

E. Problems With Step 6

1. Return the Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.

2. Replace the FD1154 Card (six-axle locomotive) or the FD1155 Card (four-axle locomotive) with an "assumed good" card.

3. Repeat Steps 4, 5 and 6 of Fig. XII-5.

F. Problems With Step 7

1. Return the Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.

2. Carefully check the cabling to the reverser. Look for shorts, grounds or loose connections between the cables and busbars.

3. Check the contacts of the reverser. Assure all contacts are picking-up properly when the reverser operates. Leave the reverser in the position it was found initially.

4. Repeat Step 7 of Fig. XII-5. If the problems still exist, return to Step 4 of Fig. XII-5 to locate the trouble. If there is no CMR system action after repeating Step 7, proceed to Step 8 of Fig. XII-5.

G. Problems With Step 8

1. Return the Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.

2. Carefully check the CMR's. Either one or more of them are not giving the proper signals at higher traction motor currents.

3. Repeat Step 8 of Fig. XII-5. If the problem still exists, return to Step 4 of Fig. XII-5 to locate the trouble. If there is no CMR system action after repeating Step 8, proceed to Step 9 of Fig. XII-5.

H. Problems With Step 9

1. Return the Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.

2. Carefully check the cabling and busbars of the dynamic braking circuits to the traction motors. Look for grounds and loose bolted connections.

3. Check the extended range braking contactors are operating properly.

4. Check for an open circuit in the braking grids; either a grid is burned open or a cable is burned off.

Proceed to Fig. XII-5, Step 10.

J. Problems With Step 11

1. Return the Throttle handle to IDLE, center the Reverse handle and place the GF breaker to OFF.

2. Use a 44-pin card extender and extend the FD406 Card from the panel.

3. With the frequency generator Test Kit still connected, set the frequency to the proper value as indicated on Fig. XII-6.

4. Adjust the card potentiometer until the CMR wheelslip system activates with a small increase in frequency above the proper value.

5. If the wheelslip system is not responsive to any setting of the potentiometer, replace the FD406 Card with an "assumed good" card. Set the potentiometer on the replacement card as specified in Steps 3 and 4 above.

6. Disconnect the card extender, replace the FD406 Card in the panel.

Proceed to Fig. XII-5, Step 12.

NOTES:

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NOTES:

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GENERAL ELECTRIC

INSTRUCTIONS

TESTING INFORMATION

INTRODUCTION

This section covers the electrical components used on board the locomotive. The information includes the drawing symbol and designation shown on electrical schematic diagrams, a pictorial view of the component and a brief description and use of the component.

The intent of this section is to provide an overall listing of the electrical components to serve as a definitive reference for the maintainer as a further aid during trouble-shooting and testing.

ELECTRICAL COMPONENTS

The material in Table XIII-I has been compiled to include the electrical components used in transportation equipment. In order to achieve the convenient size and specific type of coverage desired, many nonapplicable items have been omitted. The subject material, therefore, pertains only to those electrical components whose symbols appear on circuit diagrams and schematics. Whenever possible, the electrical components have been presented in alphabetical order; however, symbols having similar or converse meanings are grouped together for convenience.

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GENERAL ELECTRIC

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TABLE XIII-I, ELECTRICAL COMPONENTS

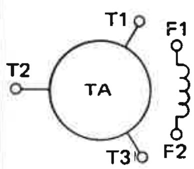
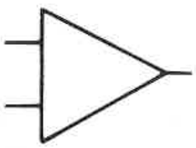
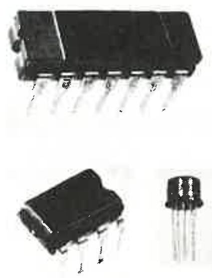
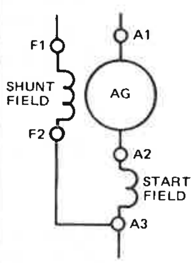
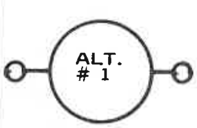
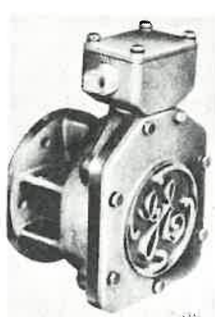
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
ALTERNATOR, TRACTION 		TA	The traction alternator is a three-phase a-c generator that provides electric propulsion power for locomotives. The output is rectified and used to power the d-c traction motors geared to the wheels.
AMPLIFIER, OPERATIONAL 		OA1, OA2, or IC1, IC2, etc.	An integrated circuit module which can be used as a voltage amplifier, current amplifier, ramp generator, comparator, voltage detector and oscillator.
AUXILIARY GENERATOR, ALTERNATOR EXCITER 		AG, EXC	Both units are d-c generators mechanically connected to the traction alternator (or generator). The exciter supplies power for alternator (or generator) excitation and the auxiliary generator is used for battery-charging and lighting.
AXLE ALTERNATOR 		AA, ALT	These alternators are single-phase a-c generators driven by the locomotive axles. The outputs are used to detect wheelslips or slides, then initiate corrective action.

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TABLE XIII-1 (Cont'd.)

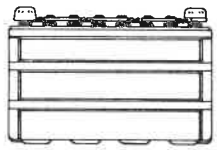
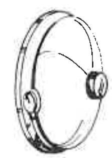
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
BATTERY 		BATT	Series-connected cells provide d-c power to locomotive circuits.
BELL 		None	A high-intensity electric bell is frequently used in the locomotive cab to signal a wheelslip condition or provide a warning of no battery charge.
CAPACITORS FIXED, NON-POLARIZED  FIXED, POLARIZED 	  	C1, C2, C3, etc.	Capacitors perform the following circuit functions: 1. Blocks the flow of dc but permits ac to flow through the circuits. 2. Bypassing; allows ac to take an easy path around a circuit in which ac is undesirable. 3. Filters and smooths out ripple in power supplies. 4. Feedback; applies some of a circuit's output into the input (in phase) to strengthen and regenerate the signal, or (out of phase) to weaken the signal.

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TABLE XIII-I (Cont'd.)

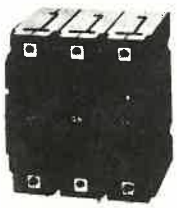
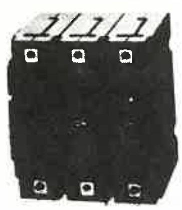
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
CIRCUIT BREAKERS **Instant Trip** 	 	B, CB, CCB, CSB, HLB, RCB, etc.	A protective device which opens a circuit during a current-overload condition. It operates on an electromagnetic principle whereby excessive current generates excessive electromagnetic force which, in turn, trips the breaker. This breaker responds very quickly to a current-overload condition. It must be reset manually following a trip.
Thermal Trip 	 	B, CB, CCB, CSB, HLB, RCB, etc.	A protective device which opens a circuit during a current-overload condition. It operates on a thermal-overload principle whereby excessive current generates excessive heat which, in turn, trips the breaker. This breaker has a delayed response to a current-overload condition, since it requires time to heat the trip mechanism. It must be reset manually following a trip.
DIODES			**CAUTION:** *As most diodes are polarity-sensitive, correct polarity must be considered when using a diode in an electrical circuit. The application of voltage with the polarity reversed may damage the diode.* **NOTE:** *Polarity of the diode may be identified by a band around its cathode end, a diode symbol, or color coded leads.*

TABLE XIII-I (Cont'd.)

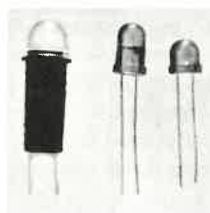
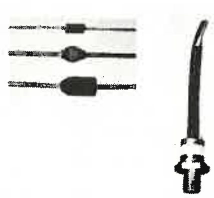
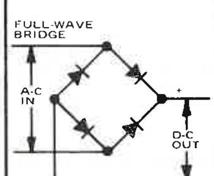
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
DIODES (Cont'd.)			
Current Regulator (Current Limiting) 		CLD1, CLD2, D1, D2, etc.	A semiconductor device which conducts a limited amount of current in one direction and blocks current in the opposite direction; used when a constant current is required from a changing voltage.
Light-Emitting (LED) 		LED1, LED2, etc.	Light-emitting diodes (LED's) produce a dull glow when they pass current. LED's are also polarity-sensitive and will not illuminate if their voltage polarity is reversed. They are used on control cards to indicate the presence of supply voltages; i.e. +15 vdc −15 vdc, etc. **CAUTION:** *LED's require a specific amount of current to function properly. The application of voltage directly to an LED without a current-limiting resistor will burn it out.*
Signal and Rectifier 		D1, D2, or RD1, RD2, etc.	A semiconductor device which conducts current in one direction and blocks current in the opposite direction; used for half-wave rectification in a-c circuits.
		RT1, RT2, or RB1, RB2, etc.	Configuration of diodes that rectifies both half-cycles of alternating current; frequently packaged as a single unit, with four pins extending from case.

TABLE XIII-I (Cont'd.)

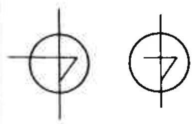
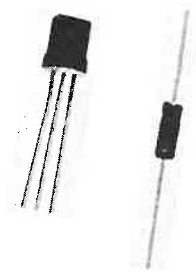
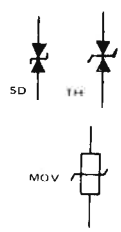
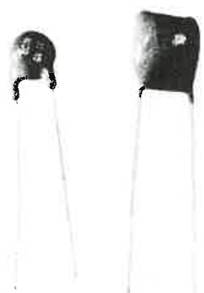
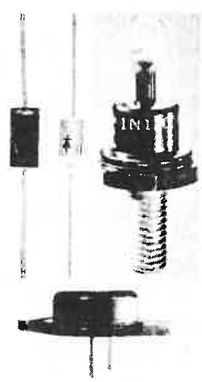
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
DIODES (Cont'd.)			
Silicon Unilateral Switches and Shockley 		SUS1, SUS2, etc.	A semiconductor device which blocks current flow in the forward direction until a specific voltage is reached (Forward Breakover Voltage). It then conducts and remains in conduction until its current flow drops below a minimum value (Holding Current). These are used in the gate circuitry of SCR's to prevent the SCR's from triggering (conducting) due to noise.
Suppressor, Thyrector and Metal Oxide Varistors 		SD1, SD2, THR1, THR2, MOV1, MOV2, etc.	A semiconductor device which conducts current when a specific voltage is exceeded. This device is not polarity-sensitive and retains the same characteristics, regardless of polarity applied. It is used to reduce voltage spikes in electrical circuits.
Zener and Reference 		ZD1, ZD2, etc.	A semiconductor device which conducts current when a specific reverse voltage is exceeded. This device normally operates with a positive voltage applied to its cathode. The voltage across the zener or reference diode remains nearly constant over its current range. It is used for regulating voltages in electronic circuits.
FUSE 		FU1, FU2, etc.	A protective device which opens a circuit during a current-overload condition. A fuse contains a strip of low-melting-point metal which burns out then opens a circuit during a current-overload condition. A fuse must be replaced after it burns open.

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TABLE XIII-I (Cont'd.)

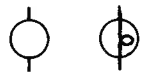
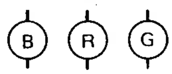
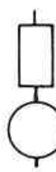
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
LAMPS			
Illumination 		Designated by location; left rear, right front, etc.	Incandescent lamps are used for both illumination and indication. Specific groups of lamps are protected by a circuit breaker.
Indicators  B-BLUE R-RED G-GREEN A-AMBER W-WHITE Y-YELLOW		Designated by lens color in a control panel.	
Low-Voltage Lamp  		Gage lights: GL1, GL2, GL3, etc.	Lamp power is provided by the locomotive battery (75 vdc). The low-voltage gage lights use a dropping resistor in each circuit to reduce the bus voltage (75 v) to the lamp voltage (6 v).

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TABLE XIII-I (Cont'd.)

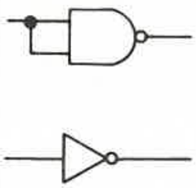
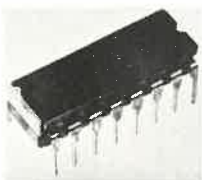
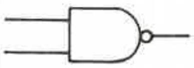
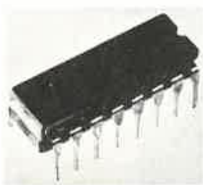
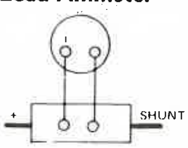
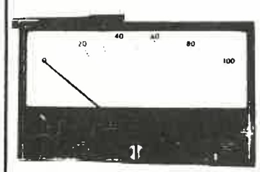
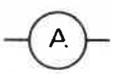
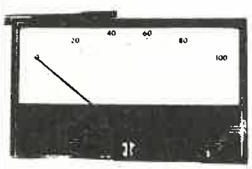
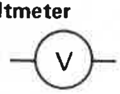
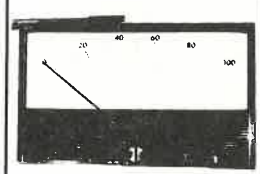
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
LOGIC GATES			
Inverter Gate 		IC1, IC2, etc.	An integrated-circuit module which performs inverting functions in digital logic circuits. A single module normally contains multiple circuits.
Nand Gate 		IC1, IC2, etc.	An integrated-circuit module which performs nand gate functions in digital logic circuits. A single module normally contains multiple circuits.
METERS			
Load Ammeter 		LA1, LA2, LS1, LS2, LM1, LM2, etc.	A typical ammeter is the load ammeter (LA) which measures d-c armature current in a traction motor. The ammeter shunt (low resistance) carries the heavy load current and only a small current actually passes through the ammeter. The shunt must be matched to the ammeter for correct meter calibration.
Ammeter 		A1, A2, MA1, etc.	The ammeter measures the current in an electrical circuit.
Voltmeter 		V1, V2, etc.	The voltmeter measures the differences of potential between different points of an electrical circuit.

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TABLE XIII-i (Cont'd.)

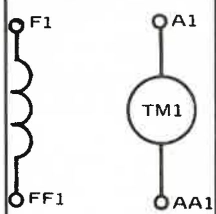
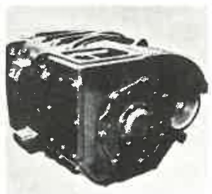
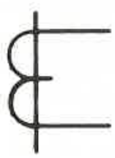
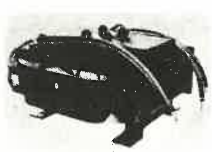
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
MOTOR **Traction** 		TM1, TM2, etc.	The series-wound d-c traction motors are mechanically connected to each set of drive wheels and receive electrical power from the traction alternator (or generator) or catenary. During transition, motor groups are connected in series/parallel or full parallel under full or reduced field conditions. During dynamic braking, the traction motors function as d-c generators and apply their output power into dynamic-braking grids (or resistors) to provide reverse torque to slow down the locomotive.
REACTORS **Inductor, Filter, Choke** 		L1, L2, L3, X1, X2, X3, etc.	Smooths out ripple in d-c signal and power circuits.
Current Measuring 		CMR1, CMR2, CMRX1, CMRX2, ACCR, etc.	A current measuring reactor (CMR) is a type of saturable reactor utilizing the magnetic flux from a high-current d-c conductor to change the current flow in its a-c winding. The a-c winding provides a signal proportional to current flow in the d-c conductor. The primary advantage of a CMR is in its ability to provide voltage isolation between its a-c signal winding and a high-voltage d-c conductor.

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TABLE XIII-I (Cont'd.)

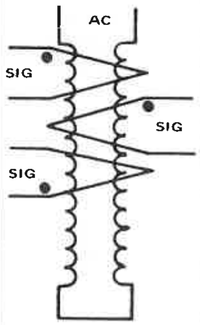
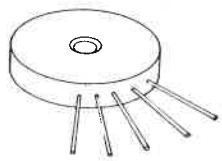
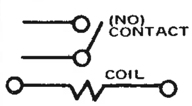
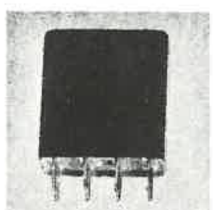
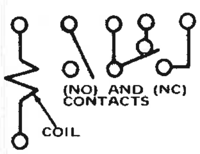
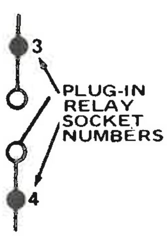
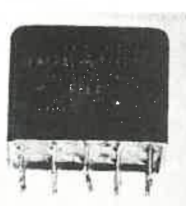
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
REACTORS (Cont'd.)			
Saturable Reactor 		PWM, VCR, VCBR, etc.	Saturable reactors are similar to transformers and consist of a magnetizable core(s) and two or more windings. A small current in one winding can magnetize the core completely (saturated), and an additional increase in current produces no increase in magnetic flux. Small currents in the signal (SIG) or d-c windings produce a cumulative effect (increase or decrease current) in the a-c winding for control purposes. The black dots on the SIG windings show proper d-c polarity for maximum "turn-on" effect.
RELAYS (AND CONTACTORS)			
Single Pole 		WSR, OPR, PCR, FPR, etc.	Relays are electromechanical devices containing an electromagnetic coil which actuates contacts when a current is passed through it. The relay contacts control other circuit functions by switching close or open.
Multipole  			Relay contacts may be normally-open (NO) or normally-closed (NC) when the coil is deenergized. Schematic diagrams show all relays in their deenergized position (coil circuit open). Socket numbers on plug-in relays are identified by a numbered dot connecting to the coil and each contact.

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TABLE XIII-I (Cont'd.)

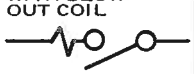
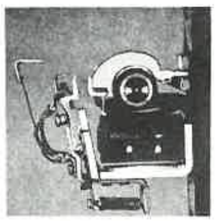
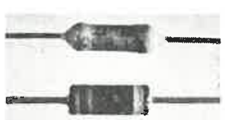
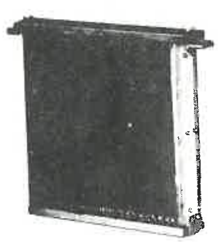
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
RELAYS (AND CONTACTORS) (Cont'd.)  CONTACTOR WITH BLOW-OUT COIL 	 		Contactors are devices that function similarly to relays, but their contacts are capable of carrying more current. Contactors utilize the same drawing symbols and designations as relays. A contactor may contain interlock contacts that can be adjusted to open or close before the opening or closing of its power contacts. Interlock contacts also utilize the same drawing symbols and designations as relays. **CAUTION:** *Equipment can be damaged or destroyed if interlock contacts are improperly adjusted. Check with test lights and/or buzzer to verify the interlock fingers OPEN or CLOSE before the OPENING or CLOSING of the associated main contacts.* A contactor also may contain a series blow-out coil to assist in arc suppression by establishing a magnetic field to oppose the magnetic field of the contact current. This causes the arc to extend and, finally, extinguish as the contacts open.
RESISTORS **Fixed or Common**  **Power (Grid)** 	 	R1, R2, etc.	Resistors limit the amount of current flow and produce a voltage drop in electrical circuits.

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TABLE XIII-I (Cont'd.)

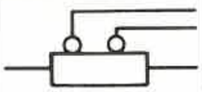
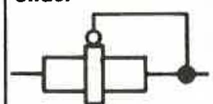
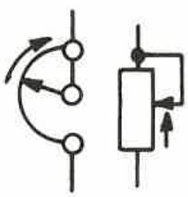
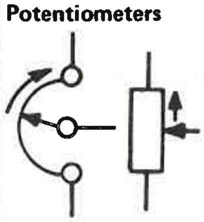
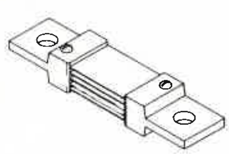
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
RESISTORS (Cont'd.)			
Tapped 		R1, R2, etc.	Tapped resistors provide one or more resistance-divider connections which function as voltage dividers. These are used where fixed voltage dividers are required.
Slider 		R1, R2, etc.	Slider resistors are variable resistors whose resistances change when the slider is repositioned; used where readjustment is seldom required.
Rheostats 	 	R1, R2, etc.	Rheostats are variable resistors with a movable wiper whose resistance changes when the wiper is repositioned. These are used in in place of slider resistors when readjustment is more frequently required. When utilized, an arrow on the symbol indicates wiper movement for a clockwise rotation.
Potentiometers 	 	P1, P2, etc.	Potentiometers select a variable voltage on their movable wiper from a potential applied to their stationary terminals; used where adjustable voltage dividers are required. When utilized, an arrow on the symbol indicates wiper movement for a clockwise rotation.
Shunt 		SH1, SH2, etc.	A device that functions like a low-value resistor. A shunt measures large amounts of current by producing a small voltage directly proportional to its current flow. A shunt can measure both a-c and d-c currents.

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TABLE XIII-I (Cont'd.)

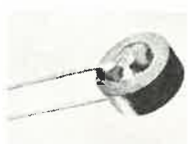
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
RESISTORS (Cont'd.) **Thermistor** 	   	R1, R2, R3, etc.	A variable resistor whose resistance changes with temperature. A thermistor may have a negative temperature coefficient (resistance decreases as temperature increases) or a positive temperature coefficient (resistance increases as temperature increases).
SILICON CONTROLLED RECTIFIER (SCR) 	   	SCR1, SCR2, DS1, DS2, Q1, Q2, etc.	A semiconductor device which blocks current in the forward direction until a positive voltage pulse is applied to its gate ("turn-on pulse"), then conducts and remains in conduction until its anode-to-cathode current flow drops to a minimum value ("holding current"). Turning off an SCR is normally referred to as "commutation". SCR's generally are used to control current in power circuits.

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TABLE XIII-I (Cont'd.)

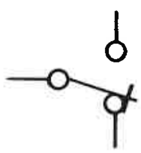
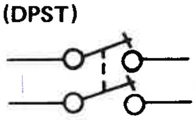
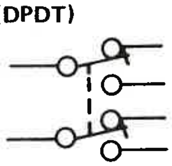
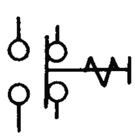
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
SWITCHES			
Single-Pole Single-Throw (SPST) 		S1, S2, S3, etc.	Mechanical devices containing manually-operated contacts which open and close to control various circuit functions.
Single-Pole Double-Throw (SPDT) 			
Double-Pole Single-Throw (DPST) 			
Double-Pole Double-Throw (DPDT) 			
Push-Button 			

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TABLE XIII-I (Cont'd.)

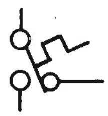
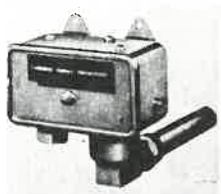
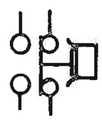
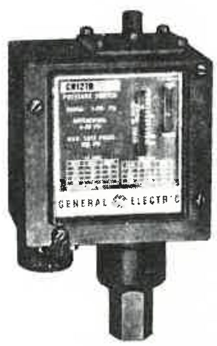
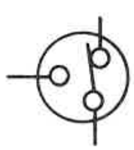
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
SWITCHES (Cont'd.)			
Temperature-Operated 		S1, S2, S3, or WT1, WT2, etc.	Mechanical devices containing contacts operated by temperature-sensitive, bi-metal strips.
Pressure-Operated 		PS	Mechanical devices containing contacts operated by variations in pressure of air, oil, or water.
		COP, COPS	Mechanical device with electrical contacts operated by very small variations in air pressure.
Cam-Operated 			Cam-operated switches utilize a cam on a rotating shaft to open and close switch contacts. The camshaft may be rotated manually by a switch handle or mechanically by a pilot motor.

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TABLE XIII-I (Cont'd.)

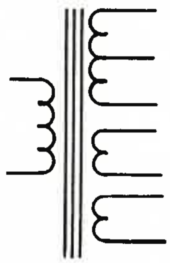
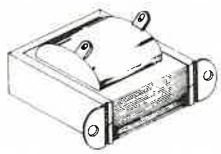
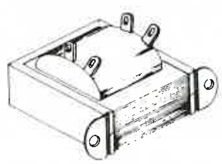
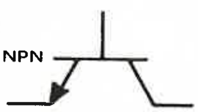
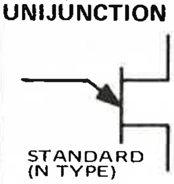
DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
TRANSFORMERS **Single Winding**  **Multiple Winding** 	 	T1, T2, T3, OST, etc.	Power transformers are used to step-up or step-down the alternating voltage received on the primary winding. A step-up transformer has a greater number of turns on the secondary winding than on the primary winding. A step-down transformer has a greater number of turns on the primary winding than on the secondary winding. All windings are insulated from the magnetic core (vertical lines), and the magnetic flux in the core operates below its saturation level.
TRANSISTORS  	 	Q1, Q2, T1, T2, FT1, etc.	A semiconductor device which operates as a current amplifier to switch and amplify electrical power. Transistors are available in two types: NPN and PNP. Each type has a separate drawing symbol, for easy identification. Transistors are utilized for general switching and amplifying applications.
TRANSISTORS, UNIJUNCTION  STANDARD (N TYPE)  COMPLEMENTARY (P TYPE)		Q1, Q2, T1, T2, UJ1, UJ2, etc.	A semiconductor device which triggers on when its emitter voltage is a specific percentage of the applied interbase voltage. Unijunctions are available in two types: standard and complementary. Each type has a separate drawing symbol, for easy identification. Unijunctions are utilized primarily in oscillator and timing circuits.

TABLE XIII-I (Cont'd.)

DRAWING SYMBOL	PICTORIAL	TYPICAL DESIGNATION	DESCRIPTION AND USE
VALVES (MAGNET AND SOLENOID) 		ASMV, OSMV, ETV, RDV, SDV, etc.	An electromagnetic device which opens and closes a valve electrically to control the flow of air, oil, sand, etc. The magnet and solenoid valves are usually energized by switches or relays and are shown as a single coil on schematic diagrams.

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TRANSPORTATION SYSTEMS BUSINESS DIVISION
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GENERAL ELECTRIC