DEPARTMENT OF THE ARMY TECHNICAL MANUAL

DIRECT AND GENERAL SUPPORT AND DEPOT MAINTENANCE MANUAL GENERATOR SET, DIESEL ENGINE: 200 KW, 60 CYCLE, AC, 120/208 V, 240/416 V, 3 PHASE, CONVERTIBLE TO 167 KW, 50 CYCLE, 120/208 V, 240/416 -V, 3 PHASE, MULTI-PURPOSE, PORTABLE; SKID MOUNTED (MILITARY DESIGN MODEL SF-200-MD/ CIED) FEDERAL STOCK NO. 6115-999-7901

This copy is a reprint which includes current pages from Change 1.

HEADQUARTERS, DEPARTMENT OF THE ARMY
FEBRUARY 1968

SAFETY PRECAUTIONS

BEFORE OPERATION

Do not operate the generator set in an enclosed area unless the exhaust gases are piped to the outside. Inhalation of exhaust fumes may result in serious illness or death.

Do not smoke or use an open flame in the vicinity when servicing the batteries. Batteries generate hydrogen, a highly explosive gas. When removing batteries, remove both negative "ground" cables before removing positive cables.

Do not operate the generator set unless the ground terminal stud has been connected to a suitable ground. Electrical faults in the generator set, load lines, or load equipment can cause death by electrocution from contact with an ungrounded system.

When filling the fuel tank, always provide metal-o-metal contact between the container and the fuel tank. This will prevent a spark from being generated as fuel flows over the metallic surface.

Do not use a lifting device with a capacity of less than 12,000 pounds. Do not allow the crated generator set to swing while it is suspended. Failure to observe this warning may result in serious injury or death to personnel.

Before making connections for parallel operation, be sure the generator sets are not operating and that all switches are off. Electrical faults in the generator set, load lines, and load equipment can cause death by electrocution from contact with an ungrounded system.

DURING OPERATION

Do not attempt to change a load connection or perform maintenance on the generator set while it is in operation. Always be sure it is not connected to an energized line before performing maintenance. The voltage generated by this equipment can cause death by electrocution.

AFTER OPERATION

Do not smoke or use an open flame in the vicinity when servicing the batteries. Batteries generate hydrogen, a highly explosive gas.

Do not use a lifting device with a capacity of less than 12,000 pounds. Do not allow the crated generator set to swing while it is suspended. Failure to observe this warning may result in serious injury or death to personnel.

Change
No. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, D.C., *13 July 1970*

Direct and General Support and Depot Maintenance Manual

GENERATOR SET, DIESEL ENGINE: 200 KW, 60 CYCLE, AC, 120/208V, 240/416V, 3 PHASE CONVERTIBLE TO 167 KW, 50 CYCLE, 120/208V, 240/416V, 3 PHASE, MULTI-PURPOSE, PORTABLE; SKID MOUNTED, (MILITARY DESIGN MODEL SF-200-MD/CIED) FSN 6115-999-7901

TM 5-6115-400-34, 13 February 1968, is changed as follows:

All references to "cycles" throughout this manual is changed to read "hertz".

Page 1. Table of Contents. Add "Appendix I, References, Page 181," and Index, Page 183-193" after last item on page.

Page 18, paragraph 5, lines 3 and 4 "and the applicable appendix in this manual" is changed to read "and in TM 5-6115-400-25P".

Page 14, paragraph 6. Line 2, "Repair Parts are illustrated and listed in Appendix II" is changed to read "Repair parts are illustrated and listed in TM 5-6115-400-25P".

Page 30, paragraph 32c, line 9, "lead rheostat" is changed to read "load rheostat".

Page 38, paragraph 34c(18), line 1, "Holder (66)" is changed to read "Holder (65)".

Page 40, figure 15. Move callout 9, leader line from housing assembly to plug.

Page 43, paragraph 34ql), line 2, "(64, fig. 15)" is changed to read "(65, fig. 15)".

Page 45, paragraph 34g(4), line 2 "(64, fig. 15)" is changed to read "(65, fig. 15)".

Page 49, paragraph 35c(21), line 1 "weight bushings (24)" is changed to read "weight bearings (24)".

Page 62, paragraph C3, line 2, "securely" is changed to read "to 100 ft. lb. torque".

Page 116, paragraph 53e(2), line 3, "torque of 16- to 170- ft. lbs." is changed to read "torque of 160- to 170- ft. lbs."

Page 133, figure 96, Item 5, "Lower thrust bearing" is changed to read "5. Lower thrust flange".

Page 146, paragraph 68. Before paragraph 68a, add the following:

WARNING

Observe Safety Regulations; The voltage used in this test are dangerous to human life. Contact with the leads on the windings under test may cause severe and possible fatal shock. Arrange the high voltage leads so that they are not in a position to be accidentally touched. Keep clear of all energized parts. Always reduce the test voltage to zero and ground the winding under test before making any mechanical or electrical adjustment on the equipment. When grounding out windings which have been tested, always connect the connecting wire to ground first and then to the winding. Never perform this test without at least one other person assisting. Generator frame shall be securely grounded. Record the ambient temperature and relative humidity. Record the winding temperature if the winding is at other than ambient temperature.

Page 151. Legend for figure 116. Add the following index numbers to legend after item 44:

45 Locknut
46 Screw
47 Insulation
48 Bridge
49 Plate
50 Bolt
51 Baffle
52 Cover-guard
53 Screw
54 Screw
55 Lockwasher.

Page 167. Legend for figure 129. Add the following index numbers to legend after item 44:

45 Potentiometer
46 Potentiometer
47 Switch
48 Relay
49 Plate
50 Plate
51 Relay
52 Relay
53 Relay
54 Relay

By Order of the Secretary of the Army:

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

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

Distribution:
To be distributed in accordance with DA Form 1225, Section IV, (qty rqr block No. 755) direct and general support maintenance requirements for Generator, Sets, Engine Driven 200 KW 60 Cycle.

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TECHNICAL MANUAL

No. 5-6115-40045

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D. C., *13 February 1968*

Direct and General Support and Depot Maintenance Manual
GENERATOR SET, DIESEL ENGINE: 200 KW, 60 CYCLE, AC, 120/208 V, 240/416 V, 3 PHASE, CONVERTIBLE TO 167 KW, 50 CYCLE, 120/208 V, 240/416 V, 3 PHASE, MULTI-PURPOSE, PORTABLE; SKID MOUNTED, (MILITARY DESIGN MODEL SF-200-MD/CIED) FSN 6115-999-7901

CHAPTER 1
INTRODUCTION

Section I. GENERAL

1. Scope

a. These instructions are published for the use of direct and general support and depot maintenance personnel maintaining the Military Standard Model SF-200-MC/CIED (Allis-Chalmers Model 25000-4444650) Generator Set. They provide information on the maintenance of the equipment, which is beyond the scope of the tools, equipment, personnel, or supplies normally available to using organizations.

b. Report of errors, omissions, and recommendations for improving this publication by the individual user is encouraged. Reports should be submitted on DA Form 2028 (Recommended Changes to DA Publications) and forwarded direct to the Commanding General, U. S. Army Mobility Equipment Command, ATTN: AMSME-MPP, 4300 Goodfellow Blvd., St. Louis, Mo. 63120.

c. Report all equipment improvements recommendations as prescribed by TM 38-750.

2. Record and Report Forms

a. DA Form 2258 (Depreservation Guide of Engineer Equipment).

b. For other record and report forms applicable to direct and general support and depot maintenance, refer to TM 38-750.

Note. Applicable forms, excluding standard Form 46 (United States Government Motor Vehicle Operator's Identification Card) which is carried by the operator, shall be kept in a canvas bag mounted on the equipment.

Section II. DESCRIPTION AND DATA

3. Description

A general description of 6 generator set, the location and description of the identification and instruction plates, and information on the differences in models are contained in the Operator and Organizational Maintenance Manual. The repair and maintenance instructions are described in appropriate sections of this manual.

4. Tabulated Data

a. General. This paragraph contains all the overhaul data pertinent to direct and general support and depot maintenance personnel. A wiring diagram (fig. 1) is also included.

b. Generator Classification and Rating.

Rating .....200 kw (kilowatts)
Voltage .....120/208; 240/416 volts
Amperes .....694/580; 347/290At 60 cycles 1200/694; 601/347
Phase 3
Power factor 0.8
Frequency .....60/50 cycles
Cooling .....Fan
Lubrication .....Sealed bearing
Duty classification .....Continuous
Degree of enclosure .....Full, dripproof, guarded
Drive .....Direct
Type .....Synchronous
Temperature rise .....185°F (85°C)

c. Exciter Classification and Rating.

Type .....Static
Rating .....At full load, 2.1 kw/60; 2.5 kw/50
Voltage .....151 volts D.C. (direct current) 58 v/60 cps; 65 v/60 cycles
Amperes 35 a/60; 39 a/60

Duty classification . .....Continuous
Degree of enclosure .....Full, dripproof, guarded

d. Generator Repair and Replacement Standards.

Revolving field:
Number of coils 4
Turns per coil 50
Total turns 200
Wire size .....No. 7 AWG (American Wire Gage) 7 square "FE"
Type of wire .....MIL-W-583C-class 155, type L-2
Coil connection .....Series
Insulating materials .....Resin treatment per winding of wire, Ret. #660 P-4818. Lead insulators (4 rqr), No. 11 vinyl glass saturated sleeving, 1 ft. long. Lead connection insulators (8 rqr), No. 6 vinyl glass saturated sleeving, 1/2 ft. long. Lead connection tie, glass untreated sleeving, 1 1/2 ft. long. Shaft insulator.
Dipping compounds .....Varnish, MIL-I-24092-class 165, type M
Dipping and baking .....After each layer of wire, procedures. .....brush on resin. Bake completely wound revolving field at 300°F. for 10 hrs. Dip revolving field in specified varnish.
Stator:
Number of poles 4
Number of slots 72
Number of coils 72
Coil span 1-13
Turns per coil 2
Wire size .....12, No. 14 round, AWG
Type of wire ..... (MILW-583A) class 155, type L-2
Insulating materials .....Slot insulators (72 rqr), coil separators (72 rqr), cell covers (72 rqr), phase insulators (12 rqr), lead insulators (12 rqr), No. 6 vinyl glass saturated sleeving, grade C1, 10 ft. long. Lead insulators (9 rqr), No. 4 vinyl glass saturated sleeving, grade C1, 2 ft. long. Tie cord, No. 8 cord, 8 ft long.
Dipping compounds .....Varnish, MIL-I-24092-class 155, type M
Dipping and baking .....Dip completely wound procedures. stator in varnish and drain well. Bake at 300°F. for 4 hrs. Repeat dipping procedure, and bake at 300°F. for an additional 4 hrs. Repeat dipping procedure, and bake at 300'F. for 12 hrs.

e. Nut and Bolt Torque Data.

Main bearing capscrews
5/8 in. U. N. C. .....160-170 ft-lb
7/8 in. U. N. C. .....370-380 ft-lb
Connecting rod nuts .....190-200 ft-lb
Cylinder head capscrews
5/8 in.… .....180-185 ft-lb
3/4 in. .....260-275 ft-lb
Fuel injection nozzle .....60-80 ft-lb retaining nut.
Nozzle holder clamp nuts ...21-24 ft-lb
Crankshaft pulley .....250-260 ft-lb retaining nut.
Front support bracket .. ..95-105 ft-lb
Timing gear housing cover capscrews
3/8 in. .....28-33 ft-lb
1/2 in. .....68-73 ft-lb
Piston cooling oil jets .....35 ft-lb
Flywheel bolt nuts .....160-170 ft-lb

f. Repair and Replacement Standards. Table 1 lists manufacturer's sizes, tolerances, desired clearances, and maximum allowable wear and clearances.

Table 1. Engine Repair and Replacement Standards

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
Cylinder sleeve:					
Type Replaceable wet inside diameter	5.2510	5.2520			
Allowable cylinder wall taper	----------	----------	----------	----------	0.0015
Allowable out-of-round when installed	----------	----------	----------	----------	0.0015
Piston skirt to cylinder sleeve clearance	----------	----------	0.0070	0.0090	

Table 1. Engine Repair and Replacement Standards-Continued

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
Outside diameter at machined area below flange	5.8710	5.8730			
Outside diameter at packing ring locations	5.7780	5.7800			
Outside diameter of sleeve flange	6.2170	6.2210			
Cylinder block to sleeve clearance-sleeve lower O.D.	----------	----------	0.0010	0.0050	
Cylinder block to sleeve clearance at machined area below flange	----------	----------	0.0010	0.0050	
Cylinder block to sleeve clearance at sleeve flange	----------	----------	0.0080	0.0170	
Fire wall height above cylinder flange sleeve	----------	----------	0.0370	0.0400	
Cylinder sleeve flange thickness	0.4630	0.4650			
Flange projection above cylinder block with sleeve installed	----------	----------	0.0020	0.0050	
Flange height adjusting shims available-0.005 in., 0.008 in., 0.010 in., 0.015 in., and 0.020 in.					
Cylinder block:					
Counterbore diameter for cylinder sleeve flange	6.2290	6.2340			
Depth of counterbore	0.4600	0.4620			
Bore for cylinder sleeve-top	5.8740	5.8760			
Bore for cylinder sleeve-bottom	5.7810	5.7830			
Bore for camshaft bearings	2.7470	2.7480			
Bearing bore in cylinder block (less bearing; cap in place; tightened to specified torque)	4.3743	4.3750			
Piston:					
Note. Combustion chamber is in piston					
Combustion chamber inside dia.	3.5570	3.5610			
Combustion chamber depth	0.8810	0.8850			
Compression pressure (minimum) at sea level, 600 rpm, (hot) pressure- 500 psi. Differential between cylinders in an engine not to exceed 25 psi					
Material-Aluminum alloy					
Length 7.000 in.					
Diameter of bottom skirt measured at right angle to piston pin	5.2430	5.2440			
Bore for piston pin (cold)	2.0018	2.0020			
Measurement from center of piston pin bore to top of piston	4.2510	4.2550			
Piston skirt-to-sleeve clearance at skirt bottom, right angle to piston pin	0.0070	0.0090			
Piston pin:					
Type-Full Floating					
Length	4.3650	4.3750			
Diameter	2.0015	2.0017			
Fit of pin at room temperature	----------	----------	0.0001	0.0005	
Inside diameter of connecting rod bushing after reaming	2.0027	2.0033			
Piston pin to connecting rod bushing clearance	----------	----------	0.0010	0.0018	
Piston rings:					
Location of rings					
Top groove-compression ring					
2nd groove-compression ring					
3rd groove-compression ring					
4th groove-oil control-ventilated w/spring					

Table 1. Engine Repair and Replacement Standards-Continued

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
Gap between ends					
Top-compression	----------	----------	0.0210	0.0390	
2nd-compression	----------	----------	0.0230	0.0410	
3rd-compression	----------	----------	0.0230	0.0410	
4th-oil control-ventilated w/spring	----------	----------	0.0130	0.0380	
Clearance of rings in grooves					
Top-compression	----------	----------	0.0040	0.0060	
2nd-compression	----------	----------	0.0030	0.0050	
3rd-compression	----------	----------	0.0030	0.0050	
4th-oil control-ventilated w/spring	----------	----------	0.0015	0.0035	
Crankshaft:					
Journal diameter for connecting rods	3.3725	3.3735			
Journal diameter for main bearings	3.9950	3.9960			
Width between connecting rod journal checks	2.1235	2.1265			
Width of main bearing journals					
Front	2.9080	2.9680			
Intermediate	2.0570	2.0670			
Center	3.2500	3.2520			
Rear	2.5570	2.5670			
Separate type thrust flanges-Available in standard size and .005 in, .010 in., .015 in. oversize					
Crankshaft end clearance	----------	----------	0.0070	0.0150	
Crankshaft journals may be ground - .010 in., .020 in., .030 in., .040 in.					
Fit of crankshaft front gear on crankshaft	----------	----------	0.0005	0.0025 tight	
Main bearings:					
Number used-7					
Type-Aluminum, steel backed					
Main bearing-to-crankshaft clearance -	----------	----------	0.0021	0.0048	
Inside diameter of bearings (bearings installed and caps tightened to specified torque)	3.9981	3.9998			
Diameter of crankshaft main bearing journals	3.9950	3.9960			
Length of front and rear bearings	1.9950	2.0050			
Length of center bearing	2.7460	2.7560			
Length of intermediate bearing	1.4950	1.5050			
Undersize bearings available for service-.010 in., .020 in., .030 in., .040 in.					
Separate type thrust flanges-Available in standard size and .005 in., .010 in., .015 in. oversize					
Standard wall thickness	0.1876	0.1881			
Torque for tightening main bearing capscrews					
5/8 in.-U.N.C.					
160-170 ft-lb					
7/8 in.-U.N.C.					
370-380 ft-lb					
Connecting rod bearings					
Type					
Aluminum, steel backed					
Inside diameter	3.3756	3.3771			
Diameter of crankshaft connecting rod journal	3.3725	3.3735			
Connecting rod bearing to crankshaft journal vertical clearance (bearings installed and caps tightened to specified torque)	----------	----------	0.0021	----------	0.0046

Table 1. Engine Repair and Replacement Standards-Continued

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
Length	1.6750	1.6850			
Undersize bearings available for service .10 in., .020 in., .030 in., .040 in.					
Standard wall thickness	0.12395	0.12446			
Connecting rods					
Type-Balanced Forging					
Connecting rod length (center-to-center)	11.9980	12.0020			
I.D. of connecting rod bushing (finished bore)	2.0027	2.0033			
O.D. of connecting rod bushing	2.2525	2.2545			
Bearing bore (less bearing, cap in place, and nuts tightened to specified torque	3.6246	3.6250			
Connecting rod width at lower end	2.1175	2.1195			
End play at crankshaft end	----------	----------	0.0040	0.0090	
Piston pin bushing length in connecting rod	1.8650	1.8860			
Piston pin-to-connecting rod bushing clearance	----------	----------	0.0010	0.0018	
Torque for tightening connecting rod cap nuts-190-200 ft. lb.					
Bore in connecting rod for piston pin bushing	2.2490	2.2500			
Exhaust valves (Two per cylinder) (Valve rotation obtained with ROTOCOIL)					
Lift at valve (with .020 in. lash)-.5236 in.					
Lift at cam .360 in.					
Lash (cold)-.023 in.					
Lash (engine coolant at normal operating temperature-.020 in.					
Head diameter	1.5830	1.5930			
Length overall-7.3645 in.					
Stem diameter	0.3715	0.3729			
Minimum clearance between valve surface and bottom deck of cylinder head	----------	----------	0.0640		
Face angle 45°					
Exhaust valve seat inserts					
Seat angle 45°					
Seat width-3/32 in.					
Insert O.D. (not installed)	1.6105	1.6110			
Bore in cylinder head for insert	1.6075	1.6085			
Fit in cylinder head .0020 in. -.0035 in.					
Run-out-.002 in. T.L.R.					
Oversize insert.005 in. over standard					
Exhaust valve guides					
Length-3-7/8 in.					
I.D.-ream in field .374 in.					
*NOTE: Exhaust guides installed in new production and new factory service heads do not require reaming in the field. They are factory bearingized to .3742 in. - .3747 in. I.D. and checked with a .3732 in. GO gage and a .3742 in. NO-GO gage, 4 in. long. Exhaust guides installed in heads in the field must be reamed after installation.					
Valve stem-to-guide clearance-after reaming	----------	----------	0.0020	0.0025	
Guide stand-out above flat surface of counterbore in cylinder head	----------	----------	1.3460	1.3610	

Table 1. Engine Repair and Replacement Standards-Continued

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
Intake valve (Two per cylinder) (Valve rotation obtained with ROTOCOIL)					
Lift at valve (with .015 in. lash) .5286 in.					
Lift at cam-.360 in.					
Lash (cold)-.018 in.					
Lash (engine coolant at normal operating temperature .015 in.					
Head diameter	1.6190	1.6290			
Length overall-7.3646 in.					
Stem diameter	0.3715	0.3720			
Minimum clearance between valve surface and bottom deck of cylinder head	----------	----------	0.0640		
Face angle-30°					
Intake valve seat inserts					
Seat angle-30°					
Seat width-1/16 in.					
Insert O.D. (not installed)	1.6445	1.6455			
Bore in cylinder head for insert	1.6415	1.6425			
Fit in cylinder head-.0020 in. - .0040 in.					
Run-out-.002 in. T.I.R.					
Oversize insert- .005 in.					
Oversize insert-.006 in. over standard					
Intake valve guides					
Length-3 7/8 in.					
I.D. ream after assembly-ream in field-.373 in. *Note. Intake guides installed in new production and new factory service heads do not require reaming in the field. They are factory bearingized to .3735 in.-.3740 in. I. D. and checked with a .3725 in. GO gage and a .3725 in. NO-GO gage, 4 in. long. Intake guides installed in heads in the field must be reamed after installation.					
Valve stem-to-guide clearance-after reaming	----------	----------	0.0010	0.0015	
Guide stand-out above flat surface of counterbore in cylinder head	----------	----------	0.7210	0.7360	
Exhaust and intake valve springs	Spring Only		Spring w/Damper		
Free length	2 5/8 in.		2 5/8 in.		
Length-valve closed	2.200 in.		2.200 in.		
Length-valve open	1.656 in.		1.656 in.		
Spring load at 2.200 in.	46-54 lb		50-63 lb		
Spring load at 1.656 in.	123-133 lb		136-150 lb		
Install new spring when old spring is 5% below the low limit or 5% above the high limit.					
Exhaust and intake valve bridge					
Bore in bridge for guide pin	0.4995	0.5000			
Bridge-to-guide pin clearance	----------	----------	0.0020	0.0030	
Guide pin length 3 5/16 in.					
Guide pin O.D.	0.4970	0.4975			
Guide pin gage height above cylinder head machined surface-2 in.					
Bore in head for bridge pin	0.4945	0.4960			
Rocker arm shafts					
Length-17 in.					
O.D.	1.2490	1.2500			

Table 1. Engine Repair and Replacement Standards-Continued

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
Rocker arms					
Bore in rocker arm for bushing	1.3110	1.3120			
Rocker arm bushing finished bore	1.2510	1.2515			
Fit of rocker arm bushing in rocker arm bore	----------	----------	0.0040	0.0065 tight	
Rocker arm shaft-to-bushing clearance	----------	----------	0.0010	0.0025	
Rocker arm ratio-1.51:1					
Size of orifice in rocker arm shaft (located in Nos. 3 and 4 rocker arm bracket positions).- 3/32 in.					
Camshaft					
Number of bearings used-4					
I.D. of installed camshaft bearings	2.4980	2.5010			
O.D. of camshaft journals	2.4940	2.4950			
Camshaft bearing-to-journal running clearance	----------	----------	0.0030	0.0070	
O. D. of camshaft bearings	2.7500	2.7510			
Bore in block for camshaft bearings	2.7470	2.7480			
Fit of camshaft bearing in bore of cylinder block	----------	----------	0.0020	0.0040 tight	
Camshaft front and rear bearing length-1 7/8 in.					
Camshaft intermediate bearing length-1 3/8 in.					
Camshaft end play	----------	----------	0.0030	0.0090	
Thrust plate thickness	0.3290	0.3310			
Valve lifter and valve lifter bracket					
Bore in valve lifter bracket for lifter	1.2495	1.2505			
O.D. of valve lifter	1.2470	1.2475			
Fit of valve lifter in bore of valve lifter bracket	----------	----------	0.0020	0.0085	
Timing gear train backlash between mating gears					
Oil pump driving gear to crankshaft gear	----------	----------	0.0060	0.0140	
Camshaft gear to crankshaft gear	----------	----------	0.0030	0.0110	
Accessory drive gear to camshaft gear	----------	----------	0.0030	0.0130	
Lubricating oil pressure pump					
Running clearance between pump driving gear and pump cover	----------	----------	0.0100	0.0290	
Gear-to-pump body radial clearance	----------	----------	0.00225	0.00325	
Pump gear side clearance	----------	----------	0.0050	0.0070	
I. D. of gear shaft bushings (finish bore)	0.7495	0.7505			
0. D. of pump gear shafts	0.7475	0.7480			
Pump gear shaft-to-bushing clearance -	----------	----------	0.0015	0.0030	
Water pump					
Front bearing					
Bearing bore (I.D. for shaft)	1.1807	1.1811			
Shaft diameter (for bearing)	1.1814	1.1819			
Fit-shaft to bearing	----------	----------	0.0003	0.0012 tight	
Bearing 0. D.	2.8341	2.8346			
Bore in water pump body (for bearing)	2.8341	2.8351			
Fit-bearing 0. D. to body	----------	----------	0.0010 loose	0.0005 tight	
Rear bearing					
Bearing bore (I. D. for shaft) -	0.9839	0.9843			
Shaft diameter (for bearing)	0.9845	0.9850			
Fit-shaft to bearing	----------	----------	0.002	0.0011 tight	
Bore in water pump body (for bearing)	2.0467	2.0477			

Table 1. Engine Repair and Replacement Standards-Continued

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
O. D. of bearing .	2.0407	2.0472			
Fit-bearing 0. D. to body	- ----------	----------	0.0010 loose	0.0005 tight	
Hub-water pump drive-bore	- 1.1260	1.1260			
Shaft diameter (for hub)	1.1255	1.1260			
Fit-bore (hub to shaft)		----------	0.0005 loose	0.0010 tight	
Fan hub					
Front bearing					
Bearing bore (I.D. for shaft)	1.1807	1.1811			
Shaft diameter	1.1808	1.1808			
Fit-bearing to hub	----------	----------	0.0008 loose	0.0001 tight	
Bearing O.D.	2.4404	2.4409			
Bore in hub (for bearing)	2.4408	2.4418			
Fit-bearing to hub	----------	----------	0.0009 loose	0.0008 tight	
Rear bearing					
Bearing bore (I.D. for shaft)	1.8775	1.8780			
Shaft diameter	1.8771	1.8776			
Fit-shaft to bearing	----------	----------	0.0009 loose	0.0001 tight	
Bearing O. D.	2.8341	2.8346			
Bore in hub (for bearing)	2.8340	2.8350			
Fit-bearing to hub	----------	----------	0.0009 loose	0.0006 tight	
Idler assembly-water pump					
Bearing bore (I.D. for shaft)	1.1807	1.1811			
Shaft diameter	1.1803	1.1808			
Fit-shaft to bearing	----------	----------	0.0008 loose	0.0001 tight	
Bore in pulley for bearing	2.1647	2.1652			
Bearing O.D.	2,1649	2.1654			
Fit-bearing to pulley	----------	----------	0.0003 loose	0.0007 tight	
Accessory drive					
Accessory drive housing					
O.D. of upper and lower shafts for housing bushings	1.2470	1.2480			
O.D. of bushing	1.4385	1.4390			
Bore in housing for bushing	1.4370	1.4375			
I.D. of bushing installed	1.2495	1.2507			
Fit-bushing to bore in housing	----------	----------	0.0010	0.0020 tight	
Upper and lower shaft-to-bushing clearance	----------	----------	0.0015	0.0037	
Accessory drive cover					
O.D. of lower shaft for cover bushing	0.9990	1.0000			
O.D. of bushing	1.2510	1.2515			
Bore in cover for bushing	1.2495	1.2500			
I.D. of bushing installed	1.0015	1.0027			
Fit-bushing to bore in cover	----------	----------	0.0010	0.0020 tight	
Lower shaft-to-cover bushing clearance	----------	----------	0.0015	0.0037	

Table 1. Engine Repair and Replacement Standards-Continued

Component	Manufacturer's dimensions and tolerance in inches		Desired clearance		Maximum allowable wear and clearance
	Min.	Max.	Min.	Max.	
Drive gear					
O.D. of shaft for drive par	1.2505	1.2516			
Bore in drive gear for shaft	1.2495	1.2500			
Fit-shaft to gear	----------	----------	0.0005	0.0020 tight	
Gear-upper shaft					
O.D. of shaft for upper shaft gear	0.7500	0.7505			
Bore in gear for upper shaft	----------	----------	0.0000	0.0010	
Fit-shaft-to-gear	0.7495	0.7500	0.0000	tight	
Gear-lower shaft					
O.D. of shaft for lower shaft gear	1.2505	1.2515			
Bore in gear for lower shaft	1.2495	1.2500			
Fit-shaft to gear	----------	----------	0.0006	0.0020 tight	
End play-upper and lower shafts	----------	----------	0.0020	0.0050	
Auxiliary pump drive					
O.D. of shaft for housing	0.7510	0.7516			
Bore in housing for shaft	0.7495	0.7505			
Fit-shaft-to-bore in housing	----------	----------	.0005	.0020 tight	
O.D. of shaft for bushing	0.8720	0.8780			
O.D. of bushing	1.0025	1.0035			
Bore in gear for bushing	0.9996	1.0005			
I.D. of bushing installed	0.8745	0.8755			
Fit-bushing-to-bore in gear	----------	----------	0.0020	0.0040 tight	
Shaft-to-bushing in gear clearance	----------	----------	0.0015	0.0085	

g. Schematic Wiring Diagram. figure 1 shows the schematic wiring diagram for this generator set.

Figure 1. Schematic wiring diagram. **(Located at back of manual)**

CHAPTER 2
GENERAL MAINTENANCE INSTRUCTIONS

Section I. SPECIAL TOOLS AND EQUIPMENT

5. Special Tools and Equipment

The special tools required to perform direct and general support and depot maintenance on the generator set are listed in Table 2 and the applicable appendix of this manual. References and illustrations indicating the use of these tools are listed in the table. No special equipment is required by direct and general support and depot maintenance personnel for performing maintenance on the generator set.

Table 2. Special Tools

Item	FSN or Part No.	Ref Fig.	Ref Par.	Use
Brace	(09367) 4446054		29	Main generator removal
Wrench	(01843) TSE76157		34	Remove base plugs
Service tool	(01843) TSE76159B		34	Compress plunger spring
Retaining pin	(01843) TSE76156B		34	Fuel injection pump camshaft removal
Tappet lifter	(01843) TSE7697		34	Tappet removal
Plunger remover	(01843) TSE7661		34	Plunger removal
Spring compressor	(01843) TSE76160		34	
Spring compressor	(01843) TSE76159		34	Install timing spacer
Wrench	(01843) TSE7919		35	Remove nut
Coupling wrench	(01843) TSE7913		35	Remove nut
Puller	(01843) TSE7920		35	Remove hub
Level	(01843) TSE7947		35	Check clutch tension
Spring scale	(01843) TSE7927B		35	Check clutch tension
Reamer	(01843) TSE7955		35	Ream bushing
Bushing installer	(01843) TSE7935		35	Install bushing
Reamer	(01843) TSE7940		35	Ream bushing
Seal installer	(01843) TSE7938		35	Install oil seal
Spring gap gage	(01843) TSE7939		35	Set spring gap
Water pump tool kit	(33287) J-21313	25	36	Water pump repair
Dial indicator adapter "F"	(33287) J-21224	30	38	Check shaft radial movement
Holding fixture "A"	(33287) J-21225		38	Hold housing and rotating assembly
Disassembly tool "B"	(33287) J-9496	33	38	Disassemble compressor wheel
Wrench "H" adapter	(33287) J-21223	37	38	Tight impeller retaining nut
Guide installer	(33287) J-9317-37		45	Install intake valve guide
Guide installer adapter	(33287) J-9317-36	67	45	Install exhaust valve guide
Guide installer pilot	(33287) J-9317-4	67	45	Install valve guides
Guide installer plate	(33287) J-9317-1	57	45	Install valve guides
Camshaft bearing remover and installer set	(33287) J-6334-01	89	56	Remove and install camshaft bearings
Counterbore tool	(87641) 6091	107	62	Cylinder sleeve reseating
Upper adapter plate	(87641) 6210-10	107	62	Cylinder sleeve reseating
Lower adapter plate	(87641) 6210-20	107	62	Cylinder sleeve reseating
Carboloy tool bits	(87641) 621-71	107	62	Cylinder sleeve reseating

6. Direct and General Support and Depot Maintenance Repair Parts

Direct and General Support and Depot Maintenance Repair Parts are listed and illustrated in Appendix II.

7. Specially Designed Tools and Equipment

There are no specially designed tools or equipment required for repair or overhaul of the generator set.

Section II. TROUBLESHOOTING

8. General

This section provides information useful in diagnosing and correcting unsatisfactory operation or failure of the generator set or any of its components. Each trouble symptom stated is followed by a list of probable causes of trouble. The possible remedy recommended is described opposite the probable cause.

9. Engine Misses or Operates Erratically

Probable cause	*Probable remedy*
Valve guides worn	Replace valve guides (para 45).
Valve springs weak or broken	Replace valve spring (para 45).

10. Engine Lacks Power

Probable cause	*Probable remedy*
Piston assemblies worn	Replace piston assemblies (para 57).
High engine temperature caused by defective water pump.	Repair or replace a defective water pump (par 36).

11. Engine Will Not Turn

Probable cause	*Probable remedy*
Engine is locked or seized.	This can be due to extended idle or storage periods, or to improper preparation of the engine for storage, in which case the parts may be rusted or corroded and seized. Broken piston rings, gears, etc., may also cause locking. The engine should be disassembled to determine the cause, and the necessary parts replaced.
Hydro-static lock	This can be due to rain water entering uncovered exhaust pipe, leaking cylinder head gasket, cranked block or cylinder head. The engine should be disassembled to determine the cause and the necessary parts replaced.

12. Engine Overheats

Probable cause	*Probable remedy*
Improper engine lubrication.	Check for proper operation of engine oil pump (para 51).

13. Starter Will Not Crank Engine

Probable cause	*Probable remedy*
Starter brush springs weak.	Check brush spring tension, replace springs if necessary (para 31).
Starter commutator dirty or worn.	Polish commutator, machine commutator and under-cut mica if necessary (para 31).
Starter armature shaft bushings worn (armature drags on fields).	Replace worn bushings and related items (para 31).
Starter armature burned out.	Replace armature (para 31).

14. Starter Pinion Will Not Engage With Flywheel Gear

Probable cause	*Probable remedy*
Grease and/or dirt in starter drive mechanism.	Disassemble and clean the drive assembly (para 31).
Broken or excessively worn parts.	Replace broken or worn parts (para 31).

15. Main Generator Fails to Build Up Rated Voltage or Generator Output Voltage Too Low

Probable cause	*Probable remedy*
Set operating below rated frequency.	Adjust R18 (fig. 89-1) frequency gain adjust. Adjust (R1) frequency adjust. Refer to TM 5-6115-400-12.
Brush holders improperly adjusted.	Adjust brush holders (para 65).

16. Ineffective Cross Current Compensation Control (Generator Terminal Voltage Should Drop with Application of Zero Power Factor Load).

Probable cause	*Probable remedy*
Current transformer CVT-CC improperly polarized.	Check connections. Correct as necessary. Refer to paragraph 72 and figure 1.

17. Generator Terminal Voltage Unstable

Probable cause	*Probable remedy*
Primary winding in transformer T2 open.	Replace transformer (para 78).
Capacitor C3 shorted	Replace capacitor (para 73).
Adjustable slide on resistor R11 not making contact.	Check and correct as necessary (para 73).

18. No-Load Generator Terminal Voltage Too Low

Probable cause	*Probable remedy*
One phase of reactor XL open.	Replace reactor (para 72).
One or more windings of current voltage transformer CVT open.	Replace transformer (para 72).
Diode in rectifier REC3 open.	Replace diode (para 72).
Zener Z1 breaks down at a voltage substantially lower than 18 volts.	Replace Z1 (para 73).
Transistor Q1 will not absorb normal maximum voltages impressed between c and e.	Replace transistor (para 73).
Improperly polarized flashing voltage.	Refer to paragraph 72 and paragraph 94. Check polarity of d.c. source and reverse connections, if necessary, to governor. Replace the governor if necessary.

19. No-Load Generator Terminal Voltage Too High

Probable cause	*Probable remedy*
Open control winding S(C) in current voltage transformer CVT.	Replace transformer (para 72).
Silicon controlled rectifier SCR does not fire or is open.	Replace rectifier SCR (para 73).
Open in unijunction semiconductor Q2 circuit.	Replace transistor Q2 (para 73).
Transistor Q1, Zener Z1, or diodes in rectifier D2 open.	Replace as necessary (para. 72).
Secondary winding of transformer T2 open.	Replace transformer (para 72).
Primary or secondary winding of transformer T1 open.	Replace transformer (para 72).
Capacitor C1 or C2 shorted.	Replace as necessary (para 72).

20. Generator Terminal Voltage "Kills" When Load is Applied

Probable cause	*Probable remedy*
Windings of current voltage transformer CVT improperly polarized.	Check connections. Correct as necessary (para 72).

21. Poor Voltage Regulator During Parallel Operation

Probable cause	*Probable remedy*
Unit parallel switch (control panel) not closed.	Reset switch. Refer to TM 5-6116400-12.

22. Circuit Breaker Trips Off or Fails to Close

Probable cause	*Probable remedy*
Circuit breaker defective	Replace circuit breaker (para 87).
Overvoltage relay defective.	Replace overvoltage relay (para 76 and para 78).

23. Sluggish Operation of Electric Governor Actuator

Probable cause	*Probable remedy*
Dirty oil	Change oil (para 92).
Defective hydraulic oil filter.	Change filter (para 92).
Low oil pressure	Adjust pressure on hydraulic pump (para 92).
Binding or sticking throttle shaft.	Correct binding or sticking (para 92).

Section III. RADIO INTERFERENCE SUPPRESSION

24. General

Refer to TM 11-483 for definitions, purposes, source and methods used to obtain proper radio suppression.

25. Interference Suppression Components

A 1.8 to 2.4 microfarad capacitor is mounted in the base of the battery charging generator regulator. The capacitor is connected in the circuit between the

terminal of the output receptacle and the lower contacts of the cutout relay. See figure 2.

26. Replacement of Suppression Components

Refer to figure 2 and replace the radio interference suppression components.

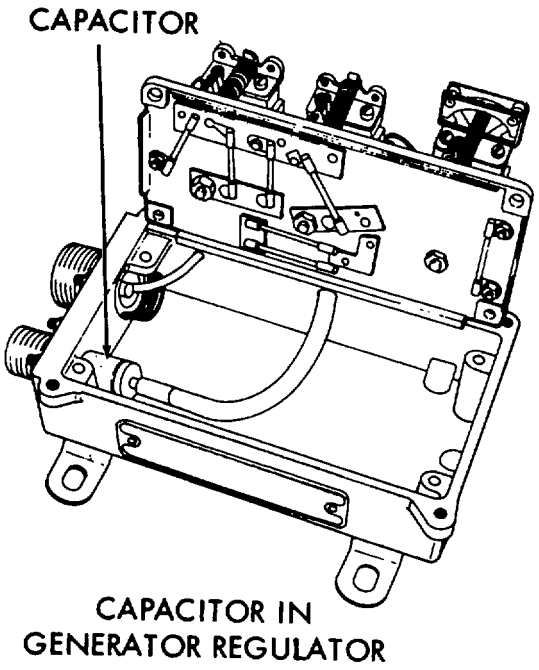


Figure 2. Radio Interference suppression components.

Section IV. REMOVAL AND INSTALLATION OF MAJOR COMPONENTS

27. Housing

a. Removal. Refer to figure 3 and remove the housing.

b. Installation. Refer to figure 3 and install the housing.

28. Engine

a. General The engine is supported in front by the front mounting bracket (fig. 4) secured to a cross member of the generator set base. The engine is supported in the rear by the main generator which is bolted to supporting plates welded into the generator set base.

b. Removal.

Note

To remove the engine, it is necessary to remove the engine and generator as an assembly and separate the engine from the generator after removal. However, the generator can be removed with the engine in the set.

(1) See figure 3 and remove housing top and rear side covers, louver doors, and louvers.

(2) Remove paralleling receptacles (located near control panel).

(3) Remove relay box to control panel wiring harness.

(4) Remove 120 VAC outlet plugs (located near control panel).

(5) Cut wire connections to fuse holder (located between 120 VAC outlet plugs and paralleling receptacles). These wires must be reconnected and soldered for reassembly.

(6) Disconnect all wiring harnesses from the control panel.

(7) Disconnect harnesses from the electric governor control unit.

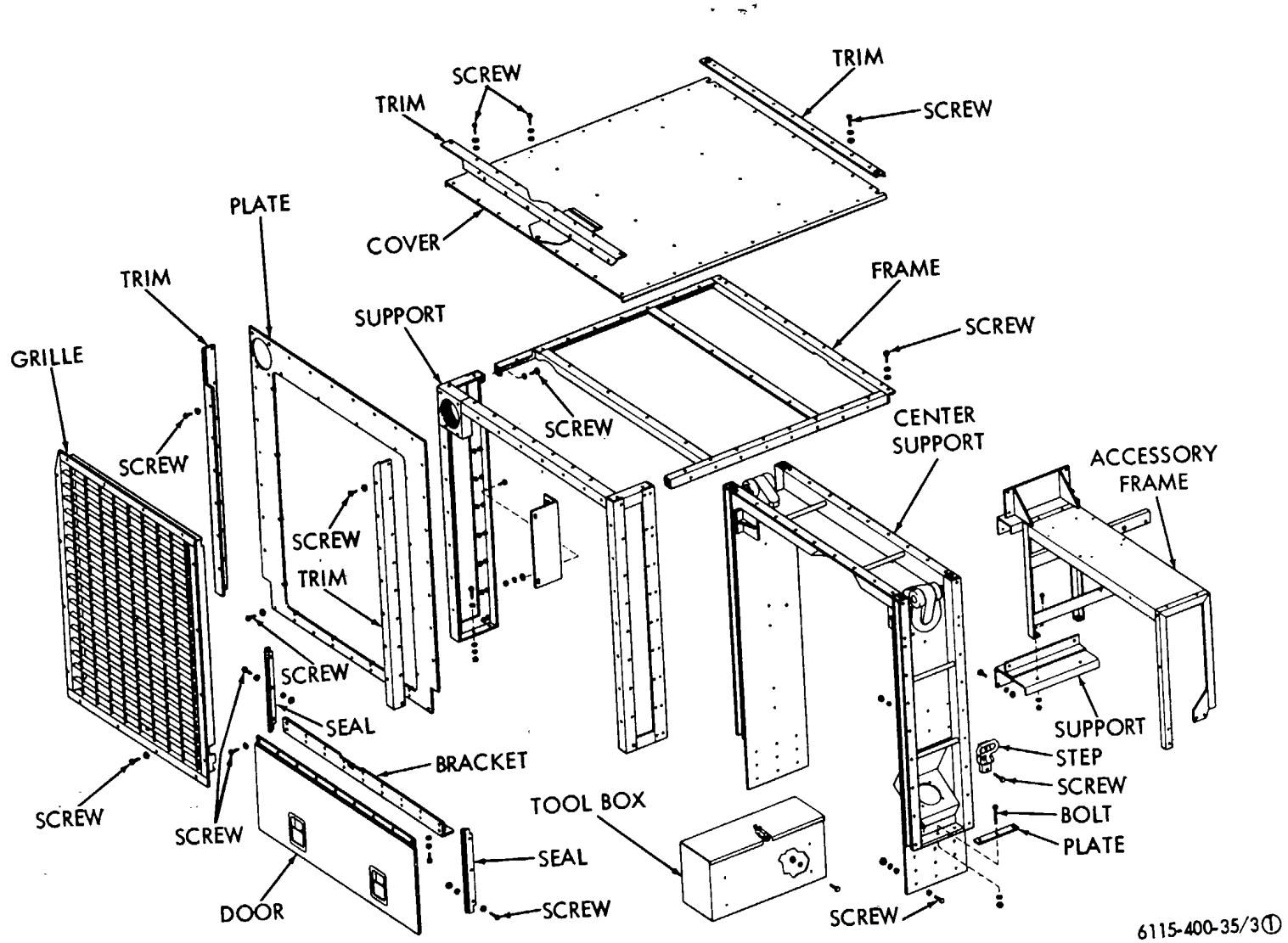


Figure 3 (1) . Housing, doors, hood, and panels.

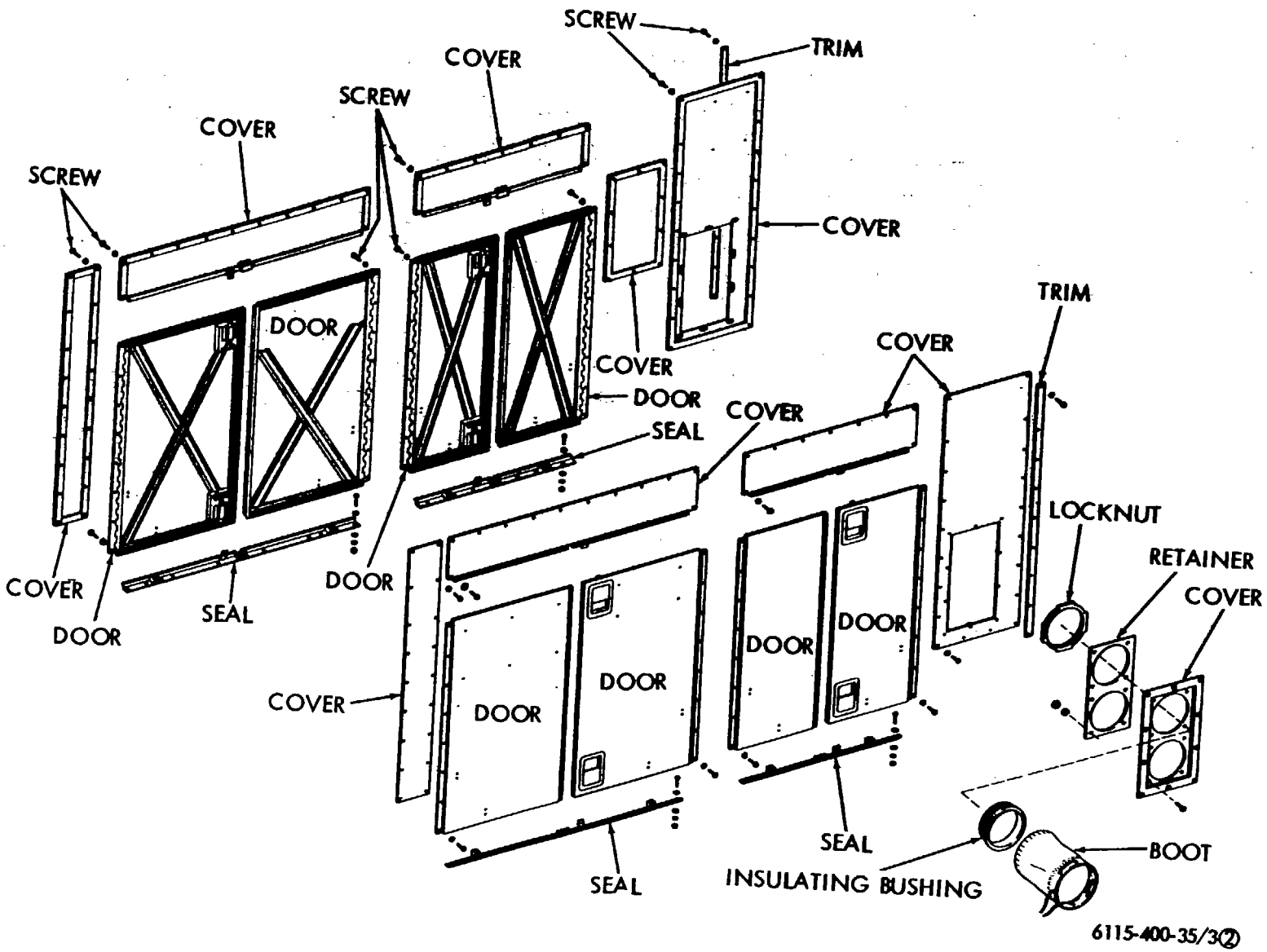


Figure 3 (20) - Continued

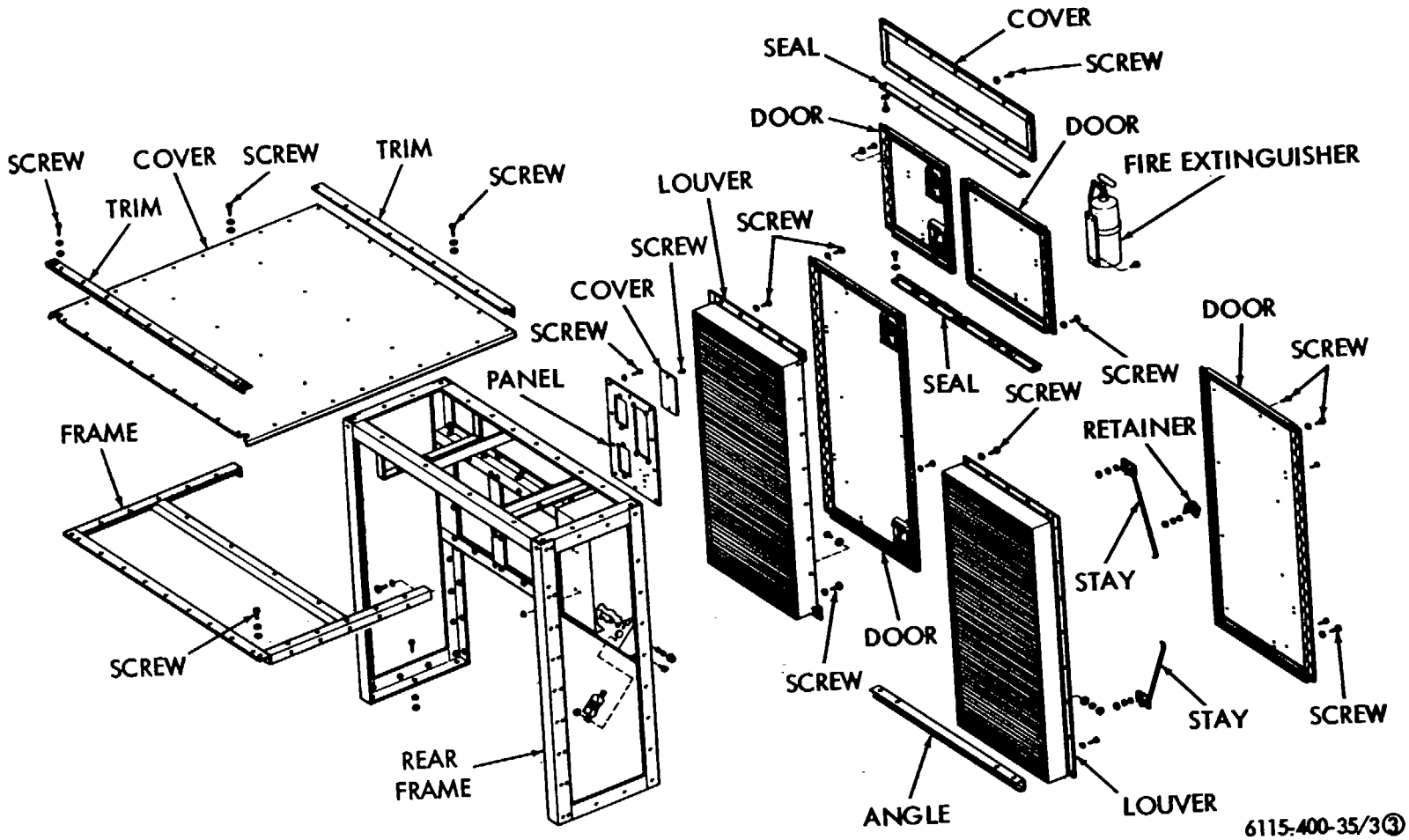


Figure 3 (3)- Continued

(8) Remove reconnection panel and tag and disconnect cables and leads (except cables to AC power circuit breaker).

(9) Remove load connection panel and tag and disconnect cables.

(10) Disconnect wiring harness from AC power circuit breaker.

(11) Remove screws attaching rear frame (fig. 3 (3)) to base and use a hoist to lift frame from base. Control panel doors, rear side doors, and AC power circuit breaker will remain attached to the rear frame. Cables will remain attached to the AC power circuit breaker.

(12) Tag and disconnect leads from current transformers. Remove cables from current transformers.

(13) Remove lifting bracket from rear of engine with air cleaner attached. Reinstall lifting bracket.

(14) Disconnect fuel line connections from the electric fuel pumps.

(15) Disconnect wiring harnesses from the relay box.

(16) Drain fuel from the day tank.

(17) Remove screws attaching accessory frame (fig. 3 (1)) to base and to accessory frame support. Use a hoist to remove accessory frame with relay box, electric governor control unit, electric fuel pumps, and current transformers attached. Remove accessory frame support.

(18) Remove day tank.

(19) Remove screws attaching center support (fig. 3 (1)) to base and use a hoist to remove center support (with center doors attached).

(20) Remove nuts from fan guard.

(21) Drain coolant and disconnect radiator hoses from engine.

(22) Disconnect oil drain hose from engine.

(23) Remove exhaust pipe clamp at turbocharger end.

(24) Install generator front lifting eye (stored in tool box).

2 (25) Attach a hoist (with bar) to engine lifting eyes and a second hoist (with bar) to the generator lifting eyes.

(26) Remove screws (fig. 4A) from engine front support bracket.

(27) Remove bolts (fig. 4B) which secure generator to base.

(28) Place engine-generator load on the hoists (lifting the engine-generator minimum amount), then carefully move the base forward so the fan clears the venturi.

(29) Lift engine-generator with hoists, then place an engine stand under the engine. Lower the engine-generator until the engine is supported by the stand. The engine-generator is now ready for separating the engine from the generator.

(30) See figure 4C and separate the engine from the main generator.

c. Installation.

(1) Assemble engine to generator in reverse order of separation. See figure 4.

Note. Install two (2) dowels in flywheel (in opposite tapped holes) to guide the coupling discs and the blower. The dowels can be made by removing the heads from 5/8 x 3 1/4 capscrews.

(2) After dowels are installed in flywheel, move generator toward flywheel with holes in coupling and blower over the dowels, then move generator into position against the engine flywheel housing and secure with twelve capscrews and lockwashers.

(8) Insert four coupling to flywheel capscrews and locking plates, remove the dowels, and then insert the four remaining capscrews with locking plates.

29. Main Generator

a. Removal.

(1) Refer to paragraph 28b and follow steps (1) to (17) inclusive.

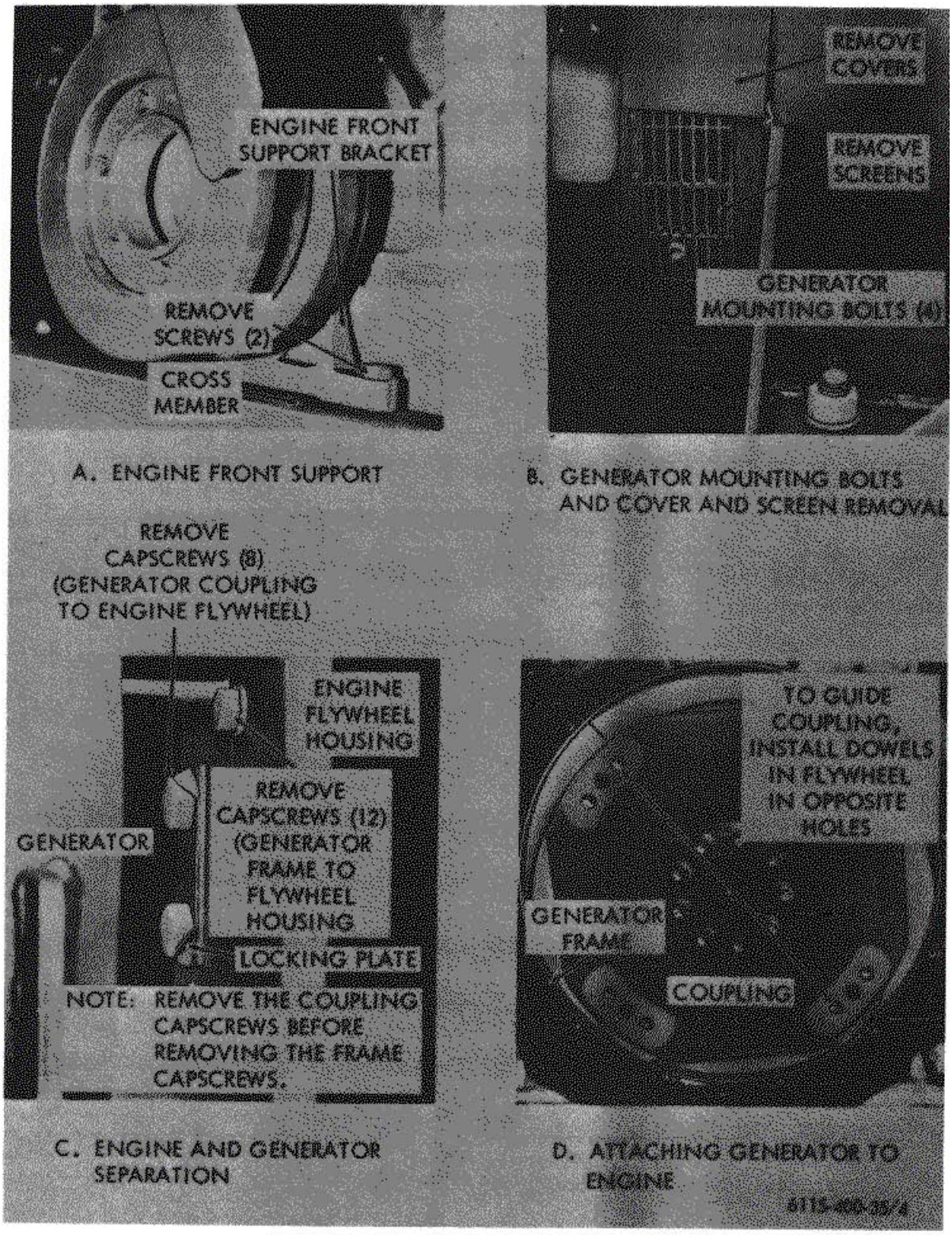
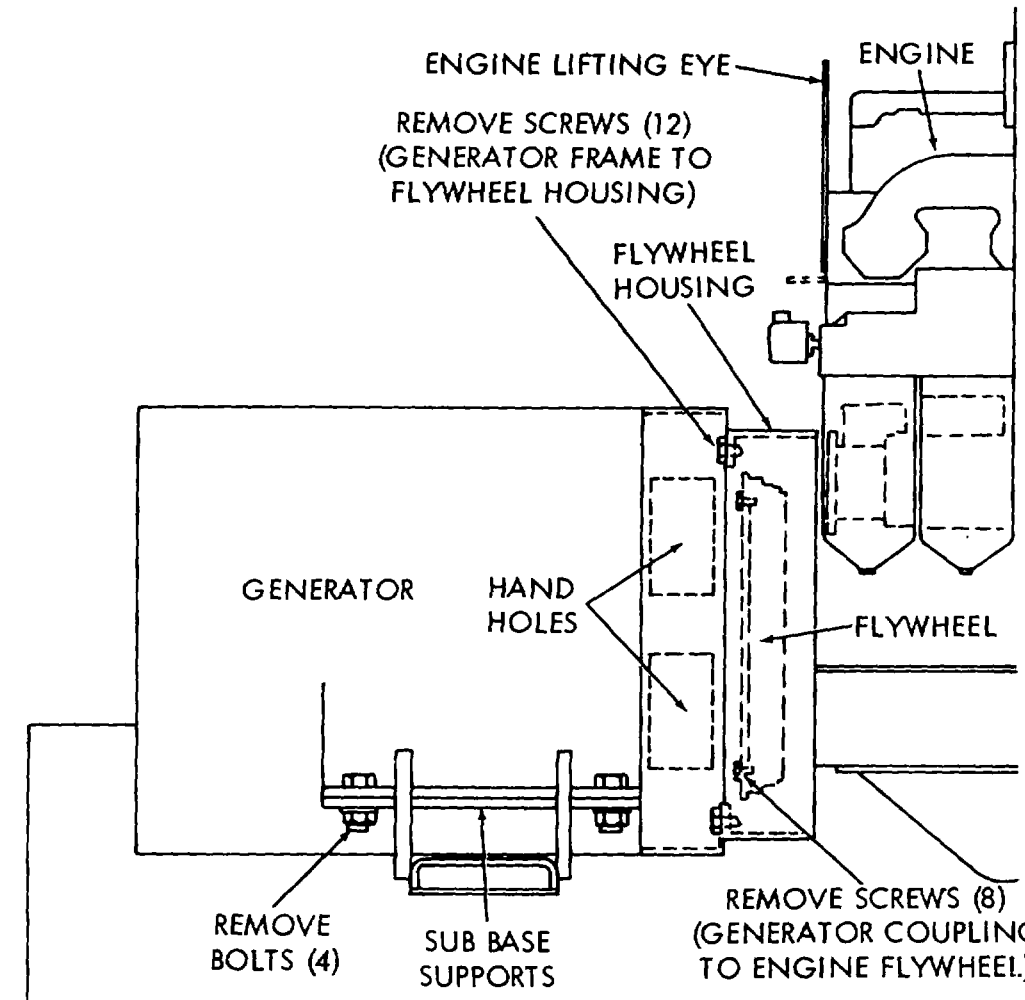


Figure 4. Engine removal and installation.

(2) Refer to figure 5 and remove main generator.

b. Installation. Refer to figure 5 and install main generator. Install two (2) dowels (fig. 4D) in flywheel to guide the coupling discs and the blower. Complete the installation as described in paragraph 28c.



STEP 1. ATTACH SPECIAL BRACE 4446054 TO ENGINE REAR LIFTING EYE AND TO CENTER SUPPORT (FIG. 3 1). THIS BRACE WILL SUPPORT ENGINE WHEN GENERATOR IS REMOVED (BRACE IS IN TOOL BOX).

STEP 2. REMOVE HAND HOLE COVERS AND SCREENS.

STEP 3. REMOVE 4 BOLTS (GENERATOR TO FRAME).

STEP 4. REMOVE 8 SCREWS (COUPLING TO FLYWHEEL).

STEP 5. REMOVE 12 SCREWS (GENERATOR TO FLYWHEEL HOUSING).

STEP 6. ATTACH HOIST TO GENERATOR LIFTING EYES AND REMOVE GENERATOR.

6115-400-35/5

Figure 5. Main generator removal and installation.

CHAPTER 3
ENGINE REPAIR INSTRUCTIONS

Section I. ENGINE ACCESSORIES

30. General
This section contains those items which are considered accessories to the engine. They consist of the starter, battery charging generator, generator regulator, fuel injection pump, mechanical governor, water pump, fan hub, turbocharger, and the Winterization heaters.

31. Electric Starting Motor
a. General. This is a heavy-duty, 24-volt, submersion proof, fungus and corrosion resistant, solenoid-operated, enclosed shift-lever type engine starter with eight brushes retained in four brush holders. The drive clutch is a heavy-duty overrunning type and the pinion clearance is adjustable.

b. Removal. Refer to TM 5-6115-400-12.

c. Bench Testing.

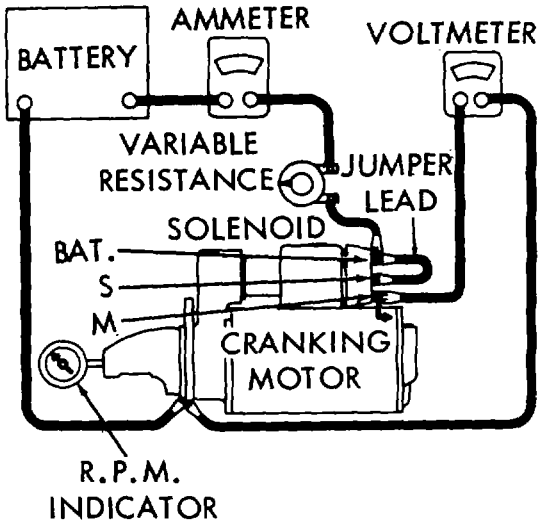
Note. Never operate the cranking motor more than 30 seconds at a time without pausing to allow it to cool at least two minutes.

(1) The armature should be checked for freedom of operation by turning the drive. Tight, dirty, or worn bearings, bent armature' shaft, or loose pole shoe screw will cause the armature to drag and it will not turn freely.

(2) No-Load Test (fig. 6).

(a) Connect the cranking motor in series with a fully charged battery to provide 24 volts, an ammeter capable of reading several hundred amperes, and a variable resistance. Also connect a voltmeter as illustrated, from the motor terminal to the motor frame. An r.p.m. indicator is necessary to measure armature speed. Proper voltage can be obtained by varying the resistance unit.

(b) Rated current draw and no-load speed indicates normal condition of the cranking motor.



VOLTS	MIN. AMPS	MAX. AMPS	MIN. R.P.M.	MAX. R.P.M.
23.0	60*	90*	7000	10700

* Includes solenoid.

6115-400-35/6

Figure 6. No load test

(c) Low free speed and high current draw indicate: tight, dirty, or worn bearings, bent armature shaft or loose pole shoes allowing armature to drag, shorted armature, grounded armature or fields.

(d) Failure to operate with high current draw indicates a direct ground in the terminal or fields.

(e) Failure to operate with no current draw indicates an open field circuit, broken brush springs, worn brushes, high insulation between the commutator bars or other causes which would prevent good contact between the brushes and commutator.

(f) Low no-load speed and low current draw indicate a high internal resistance due to poor connections, defective leads, dirty commutator and causes listed under (e).

(g) High free speed and high current draw indicate shorted fields.

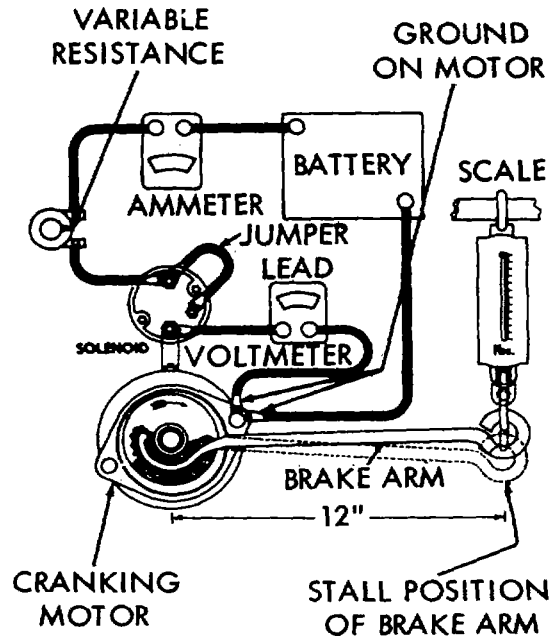
(3) Lock-Torque Test (fig. 7). The lock-torque test requires the equipment illustrated. A variable resistance with a high current capacity should be used. The cranking motor should be securely mounted and a brake arm hooked to the drive.

When specified current is applied, the torque can be computed from the reading on the scale. A one foot brake arm will directly indicate feetpound. If the torque is low, the motor must be disassembled for further tests and repair.

d. Disassembly.

(1) Scribe marks across drive housing, lever housing, frame and end bell to facilitate reassembly in the correct relationship.

(2) Refer to figure 8 and disassemble the starter.



AMPS	MIN. TORQUE (LB—FT)	APPROX. VOLTS
500	26	3.5

6115-400-35/7

Figure 7. Lock torque test

e. Cleaning.

(1) The drive, armature and field should not be cleaned in any degreasing tank, or with grease dissolving solvents, since these would dissolve the lubricant in the drive and damage the insulation in the armature and field coils. All parts except the drive should be cleaned with oleum spirits and a brush. The drive can be wiped with a clean cloth.

(2) If the commutator is dirty it may be cleaned with No. 00 sandpaper.

Caution: NEVER USE EMERY CLOTH TO CLEAN COMMUTATOR.

f. Inspection and Repair.

(1) Inspect housings and frames for cracks and distortion. Inspect threads in tapped holes for damage.

Replace defective parts.

(2) Inspect sleeve bearings for wear. Replace bearing if defective. Check for looseness in housing or end bell.

Replace worn or defective bearings. If new bearing is loose in bore, replace housing or end bell.

(3) Inspect wicks for tests, fraying, or wear. Replace if defective.

(4) Turn down commutator if grooved or out of round. Undercut mica to a depth of 0.025 to 0.032 inch below surface of commutator. Do not widen slots when undercutting mica.

(5) Inspect drive pinion for broken or badly worn teeth. Inspect clutch splines for wear and damage. Inspect shell for cracked or broken condition. Check to make sure pinion will drive into one direction and will slip in opposite direction. Replace drive clutch if defective.

(6) Inspect shift lever, shaft, and solenoid plunger for cracks or distortion.

Replace defective parts.

(7) Inspect bellows for tears, punctures, and deterioration.

(8) Inspect solenoid relay case for cracks or other damage. Replace if defective.

(9) Inspect brushes for wear or damage.

If damaged, or worn excessively, replace them.

g. Testing.

(1) To test armature for grounds or short, refer to TM 5-764.

(2) To test field coil windings for open circuits, connect multimeter probes to the ends of field coil, if multimeter does not read field coil is open and should be replaced.

(3) To test field coil windings for grounds, disconnect field coil winding ground connection. Connect meter probes to field frame and field connector, if multimeter reads, field coil is grounded, and must be repaired or replaced.

h. Assembly of End Bell and Brush Holder Plate.

(1) If wick was removed during disassembly, saturate a new wick and plug with oil and install in end bell.

Wick must not be in fill hole.

(2) Apply sealer to expansion plug hole and install plug. Fill reservoir with oil and install pipe plug.

(8) If bushing was removed, press a new bushing in end bell and install expansion plug.

(4) Assemble brush holder plate and end bell in the reverse order of disassembly but do not install brushes.

i. Starter Assembly.

(1) If wicks were removed during disassembly, install wicks and plugs following same instructions specified for end bell ((1) and (2) above).

(2) If bushings-were removed, press new bushings into housings.

(3) Assemble starter in reverse order of disassembly with the following exceptions and additions.

(4) If field windings were removed, coat threads of pole shoes screws with a suitable thread sealer before installation. Varnish inside of frame and winding assembly. Leave 0.38 inch from each end of frame free of varnish.

(5) Partially install lever housing lever and solenoid plunger before installing drive clutch. With frame in vertical position and lever housing upward, install nonmetallic washer and install drive clutch. Tilt clutch to engage lugs on shift lever. Seat housing making sure bellows is not crimped.

(6) If new brushes are being installed cover commutator with No. 00 sandpaper temporarily install armature, ,brushes, and end bell and turn in brushes. Disassemble, remove sandpaper, and clean armature and brush holder, plate assembly.

(7) Install thrust washer on armature shaft and install preformed packing

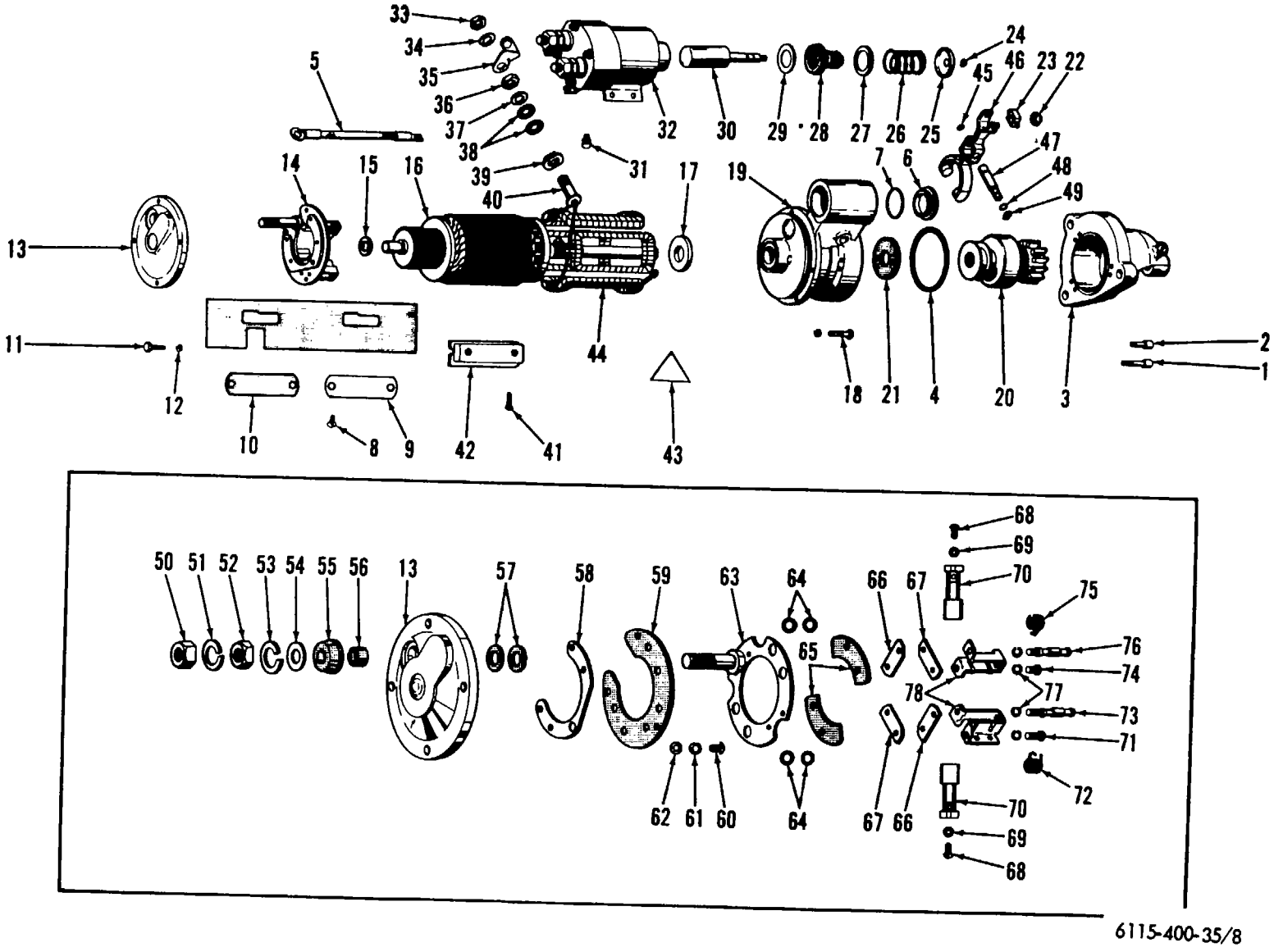


Figure 8. Electric starter.

1 Screw
2 Screw
3 Housing
4 Gasket
5 Lead
6 Plug
7 Gasket
8 Screw
9 Plate
10 Gasket
11 Screw
12 Lockwasher
13 Frame
14 Plate assembly
15 Washer
16 Armature
17 Washer
18 Screw
19 Housing
20 Clutch
21 Washer
22 Nut
23 Guide
24 Retaining ring
25 Retainer
26 Spring
27 Retainer
28 Boot
29 Washer
30 Plunger
31 Screw
32 Switch
33 Nut
34 Lockwasher
35 Connector
36 Nut
37 Washer
38 Washer
39 Bushing
40 Stud
41 Screw
42 Pole shoe
43 Insulation
44 Coil
45 Packing
46 Lever assembly
47 Lever
48 Packing
49 Retaining ring
50 Nut
51 Lockwasher
52 Nut
53 Lockwasher
54 Washer
55 Insulator
56 Bushing
57 Washer
58 Plate
59 Plate
60 Screw
61 Lockwasher
62 Washer
63 Plate and stud
64 Bushing
65 Plate
66 Plate
67 Plate
68 Screw
69 Lockwasher
70 Brush
71 Screw
72 Spring
73 Screw
74 Screw
75 Spring
76 Screw
77 Lockwasher
78 Holder

Figure 8-Continued.

on end bell. Install end bell assembly with assembled brush holder assembly on commutator and install brushes. Install flat washer on armature shaft and install armature and end bell as a unit into frame.

j. Adjusting Drive Clutch Pinion Clearance.

(1) Remove plug.

(2) With starter pinion in engaged position, press clutch inward lever to take up slack.

(3) Adjust hex self-locking nut until clearance between outer face of pinion and inner face of housing overhand is 23/64 inch + 1/32 inch.

k. Installation. Refer to TM 5-6115-400-12.

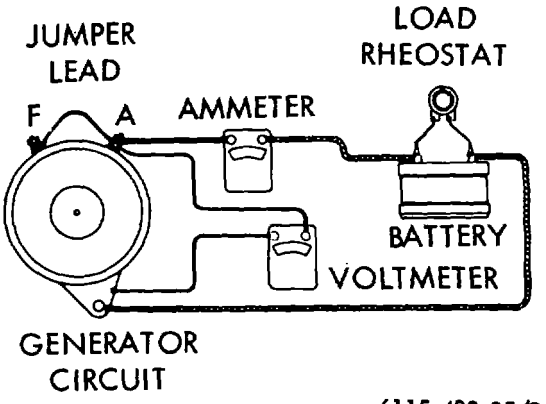
32. Generator - Battery Charging

a. General. The generator is a 24-volt 18ampere type mounted on the front of the engine. It is fungus and corrosion resistant and is arranged for "B" type circuit with the field grounded inside the generator.

*b. Removal***.** Refer to TM -6115-400-12.

c. Bench Testing. To check the generator for electrical output, connect an ammeter in series with a battery to the generator output terminal. Also connect a voltmeter from the generator output terminal to ground, and a load rheostat across the battery. Connect a jumper lead to the generator field terminal as shown in figure 9. operate the generator at 1,775 r.p.m., and adjust the lead rheostat to obtain a reading of 18 amperes on ammeter, and 28.5 volts on voltmeter. If the generator will not meet these conditions, it should be disassembled for further testing.

d. Disassembly. Refer to figure 10 and disassemble the generator.



e. Cleaning.

(1) Clean the armature and field windings of any dirt or magnetized particles. To remove grease and oil, apply a light coat of a safety type petroleum solvent such as MILT-6003, with a brush. Wipe clean, then use compressed air to remove any remain 30 ing dirt film. Do not use any degreasing compounds or submerge the armature in a degreasing tank as this would damage the insulation.

(2) Clean the commutator with 00 sandpaper and remove sand particles with compressed air.

(3) Clean the commutator end frame, drive end frame, and components with an approved solvent and dry thoroughly.

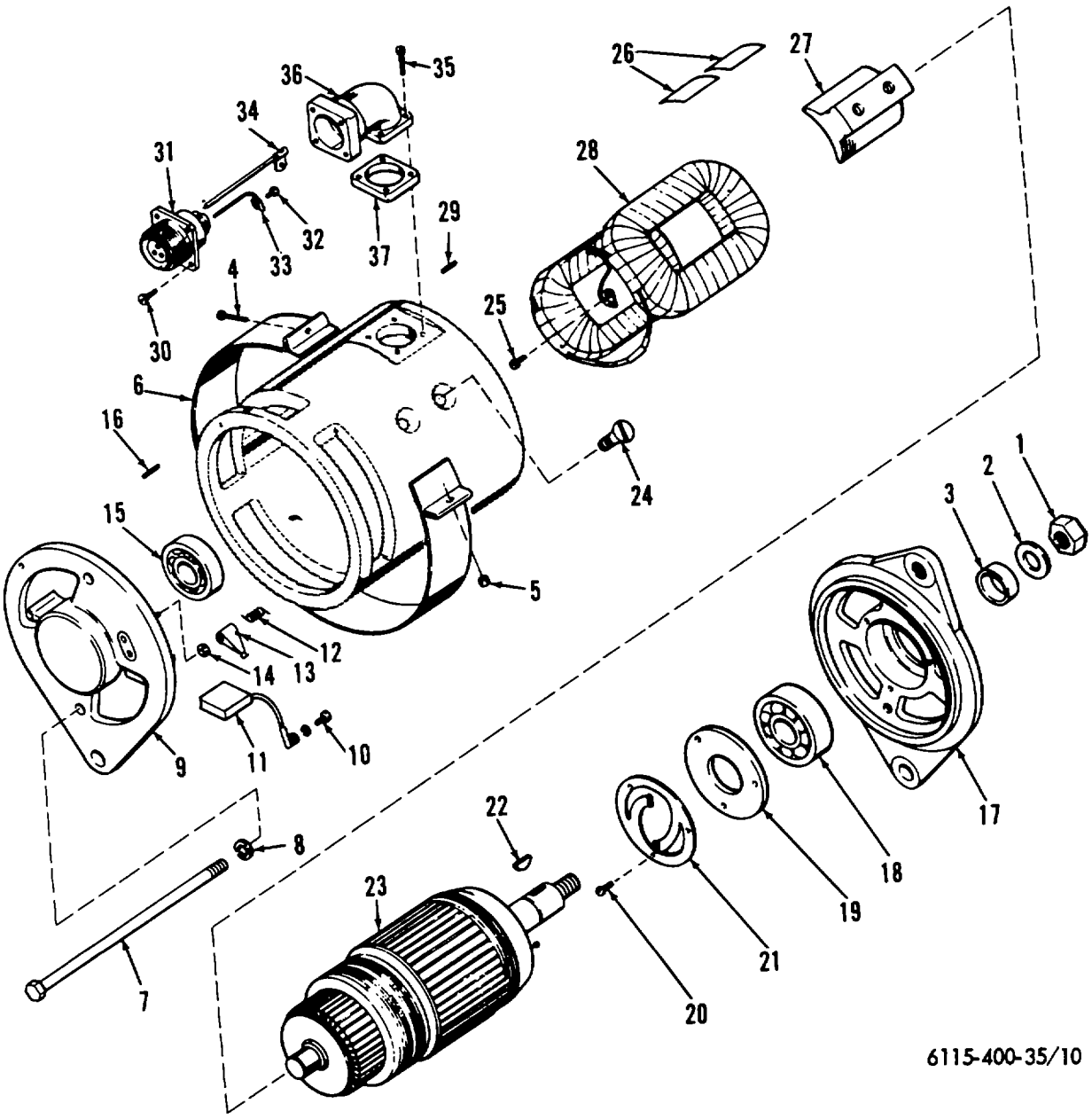
Caution. Do not soak insulators

f. Inspection and Repair.

(1) Inspect the commutator for roughness, high mica, loose winding, burrs, or pits. Smooth the commutator with 00 sandpaper or undercut on a lathe. Replace the armature if the commutator bars are less than 1/16-inch thick after undercut. Undercut the mica between the bars to a depth of 1/32-inch.

Caution. Do not widen commutator slots by removing metal from bars when undercutting. Use only solder with a rosin core flux.

(2) Inspect the armature shaft for wear, pits, bends, corrosion, or breaks.



1 Nut
2 Washer
3 Spacer
4 Screw
5 Nut
6 Cover
7 Bolt
9 Lockwasher
9 End bell
10 Screw
11 Brush
12 Spring
13 Arm
14 Washer
15 Bearing
16 Pin
17 End bell
18 Bearing
19 Retainer
20 Screw
21 Ring assembly
22 Key
23 Armature
24 Screw
25 Screw
26 Insulation
27 Pole shoe
28 Winding
29 Pin
30 Screw
31 Receptacle
32 Screw
33 Clip
34 Clip
35 Screw
36 Elbow
37 Spacer

Figure 10. Battery charging generator.

(3) Place the armature ends in V blocks and measure the commutator for out-of-round with a dial indicator. Turn down if in excess of 0.001-inch out-of-round.

(4) Inspect end frames for cracks and damaged or worn bearing surfaces.

(5) Inspect brush plate for cracks and loose rivets. Inspect insulated brush holders for grounds.

(6) Inspect brush springs for tension and signs of breaks or other damage. Replace brushes.

(7) Inspect the ball bearings for smooth operation. Inspect for excessive side play and damaged surfaces.

(8) Inspect the generator field frame for breaks, cracks, and damaged threads.

(9) Inspect all hardware for damaged threads.

g. Testing.

(1) Test for windings grounded to core with a continuity tester. Touch one probe of the tester to the armature shaft and the other to each commutator riser. An indication of continuity indicates the armature is grounded.

(2) Check for open windings with a test lamp. Touch the probes to a pair of adjacent commutator risers. Failure of the lamp to light indicates an open winding.

(3) Inspect for shorts with a growler and steel strip. The steel strip will vibrate against the armature over a shorted area as the armature is turned.

(4) Inspect the field windings for worn or frayed insulation, defective connections, opens, and field current draw.

(5) Replace or repair all defective parts as necessary.

h. Assembly. Reassemble generator in direct reversal of disassembly. Seat brushes using a seating hone or sandpaper wrapped around commutator. Clean commutator thoroughly and complete assembly.

i. installation. Refer to TM 5-61140012.

33. Generator Regulator

a. General. The generator regulator (fig.11) is a watertight, fungus and corrosion resistant unit for military applications. It is a heavy-duty, 24-volt, 18-ampere unit, designed for use in a negative grounded system and for generators having an internally grounded field circuit. Terminals of the regulator are housed in special receptacles conforming to Ordnance specifications. Connections to the regulator are made by means of mating Ordnance-type receptacles on the vehicle wiring harness.

b. Removal. Refer to TM 5-6115400-12.

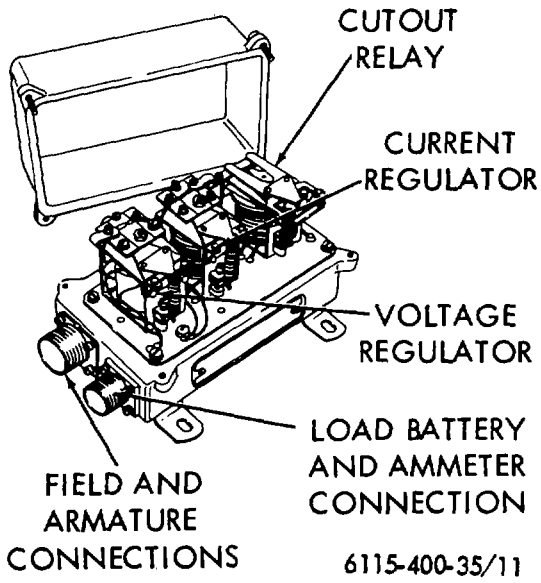
c. Regulator maintenance.

(1) Test specifications for regulator Model 111 8644 are as follows.

VOLTAGE REGULATOR
Air Gap (inches) ..... .087
Satisfactory Operating Range
(volts) 27.6-29.5*
If outside range, adjust to (volts) 28.2*
CURRENT REGULATOR
Air Gap (inches) ..... .087
Satisfactory Operating Range
(amp.) 16-20*
If outside range, adjust to (amp.) 18*
CUTOUT RELAY
Air Gap (inches) 048
Point Opening (inches) ..... .035
Satisfactory Closing Range (volts) 25-27*
If outside range, adjust to (volts) 26*
RESISTOR VALUES (OHMS)
A 200 (2)
B -..... 750 (2)
C 600 (1)
D 800 (2)
E 80 (1)

*THESE VALUES APPLY ONLY WHEN THE REGULATOR IS BEING TESTED AT OPERATING TEMPERATURE, ON THE VEHICLE, AND IN ACCORDANCE WITH THE PROCEDURE DESCRIBED IN THE FOLLOWING SECTION.

(2) Mechanical checks and adjustments (air gaps, point openings) must be made with the battery disconnected and the regulator preferably off the vehicle.



d. Cleaning Contact Points. Clean contact points with a fine-cut riffler file. The contact file should not be allowed to become greasy and should not be used to file other metals. When cleaning the contact points it should be remembered that tungsten is extremely hard and platinum is relatively soft. Platinum points should be filed very lightly to avoid excessive loss of metal. Never use sandpaper or emery cloth to clean contact points.

e. Regulator Checks and Adjustments (fig.12).

(1) Cutout Relay. Three checks and adjustments are required on the cutout relay; air gap, point opening, and closing voltage. Air gap and point opening are checked with the battery disconnected.

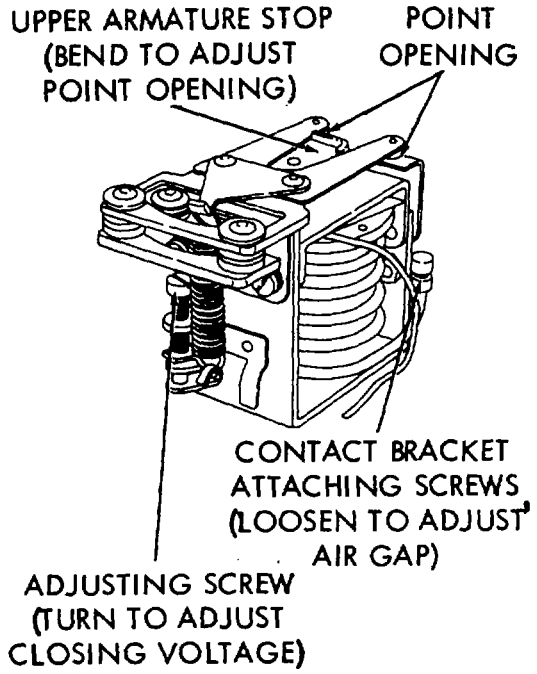
(a) Air Gap-Measure the air gap between the armature and the core-not between the brass pin in the armature and the core-with the contact points barely touching. If both sets of points do not close together, it will be necessary to realign the lower contact bracket slightly or to bend the spring fingers on the armature until points TM 5-115-40-3 do meet simultaneously. Adjust air gap by loosening the two screws attaching the lower contact bracket, and raise or lower the contact bracket as required. Be sure the points are properly lined up and tighten the screws well after adjustment.

(b) Point opening-Measure the point opening and adjust by bending the upper armature stop.

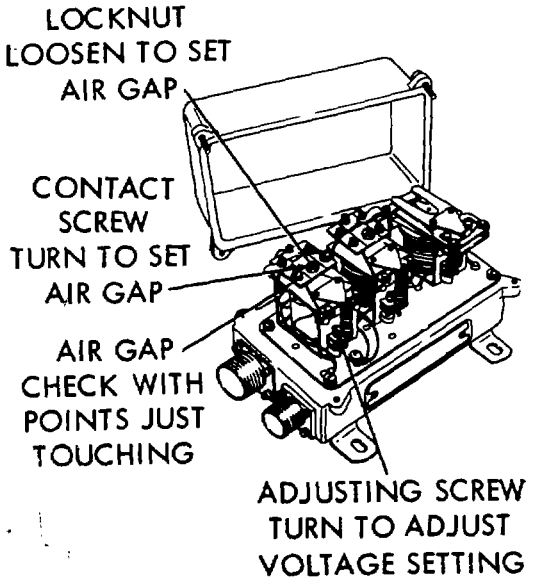
(c) Closing Voltage-To check the closing voltage on the cutout relay, insert Special Testing Harness No. 1 (fig. 13) in the generator circuit, and connect a voltmeter between T-1 (armature) and the regulator (fig. 13). Gradually increase generator speed and note the voltage at which the relay contact points close. Adjust the closing voltage, if necessary, by turning the adjusting screw at the base of the cutout relay frame. Increasing the spiral spring tension increases the relay closing voltage decreasing the spiral spring tension lowers the closing voltage.

(2) Voltage Regulator. Two checks and adjustments are required on the voltage regulator: air gap and voltage setting. Attention is called to fact that the AIR GAP and not the POINT OPENING is checked and adjusted.

(a) Air Gap-The air gap should be measured between the armature and the part of the core (not the residual pin in the core) next to the residual pin, with the points just touching. The proper way to measure this air gap is to push the armature down until the points open, release until the points barely close, then measure the air gap. Do not measure the gap with the flat spring that supports the contact screw raised up off the fiber mounting plate. To adjust, loosen the locknut and turn the contact



A. CUTOUT RELAY ADJUSTMENTS



B. ADJUSTMENTS REQUIRED ON VOLTAGE REGULATOR ARE AIR GAP AND VOLTAGE SETTING. ADJUSTMENTS REQUIRED ON CURRENT REGULATOR ARE AIR GAP AND CURRENT SETTING

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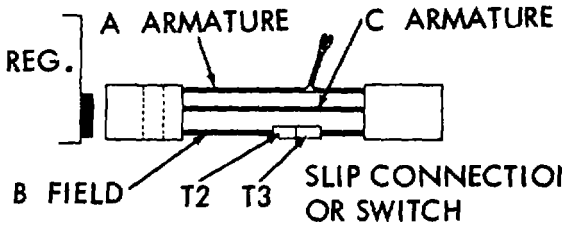
screw. The most convenient method of performing this operation is to insert the gage, press the armature down against it to hold it in place, and then turn the contact screw until the contacts barely touch.

(b) Voltage Setting-(fig. 13). Disconnect battery cable from regulator, and connect voltmeter between regulator battery terminal, and ground screws in the end of the regulator. With the generator operating at approximately 3,000 RPM and the regulator at operating temperature, note the voltage setting. Adjust by turning the adjusting screw at the base of the unit, thereby changing the spiral spring tension. Increasing the spring tension increases the voltage setting. After each change of adjustment, reduce generator speed until cutout relay opens; then return to speed and read voltage.

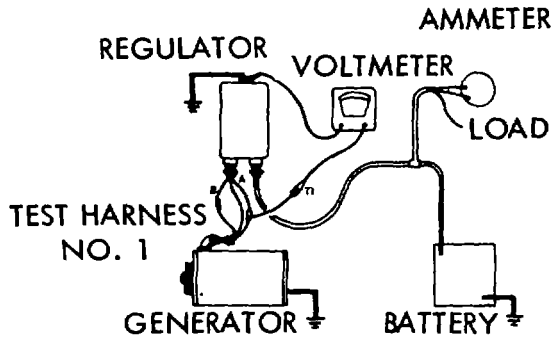
(3) Current Regulator. Two checks and adjustments are required on the current regulator: air gap and current setting. The AIR GAP and not the POINT OPENING is checked and adjusted-procedure being the same as for the voltage regulator above.

Current Setting (fig. 13). To check the current regulator setting, it is necessary to keep the voltage regulator from operating so that the generator output can increase to the value for which the current regulator is adjusted, and thus cause the current regulator to operate. Three methods of preventing voltage regulator operation are available. Regardless of the method used, disconnect battery cable from the regulator and connect an accurate ammeter in series between these junctions. This meter will measure the current regulator setting. The three methods of preventing voltage regulator operation are:



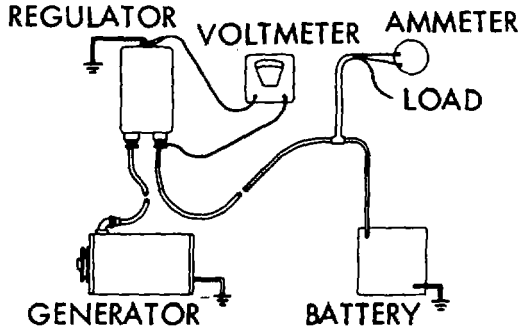
A. SUGGESTED SPECIAL TESTING HARNESS NO. 1 FOR ELECTRICAL CHECKING

CUTOUT RELAY CHECK



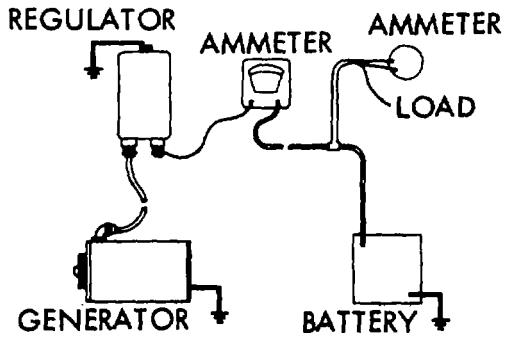
B. METER CONNECTIONS FOR CHECKING CUTOUT RELAY CLOSING VOLTAGE

VOLTAGE REGULATOR CHECK



C. METER CONNECTIONS FOR VOLTAGE REGULATOR CHECK

CURRENT REGULATOR CHECK



D. METER CONNECTIONS FOR CURRENT REGULATOR CHECK

6115-400-35/13

Figure 13. Wiring for generator regulator checks.

(a) Battery Discharge Method-By this method, the battery is partly discharged by cranking the-engine for 30 seconds with lights, and other accessories turned on. NEVER USE THE CRANKING MOTOR FOR MORE THAN 30 SECONDS AT A TIME WITHOUT PAUSING TO ALLOW THE CRANKING MOTOR TO COOL OFF. Excessive cranking will damage the cranking motor. Immediately after the cranking cycle, Start the engine and allow the generator output to increase to its maximum as determined by the current regulator setting before rising battery voltage causes the voltage regulator to operate. Since battery voltage recovers very quickly, this method requires prompt action.

(b) Load Method-If a load approximating the current regulator setting is placed across the battery during the time that the current regulator setting test is made, the voltage will not increase sufficiently to cause the voltage regulator to operate. This load may be provided by a carbon pile or other suitable resistance.

(c) Jumper Lead Method-If the regulator cover is removed and a jumper lead placed across the voltage regulator contact points, the voltage regulator cannot operate. Consequently, the generator output will increase to its maximum as determined by the current regulator setting. Lights and accessories should be turned on during the test to prevent excessive voltage. To adjust the current regulator setting, turn the adjusting screw at the base of the unit thereby changing the spiral spring tension. Increasing the tension will increase the current setting. After each change of adjustment, reduce generator speed until cutout relay opens, then return to speed and read current. (Higher residual magnetism resulting from uncontrolled voltage during this test will cause the voltage to regulate at an abnormally low voltage after the jumper is removed.) To restore proper operation, the generator must be "cycled", that is, stopped and stared."(Do not attempt to check voltage. regulator after using JUMPER LEAD METHOD until this condition has been corrected.)

f. Installation. Refer to TM 5-611-400 12.

34. Fuel Injection Pump

a. General.

(1) The fuel injection pump and governor are mounted on the left side of engine. The camshaft of the pump is driven at one-half engine speed by the accessory drive through an adjustable pump coupling. The pump plungers are lifted by the pump camshaft through tappet assemblies, located below the plungers and in contact with the pump camshaft. The plungers are lowered by plunger springs.

(2) Fuel is supplied by the fuel transfer pump through the second stage fuel filter and into the fuel sump (9, fig.14) of the fuel injection pump. surrounding the plungers (11). When a plunger is at the bottom of its stroke, the fuel flows through the plunger barrel above the plunger. The plunger moving upward closes the barrel ports, and as it continues its upward movement, the fuel now under pressure, opens the corresponding delivery valve assembly and flows through the fuel injection line to the corresponding fuel injection nozzle, where it is injected into the combustion chamber for that particular cylinder. Delivery of fuel ceases when the helix (10) (upper edge of the annular groove in the plunger) opens the by-pass port in

the plunger barrel. The by-passing of fuel back to the fuel sump of the injection pump relieves the pressure and permits the delivery valve to close. Excess fuel, delivered to the fuel sump on the injection pump, opens the pressure relief valve and returns to the fuel tank.

b. Removal. Refer to TM 5-6115-400-12.

c. Disassembly.

(1) Remove the drive assembly from the pump flywheel.

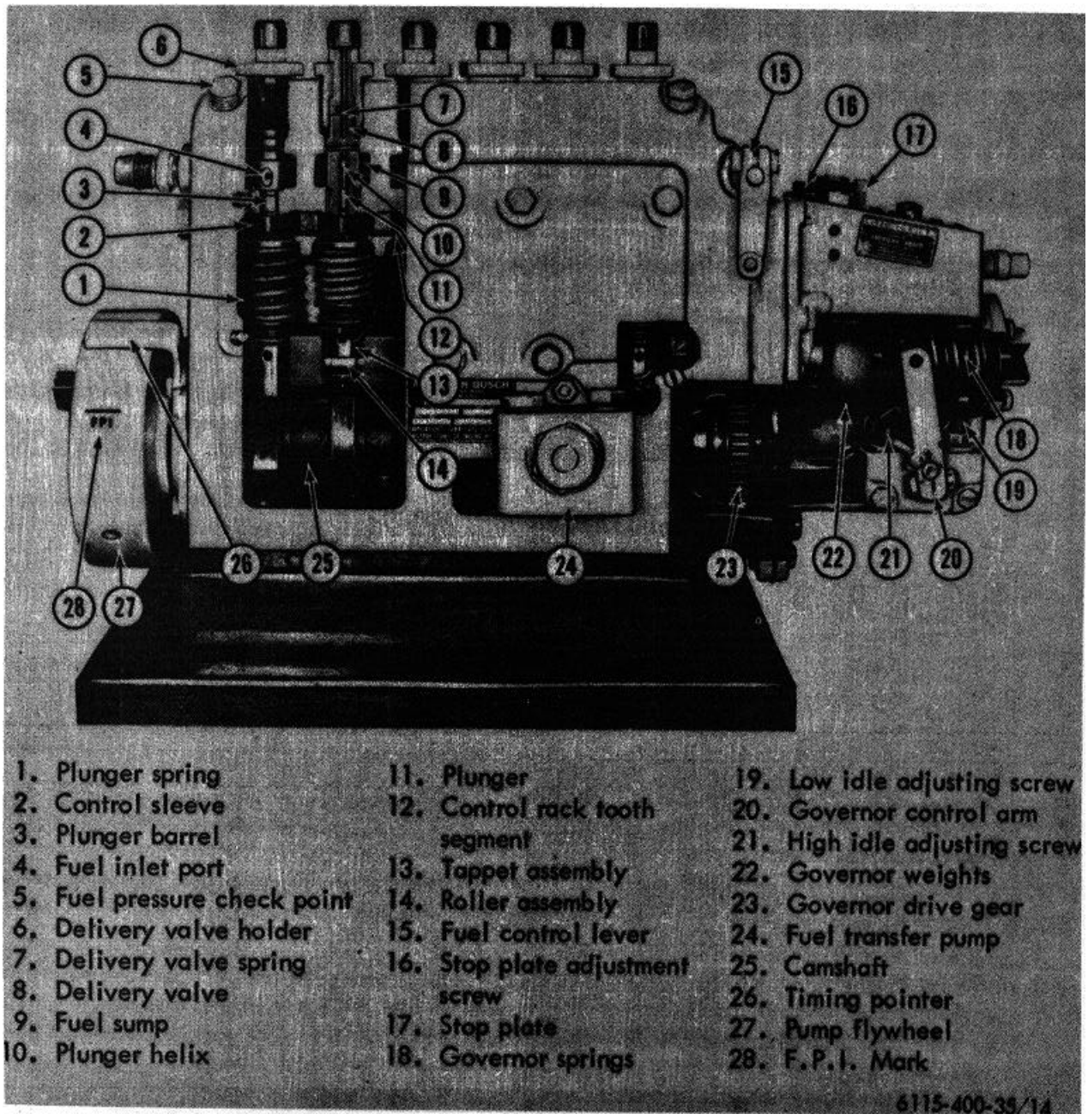


Figure 14. Fuel injection pump-cut-away view.

(2) Remove the fuel transfer pump (33, fig. 15).

(3) Drain all lubrication oil from the governor assembly.

(4) Remove the governor housing fastening screws (97, fig. 20).

(5) Carefully disengage the governor housing (99, fig. 20) from the fuel pump housing and disengage the governor linkage pin (45) from the injection pump control rack.

(6) Remove the governor housing gasket (53).

(7) Remove inspection cover (37, fig. 15).

(8) Remove base plus (84, fig. 15) with special pronged wrench Service Tool TSE 76157.

(9) Service Tool TSE 76159B or equivalent is used to compress plunger spring. Hold the compressing tool so the lever and adjustable prongs are on top. The lower prongs are inserted between the lower spring seat and tappet knob. The adjustable prongs are placed between the delivery valve holder and pump. The lever is pressed downward to compress the spring. With the plunger spring compressed, rotate the camshaft (78, fig. 15) until tappet assembly is positioned to allow access to the tappet knob (51). Use two narrow bladed screw drivers to pry tappet knob sufficiently to remove the timing spacer (49). Reseat the tappet knob.

(10) Rotate the camshaft until the hole in the tappet shell (48, fig. 15) is exposed and insert tappet retaining pins, Service Tool TSE 76156B to facilitate removal of the camshaft.

Follow the same procedure for the remaining tappet assemblies.

(11) Remove hexagon nut (68) and lockwasher (69). Remove flywheel.

(12) Remove end plate fastening screws (70, 71 and 30) from both ends of 38 pump housing and withdraw end plates (73 and 27).

(13) Remove two center bearing retaining screws (80). Carefully withdraw camshaft and center bearing from pump housing.

(14) Insert the plain end of tappet lifter TSE 7697 or equivalent through the base plug bore and rest the plain end squarely on the tappet roller.

Compress the plunger spring and remove the tappet retaining pin. Remove the remaining tappet retaining pins in a similar manner. The tappet lifter is inserted through the end plate bore, the prongs are snapped around the tappet shell. Tappet assembly (52) is then lifted and withdrawn through the end plate bore.

(15) Use Service Tool TSE 7661 if available, through the base plug bore, and carefully withdraw plunger (56) and lower spring seat (53).

Note. **Plunger and barrel are lapped, precision built and mated parts. It is essential that each plunger be returned to its mated barrel. The components parts are not interchangeable. Therefore, it is recommended that as each plunger is removed from the pump it be placed in a numbered pan. The plunger and barrel nearest the drive coupling is usually considered the number one "cylinder". Further, the lapped surface of the plunger should not be handled as this is apt to corrode it.**

Withdraw plunger spring (54). Remove control sleeve (58) and upper spring seat (55) as a unit by raising them over the barrel and withdrawing it through the inspection opening.

(16) Remove control rack stop screw and carefully withdraw control rack (3).

Remove tappet guide screws (44) and gaskets (45).

(17) Remove and replace the pump in a vise in an upright position.

(18) Delivery valve holder (66) is removed with 1-1/4 inch socket wrench (modified to thin wall construction). Remove delivery valve springs (64).

(19) A delivery valve puller is used to extract delivery valve assembly and delivery valve gasket.

Note. Delivery valve and delivery valve body are lapped parts. These component parts are not interchangeable and must remain together.

(20) Remove barrel locating screws (60) and gaskets (61) and remove the barrel from pump housing. As such barrel is removed return it to its respective plunger.

(21) Do not remove the ball bearings (32) from the camshaft unless it is necessary to replace them. If the ball bearings are to be removed, they must be pressed off the camshaft with a suitable arbor press.

d. Cleaning.

(1) Clean all parts thoroughly with an approved cleaning solvent. Air-blow dry.

(2) Handle parts as little as possible with bare fingers. Lubricate all parts lightly with preservative oil to prevent corrosion from perspiration acids. Ordinary clean engine oil is suitable if preservative oil is not available.

(3) Gaskets, seals, fastening screws, nuts and washers are to be replaced if worn or damaged.

(4) Drive and driven gear should be examined for wear or broken teeth and replaced if necessary.

(5) Ball bearings should be examined for excessive wear or roughness. Replace if not in good condition.

(6) Springs must be free from nicks, rust spots or signs of corrosion. Replace if necessary.

(7) Replace lubricating oil baffle (25, fig. 15) if button end is worn.

e. Reassembly.

(1) Clamp the pump in the vise, incorporating brass jaws or equivalent, in an upright position. Remove --- plunger from the barrel and ----- the barrel in the pump. Align the slotted side of the barrel with the barrel locating screw hole. Replace barrel locating screw (60, fig. 15) and gaskets (61) and secure firmly.

After the barrel locating screws have been tightened, check the barrels; barrel should move freely in the elongated slot.

Note. **Always complete one operation 'before proceeding further, i.e., insert all barrels before inserting delivery valves.**

(2) After making certain that the barrel is seating squarely on its pump housing seat, insert the delivery valve assembly (63) exercising care that the lapped surfaces at the bottom of the delivery valve body and top of the plunger (56) are absolutely clean.

***Note*.** **If delivery valve and barrel lapped surface is discolored or shows signs of not seating properly, use lapping plate with 900 lapping compound or finer to clean up lapped surfaces.**

***Caution*.** **Make certain that lapping is perfectly true and not worn in center. Install gasket (62), delivery valve spring (64) and delivery valve holder (65). Secure delivery valve holders with 1 1/4 inch socket and place protection caps on delivery valve holders.**

(3) Remove the pump from the vise and replace in an inverted position clamping the pump at the flats of the hexagon on the delivery valve holders.

(4) Insert the control rack (3) in the same position as it was found before disassembly. Replace the control rack stop screw (4) and tighten firmly. Located at both ends of the control rack are two punch marks, position the control rack so that these punch marks protrude equidistant at both sides of the pump housing.

(5) Stamped on the control sleeve (58) and gear segment (59) are calibration marks. If neither of these parts

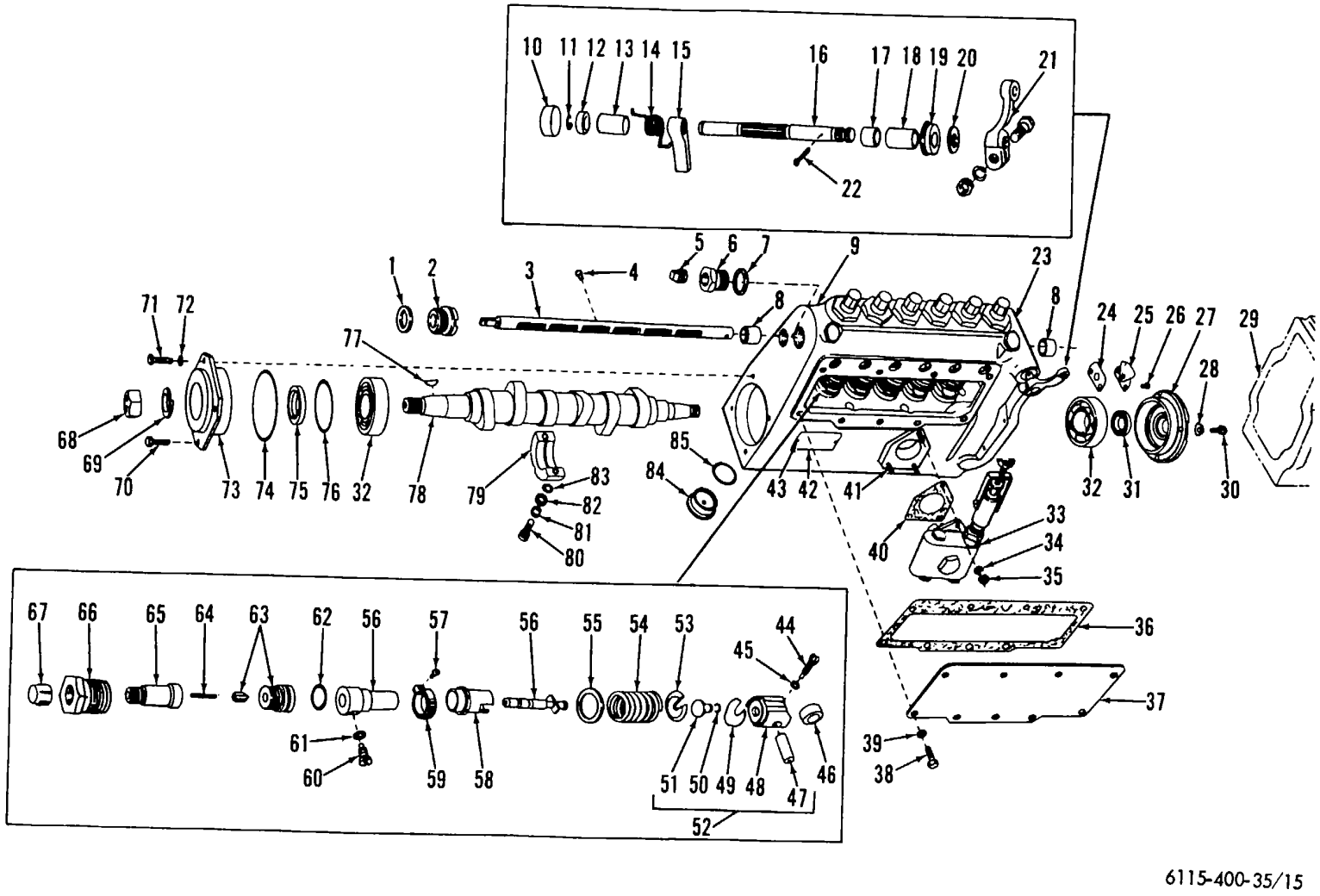


Figure 15. Fuel injection pump-exploded view.

1 Lockwasher
2 Collar
3 Control rack
4 Screw
5 Plug
6 Plug
7 Gasket
8 Bearing
9 Plug
10 Plug
11 Retaining ring
12 Washer
13 Bearing
14 Spring
15 Lever
16 Shaft
17 Spacer
18 Bearing
19 Seal
20 Washer
21 Lever
22 Cotter pin
23 Housing assembly
24 Gasket
25 Baffle
26 Screw
27 Plate
28 Washer
29 Governor
30 Screw
31 Seal
32 Bearing
33 Transfer
34 Lockwasher
35 Nut
36 Gasket
37 Cover
38 Screw
39 Lockwasher
40 Gasket
41 Stud
42 Plate
43 Screw
44 Screw
45 Gasket
46 Roller assembly
47 Pin
48 Shell
49 Spacer
50 Retaining ring
51 Knob
52 Tappet assembly
53 Seat
54 Spring
55 Seat
56 Plunger assembly
57 Screw
58 Sleeve
59 Gear
60 Screw
61 Gasket
62 Gasket
63 Valve assembly
64 Spring
65 Holder
66 Nut
67 Cap
68 Nut
69 Lockwasher
70 Screw
71 Screw
72 Lockwasher
73 Plate
74 Gasket
75 Seal
76 Washer
77 Key
78 Camshaft
79 Bearing
80 Screw
81 Lockwasher
82 Washer
83 Gasket
84 Plug
85 Gasket

Figure 15-Continued.

have replaced them one of the marks must be deleted. Delete the calibrating mark stamped on the control sleeve, use a very fine narrow file for the operation. (Do not file at the bench where the pump assembly is being done.) After the calibrating mark has been removed, thoroughly clean the control sleeve and dry with dry compressed air. Replace control sleeves meshing the control sleeve segment with the control rack and positioning the control sleeves so that the segment clamping screws are parallel with the control rack.

***Caution*. Move control rack to maximum travel in both directions to see that the slot in gear segment lines up with boss on .pump housing at each end. If it does not, then gear is not timed properly and will have to set gear segment in proper tooth on control rack. Check that the control rack operates freely. The deleted calibration mark will be replaced in alinement with the mark on the gear segment after the pump has been calibrated.**

(6) Replace upper spring seat (55) over control sleeves and insert the plunger springs (54) through the base plug bore, so it rests on the upper spring seat.

Caution. The plunger and barrel are lapped assemblies and it is imperative that the plunger returns to its respective barrel.

(7) Hold the correct plunger for the particular barrel being served in a vertical position with the special plunger puller, slip the lower spring seat on the plunger above the plunger yoke. Insert the plunger into the barrel through the base plug bore. Exercise care, do not use force when inserting the plunger.

***Note*. The assembly marks on the yoke of the plunger and on the guide slot of the control sleeve must coincide (fig. 16). The plunger must slide freely in its barrel and also in the slots of the control sleeve. Release the plunger puller and remove it.**

(8) Replace tappet guide screws (44, fig. 15) and gaskets (45) and tighten to 145-155 inch lbs. To facilitate the installation of the camshaft later, install the tappets without the timing spacer (49). Special Service Tool TSE 76160 or equivalent is used to compress the plunger springs. Screw the base plug attached to the tool in number one base hold, position the lever so the brass ram will enter the tappet roller.

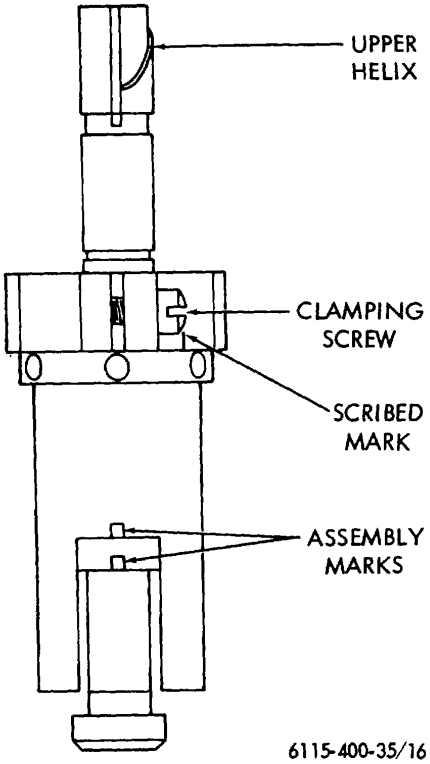


Figure 16. Alining plunger and control sleeve assembly marks.

Before compressing the plunger spring, check that assembly marks on the plunger yoke and control sleeve are in alinement. This determined, press down on the lever until the tappet retaining pin hole in the tappet is exposed and temporarily insert the tappet retaining pin.

(9) Position center bearing (79, fig. 15) on camshaft and carefully install the camshaft in the housing. Make certain that the notched end of the camshaft is located at the same side of the pump as it did before disassembly. The firing order will be changed if the camshaft is not installed properly in this respect. Replace center bearing screws with two gaskets (83) and tighten firmly.

(10) Install both end plates (73 and 27) and secure with screws and lockwashers.

(11) Replace woodruff key and install flywheel, secure with lockwasher and hexagon nut.

(12) Check the end (longitudinal) play of the camshaft by measuring the distances between the end plate and the coupling face. Use dial indicator clamped to pump housing with indicator on end of camshaft. The end play must measure between -0.004 inches and 0.008 inches. To measure the distance it will be necessary to tap (and hold) the camshaft in each direction. Should the end play be found in excess of these permissible limits, correct this condition by inserting or removing a sufficient number of spacing washers (76) between the ball bearing and the end plate. Whenever adding or removing spacers, divide the amount between both ends of the camshaft if possible.

(13) Remove pump from vise and invert.

(14) Rotate the camshaft and as each tappet rises sufficiently, remove the tappet retaining pin (fig. 17).

(15) Replace the base plugs with new gaskets (85, fig. 15) and secure firmly.

(16) Remove the pump from the vise and remove the protection caps from the delivery valve holders. The pump is now ready for timing and calibration.

(17) The timing spacers (49, fig. 15) will be assembled to the pump during the timing operation when the pump is on the test stand. The method following is used to insert the timing spacer. Use Service Tool TSE 76159 to compress plunger spring. Hold the compressing tool so the lever and adjustable prongs are on top. The lower prongs are inserted between the lower spring seat and tappet knob.

The adjustable prongs are placed between the delivery valve holder and pump. The lever is press downward to compress the spring. With the plunger spring compressed, rotate the camshaft until tappet assembly is positioned to allow access to the tappet knob. Use narrow bladed screw drivers to pry the tappet knob sufficiently to insert timing spacer. Reset the tappet knob on the spacer. Remove the special compressing tool.

f. Internal Timing of the Fuel Injection Pump.

(1) Remove the delivery valve holder (64, fig. 15) and delivery valve spring (64) which is located above the plunger and barrel nearest the pump drive end. Then, remove the valve from the delivery valve body (63). Do not remove the valve body. Reinstall the delivery valve holder, after which it becomes possible to insert a depth gage or dial indicator through the delivery valve holder and delivery valve body to contact the top of the plunger (56).

(2) Rotate the camshaft in anti-clockwise rotation until the plunger is at the top of its stroke and record the measurement with the depth gage or dial indicator.

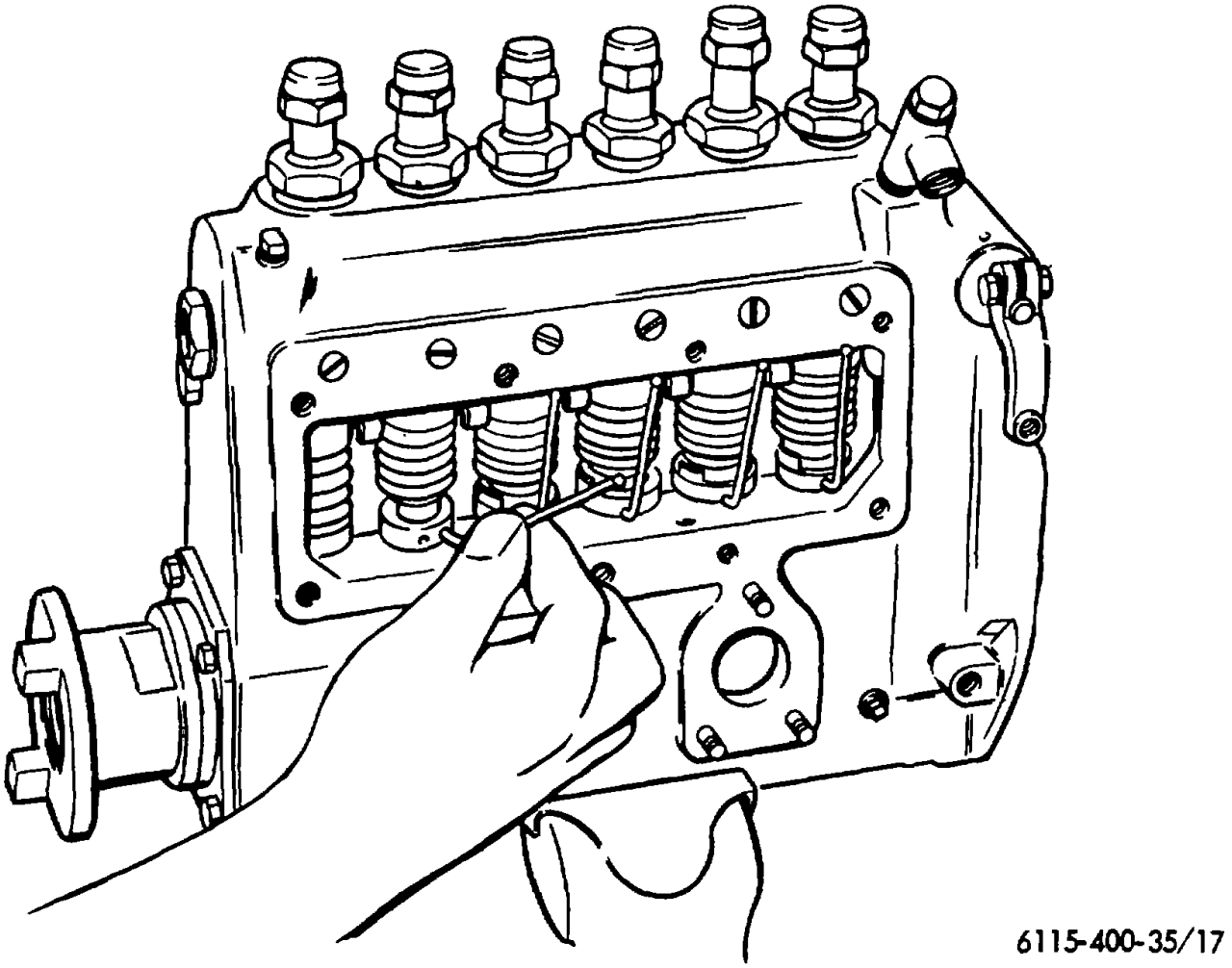


Figure 17. Remaining (or installing) temporary tappet retaining pins.

***Note*. Make certain timing line on coupling and No. 1 top center timing line coincide (fig. 19).**

(3) Position a suitable screw driver under the knob (51, fig. 15) of the tappet and raise the plunger until it contacts the bottom of the delivery valve body. Hold the plunger in this position and record measurement on depth gage or dial indicator.

(4) The difference between the two figures represents the distance between the top of the plunger and the bottom of the delivery valve body. This figure is generally (0.020 inch) with limits of 0.012 inch to 0.028 inch.

(5) If adjustment is required, it can be accomplished through the raising or lowering the tappet with adjusting spacers (49, fig. 15).

(6) Reinstall the delivery valve, spring and delivery valve holder.

(7) The pump can now be timed internally in the manner outlined in subparagraph g, below.

(8) Mount pump on test stand and connect test oil lines for flow timing.

(9) Inscribe a line on the pump end plate to coincide with the line on the drive coupling to indicate the flowed position of this plunger, if no mark is present, or a new end plate used.

***Note*. Never change timing mark on pump coupling.**

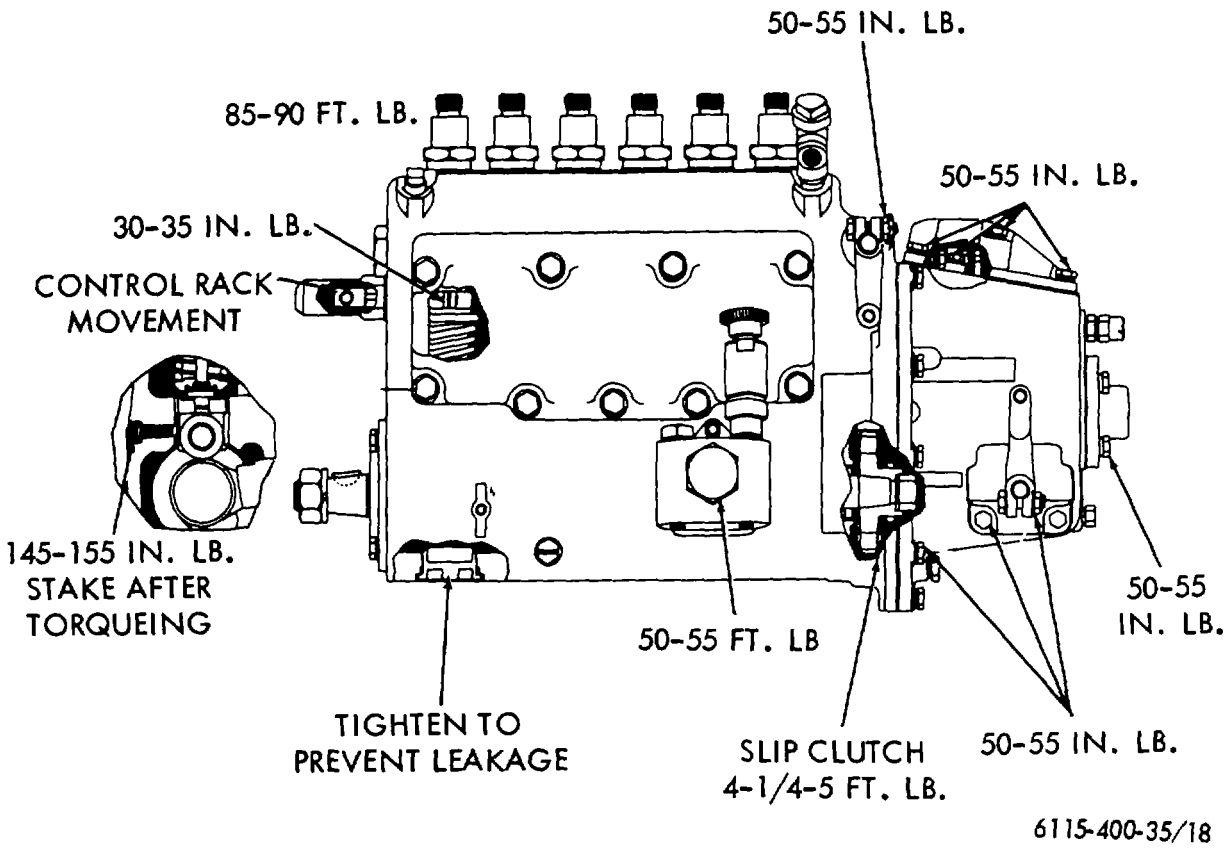


Figure 18. Fuel injection pump torque valves.

g. Flow Timing of the Fuel Injection Pump. Whenever a fuel injection pump has been completely disassembled and reassembled, it is necessary that both internal timing and calibration of the pump be checked even though none of the component parts were replaced. Timing in this particular case does not refer to the setting of the fuel injection pump to the engine, but refers to the internal adjustment of the various pumping elements, which in a multi-cylinder injection pump must each function at a definite time in relation to the rotation of the camshaft. For instance, in a six cylinder pump, injection must take place every 60 degrees of pump camshaft rotation.

(1) Connect the supply tank, filter and shutoff valve to the inlet connection of the injection pump.

(2) Bleed the pump of all air by loosening one of the bleeder plugs located at top of the pump housing. Thorough bleeding is essential.

(3) Place the control rack of the pump in its full fuel position.

(4) Remove the delivery valve holder (64, fig. 15) from cylinder number one.

Note. Number one pumping element is plunger nearest to drive end.

(5) Remove the delivery valve and its spring (64, fig. 15) with the fingers.

The valve body must remain in position. DO NOT USE MAGNET.

Needle nose pliers are permissible.

(6) To determine that there is sufficient clearance between maximum plunger stroke and the delivery valve body, check this measurement as described in (f) above.

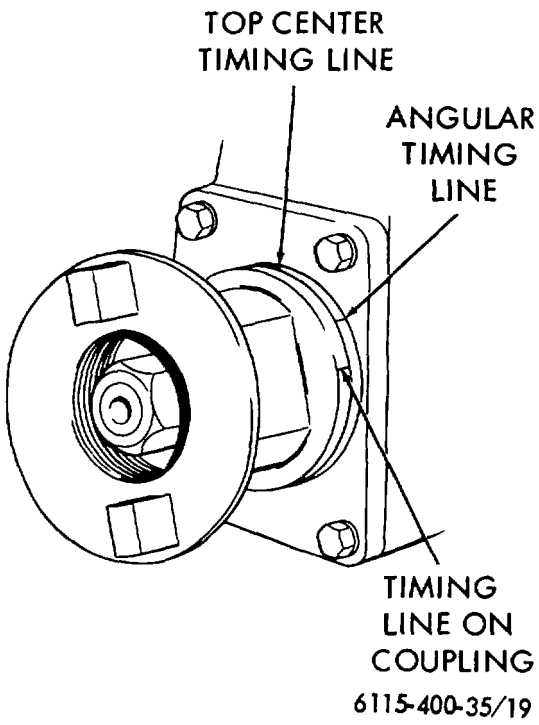


Figure 19. Fuel injection pump timing marks for internal timing

(7) Replace the delivery valve holder. Manually turn the drive until number one (1) plunger of the pump is in its lowest position. The spill port now being open, fuel will flow through the delivery valve holder.

Note. **The pump must be rotated counterclockwise for each timing operation to obtain accurate readings. Back-lash in test stand and pump parts may otherwise cause erroneous settings, far beyond specified tolerances.**

(8) Turn the pump counter-clockwise, through the port opening position, just to the point where the fuel stops flowing. This indicates the port closing position.

(9) The timing mark on the drive flywheel should now coincide with the timing mark pointer. Eliminate the old mark by filing, if necessary, and establish a new one.

(10) Adjust the graduated wheel on the test stand so that the zero mark on its rim lines up with the pointer.

(11) Recheck the number one pump element for port closing to make sure that the fuel stops flowing from the delivery valve holder when the pointer lines up with the zero mark on the test stand wheel. THIS IS IMPORTANT.

(12) Having thus determined the port closing position for plunger number 1, remove the delivery valve holder and re-install the delivery valve and spring previously removed. Make sure these parts are clean. Replace the delivery valve holder and tighten it firmly, but not excessively.

(13) Now proceed to the next pump element in the firing order which is 1-5-3-6-2-4. Determine port closing of the next pump element in the same manner as outlined for plunger number one, except that it should occur 60 degrees later. Proceed until all six pump elements are timed at 60 degree intervals in firing order.

(14) As an example, when checking the number five plunger, the fuel should stop flowing when the graduated wheel on the test stand indicates 300 degrees. Add or remove spacers as necessary. Also check each pumping element for proper clearance between plunger and delivery valve body at top-dead-center.

(15) Only one spacer is used between the tappet and the tappet knob. Spacers are furnished in sizes of 0.050, 0.054, 0.058, 0.062 and 0.066 inch.

Note**. 0.004 inch is about 1/2 degree on the graduated wheel of the test stand.**

(16) Only 1/2 degree tolerance is allowed on the fuel settings. If any deviation from these figures is observed, the plunger must be adjusted.

h. Calibrating the Fuel Injection Pump. Engine performance depends to a great extent upon the accuracy with which the injection pump is calibrated.

It is important that an equal amount of fuel is delivered to each engine cylinder and at the correct time.

***Note*. Worn delivery valve will show wide variation at full load speed and very little variation at low idle speed. Badly worn delivery valve will usually show increases in fuel delivery at full load position.**

(1) Mount injection pump on the test stand.

(2) Pump delivery requirements are as follows:

Fuel rack setting (inches)	RPM	Delivery CC's/500 strokes	Max variation between cylinders CC's/500 Strokes
1.398	910	82.--84.0	3.2
1.396	875	80.0	3.2
1.121	275	14.0-19.0	1.4 (12% max.)

(3) Fuel rack setting is the distance from the flywheel end of the pump housing to the end of the fuel rack. The fuel rack end must be within 0.005 inch of specified setting. Use a 2inch depth mike.

(4) Use holder assembly number AKB 50SD 150F adjusted to 2500 psi. Use Nozzle assembly ADN 8S2-C and 1/4 X 0.120 X 0.20 tubing. Use TSE-76141 calibrating oil or equivalent.

(5) Calibrating oil temperature is to be 110 to 120°F.

(6) In order to obtain an accurate calibration, it is advisable to run a minimum of 250 strokes. Run 500 strokes whenever fuel delivery is less than 75 cc.

(7) All data is given for a transfer pump fuel pressure of approximately 15 psi.

(8) Variation percentage is calculated by taking the difference between the highest and the lowest fuel draw and dividing the highest number into the variation.

Example: Highest draw-86cc
Lowest draw-81 cc
Variation: - 5 cc (5.6%)

(9) AA the most accurate calibration is desirable at full load speed, variation between pumping elements should not exceed 3 percent at full load speed and 12 percent at low idle. On a used pump it is permissible to go slightly above 12 percent on low idle.

(10) Test stand should be run with pump at full load position (875 rpm) for several minutes or until all air is out of system and calibrating oil is warmed up if test stand is in a cold room.

***Note*. Nozzles in test stand must be in perfect condition at all times or the pump cannot be calibrated properly.**

(11) If fuel draw shows considerable variation, the nozzles should be removed and the high and low ones switched to make certain that the variation is not in the nozzles. If different nozzles show variation on the same plunger or injection pump, they will have to be repaired and recalibrated.

(12) When attaching pump to test stand, always connect fuel lines to pump and leave nozzle lines disconnected until pump is run several minutes to flush out pump and fuel lines.

(13) Add one pint of OE-30 lubrication oil to camshaft components. Do not use calibrating oil.

(14) Check and record the fuel flow of each cylinder. Check the variation between cylinders.

(15) Make adjustments as necessary to bring the variation within the specified limits. Loosen the gear segment clamping screws (57, fig. 15). Hold the gear segment with a screw driver and adjust the sleeve with close fitting pin, part number TSE 7695, or equivalent.

(16) The fuel flow is increased by turning the sleeve to the right. To decrease the fuel flow, turn the sleeve in the opposite direction.

(17) Run fuel draws and adjust until pump calibration is within limits.

(18) Check the low idle setting (275 rpm) in the same manner, but do not change the fuel settings on the gear segment. If the correct low-idle flow cannot be obtained after calibrating for full load speed, delivery valves must be checked for wear and replaced if necessary. If delivery valves are in good condition, replace the valve springs.

(19) The calibration mark on the control sleeves, which had been removed at time of overhaul, should now be reinscribed to coincide with the mark on the gear segment. Firmly tighten the segment clamping screw.

i. Installation. Refer to TM 5-6115-400-12.

35. Mechanical Governor

a. General

(1) The governor drive gear, located on the rear end of the fuel injection pump camshaft, is engaged with the driven gear mounted on the front end of the governor weight shaft. A friction clutch, built into the governor drive gear, is so designed that it causes the drive gear to slip on the hub momentarily whenever sudden speed changes of the pump camshaft occur. This clutch assures smooth operation of the governor weights and helps to minimize governor wear.

(2) The governor weights are attached to and rotate with the governor weight shaft, thus providing governor control at all engine speeds. As the weights revolve, centrifugal force tends to throw them outward, moving the weights along the shaft. This movement is opposed by the governor springs through a sliding sleeve. The higher the speed. the greater the centrifugal force and movement of the sleeve against the governor springs. If the speed is decreased, the centrifugal force of the weights lessens, and the governor springs force the sleeve forward toward the fuel injection pump. A control rod, connected to the fulcrum lever on the governor sleeve and engaged with the tooth segment of the control sleeve on each plunger barrel of the injection pump, transmits the movement of the governor sleeve to the control sleeve on each plunger barrel. Movement of the plunger sleeve by the control rack rotates the corresponding pump plunger in its barrel, which in turn controls the amount of fuel delivered by the plunger.

b. Removal.

(1) The mechanical governor is attached to the fuel injection pump and they are removed from the engine as an assembly. Refer to TM 5-6115-400-12.

c. Disassembly.

(1) Drain all lubrication oil from the governor assembly.

(2) Remove the governor housing fastening screws (97, fig. 20).

(3) Carefully disengage the governor housing (99) from the fuel pump housing and disengage the governor linkage pin (45) from the injection pump control rack.

(4) Remove the governor housing gasket (53).

(5) Remove the governor inspection cover (67).

(6) The adjustable bumper spring (70 and 71) assembly need not be removed unless the spring is damaged.

(7) The stop plate unit (68) is held by two screws and can be removed from the governor housing.

(8) Remove the operating lever covers (83 and 92).

(9) If the operating lever (86) is damaged and must be replaced, scribe a line across the end of the lever shaft to coincide with the mark on the operating lever for correct positioning at reassembly.

(10) Remove the setscrew (35) from the operating shaft spring hub (36).

(11) Withdraw the operating lever shaft (93) and spring hub.

(12) Remove the end cap (81).

(13) Unscrew the four fastening screws from the bearing retaining plate (19) and carefully pull out the operating parts from the governor housing.

(14) Remove the operating lever shaft bearings (55) and oil seal (94) if necessary.

(15) Withdraw the spring seat inner and outer spring spacers (31 and 32 and inner and outer springs (29 and 30), and sleeve.

(16) The fulcrum lever is then disengaged from the sleeve (101).

(17) Remove the weight lubricating plunger (11) and spring (12). Remove the nut, lockwasher and driven gear (15).

(18) Use an arbor press to remove shaft (27) from the ball bearing (20) and bridge.

(19) Remove the bearing plate (21) and ball bearing from the bridge.

(20) Use arbor press to remove the weight pins (26).

Caution. Weight pin has one end of greater diameter than the other.

(21) Press out weight bushings (24).

(22) The drive gear and friction clutch assembly can be removed from the injection pump camshaft extension by removing the hex nut (10) and lock washer.

(23) Remove the securing nut (10) using special wrench Service Tool TSE 7919. The camshaft is prevented from turning by the use of the coupling wrench TSE 7913 on the drive coupling on the opposite end of the camshaft. With the securing net remove, the lock washer, spring discs (5 and 7), adjusting spacer (4) or spacers and drive gear may be removed.

(24) Use special puller, Service Tool TSE 7920, which is threaded on to the hub (2) to withdraw the hub from the camshaft taper.

d. Cleaning, Inspection and Repair.

(1) Clean all parts thoroughly with an approved cleaning solvent. Air-blow dry.

(2) Handle parts as little as possible with bare fingers. Lubricate all parts lightly with preservative oil to prevent corrosion from perspiration acids. Ordinary clean engine oil is suitable if preservation oil is not available.

(3) Gaskets, seals, fastening screws, nuts and washers are to be replaced if worn or damaged.

(4) Drive and driven gear should be examined for wear or broken teeth and replaced if necessary, (5) Ball bearings should be examined for excessive wear or roughness, Replace if not in good condition.

(6) Springs must be free from nicks, rust spots or signs of corrosion. Replace if necessary.

(7) Sliding sleeve assembly (101, fig. 20) must be inspected for wear in grooves. Check thrust washer face for wear and freeness. Check bushing for wear.

(8) Flyweights must move freely on weight pins, needle bearings and bushings but not loosely.

(9) Fulcrum yoke assembly should be checked for wear or pivot pins, bushings, control rack linkage and link pin.

(10) The stop plate must be tight on operating lever shaft (93).

(11) The maximum fuel stop plate assembly (68) should be inspected for any wear by the torque cam (50). The threaded stud and guide pin must be firmly fastened to the stop plate.

(12) The surface on the face of the gear contacted by the clutch disc (5) must be smooth. Discs must be replaced if worn excessively.

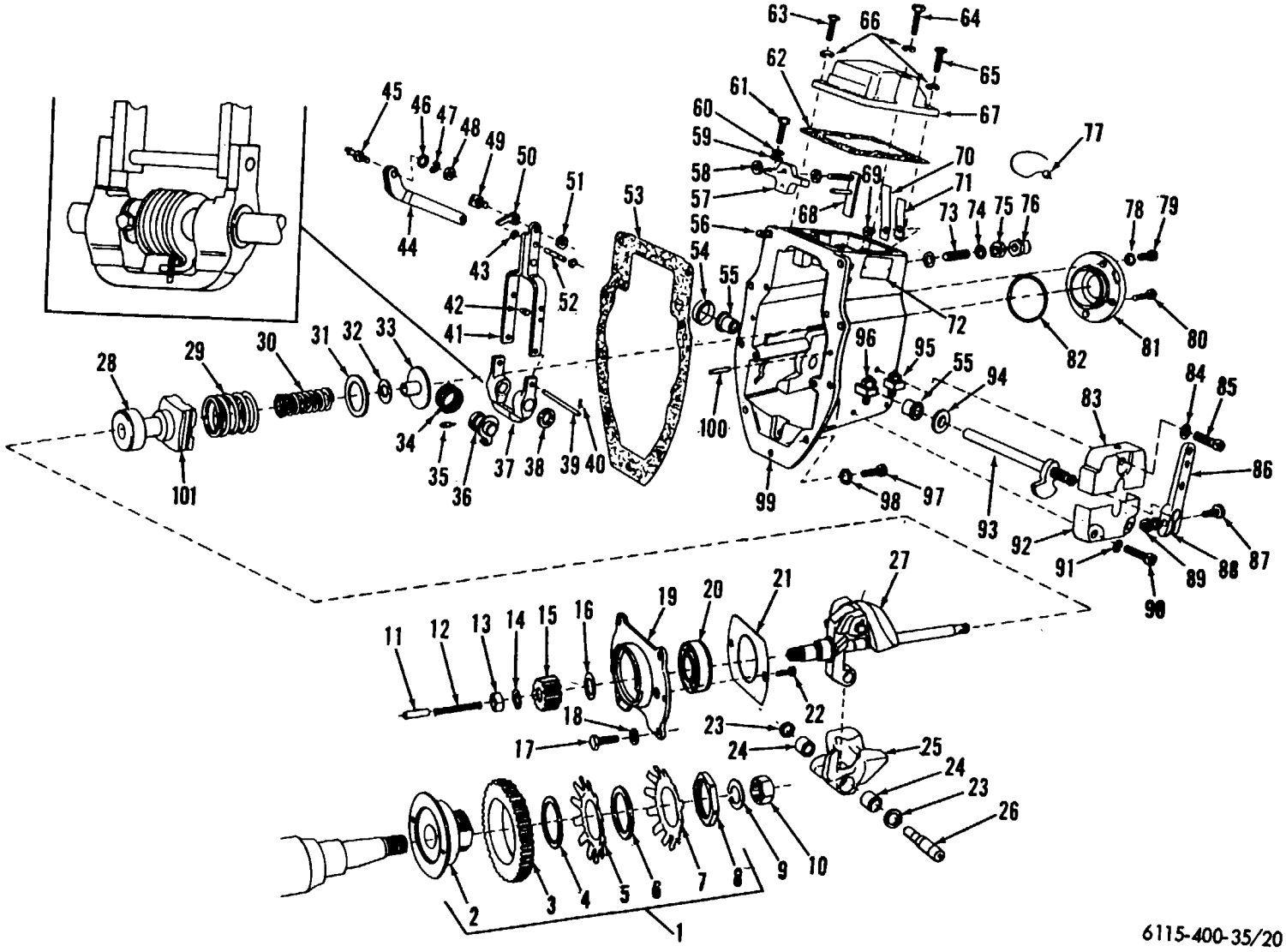


Figure 20. Mechanical governor-exploded view.

1 Gear assembly
2 Hub
3 Gear
4 Spacer
5 Disc
6 Spacer
7 Disc
8 Nut
9 Lockwasher
10 Nut
11 Plunger
12 Spring
13 Nut
14 Lockwasher
15 Gear
16 Washer
17 Screw
18 Lockwasher
19 Plate
20 Ball bearing
21 Plate
22 Screw
23 Washer
24 Bearing
25 Weight assembly
26 Pin
27 Shaft
28 Ball bearing
29 Spring
30 Spring
31 Spacer
32 Spacer
33 Seat
34 Spring
35 Screw
36 Hub
37 Bracket
38 Spacer
39 Pin
40 Cotter pin
41 Lever
42 Pin
43 Retaining ring
44 Link
45 Pin
46 Washer
47 Lockwasher
48 Nut
49 Screw
50 Cam
51 Nut
52 Pin
53 Gasket
54 Plug
55 Bearing
56 Screw
57 Bridge
58 Nut
59 Washer
60 Lockwasher
61 Screw
62 Gasket
63 Screw
64 Screw
65 Screw
66 Lockwasher
67 Cover
68 Plate
69 Screw
70 Spring
71 Spring
72 Plate
73 Screw
74 Gasket
75 Nut
76 Cap
77 Seal
78 Lockwasher
79 Screw
80 Screw
81 Cap
82 Packing
83 Cover
84 Washer
85 Screw
86 Lever assembly
87 Screw
88 Lockwasher
89 Nut
90 Screw
91 Washer
92 Cover
93 Shaft assembly
94 Seal
95 Nut
96 Screw
97 Screw
98 Lockwasher
99 Housing assembly
100 Pin
101 Sleeve assembly

Figure 20. Continued.

e. Reassembly of Governor.

(1) After the parts have been cleaned, inspected and replaced where necessary, the governor can be reassembled.

(2) The clearance between the drive gear hub (2, fig. 20) and the drive gear must be checked. With ample clean lubricating oil between the hub and the drive gear, the latter should rotate freely and easily without binding in any position. If necessary, the gear and its hub may be lapped slightly to provide a non-binding assembly. Reassemble the component parts of the clutch assembly. The drive gear and clutch assembly is mounted on the extending camshaft taper. No key is used, although a keyway is provided in the camshaft taper.

(3) Install a 0.035 inch spacer (6) between the two spring discs. With the securing nut firmly tightened, the clutch tension should be carefully checked. The friction surfaces of the drive gear and the spring disc must be well lubricated with oil.

(4) The gear should rotate with a steady pull of 4 1/4-5 foot-pounds. A one foot lever, Service Tool, TSE 7947, is used to measure this pull with the spring scale TSE 7927B.

***Note*. If checked on test stand, run pump at 160 rpm.**

(5) The drive gear should move through a complete revolution on its hub with uniform resistance. The gear should revolve without clutching with a pull of 4 1/4 to 5 pounds. If tension is too great, install another spacer, or if the gears move too freely, remove spacers to give the proper slippage. Three spacer thicknesses are available 0.035 inch, 0.049 inch and 0.065 inch.

(6) Press bearing (24) into flyweights (25).

Note. A two step reamer with pilot, Service Tool TSE 7955, is used to ream the bronze bearing.

(7) Secure the weights to the shaft by pressing the weight pin into position.

***Note*. Position the weight pin so that the center lubricating groove is directly in line with the weight shaft spider lubricating hole.**

(8) The ball bearing (20) is a press fit on the shaft (27) and a slip fit into the bridge (19).

(9) Install new weight lubricating plunger (11) and spring (12). Assemble the driven gear on the shaft and secure with lockwasher and hex nut. Upset lock washer against all sides of hex nut (13).

(10) Slide the sleeve assembly (101) over the shaft with the ball bearing end first.

(11) Slide the inner spring (30) over the shaft and the outer spring (20) over the inner spring. Install the spring seat (33).

(12) The forks of the fulcrum lever (41) have two positions for the pivot pins (42). The upper holes are for governors requiring 10 percent regulation. The lower holes are for governors requiring 5 percent regulation.

Install the pivot pins in the lower holes. The fulcrum pivot pins are a press fit from inside the fulcrum lever.

(13) With the control rack link (44) facing the weights, assemble the fulcrum lever to the weight shaft with the pivot pins in the grooves of the sliding sleeve (101).

(14) Install the hub (36) and spring (34) to the fulcrum lever assembly so that the spring ends straddle the lever bracket bar. The spring ends must firmly grip the bracket bar and lip on the hub.

(15) If necessary to install new control shaft bearing (65), press into the housing with Service Tool 7935 and ream with reamer TSE 7940. Oil seals (94) should be soaked in oil and pressed in with Service Tool TSE 7938.

(16) The internal mechanism consisting of the weight and fulcrum lever assembly should be placed in the governor housing. Locate the plate (19) on the dowel pins (100) and secure.

The fastening screws are to be wired together vertically on either side of the plate.

Note. **The cut-away portion of the plate must face downward.**

(17) Slide the operating lever shaft (93) into place and secure the hub and spring assembly on the shaft with the setscrew (35).

(18) Fasten the governor to the injection pump engaging the pin (45) into the control rack of the injection pump.

(19) To set the proper spring spacing, remove the string seat (33) together with the outer spring from the shaft.

Use spring gap gage TSE 7939. The holes in the spring seat are not used when setting the spring gap (fig.

21)

(20) The inner spring gap is measured with the outer spring removed. Reinstall the spring seat and place the gap gage over the spring compartment. Loosen the thumb screw on the gap gage and bottom the prongs on the spring seat until the seat touches the inner spring. Tighten the thumb screw and measure the distance that the prongs protrude in the gap gage. This measurement is the inner spring gap and should be 0.068 inch. Add or remove spacers to obtain the correct gap.

(21) The outer spring should have no gap and is measured in the same manner as the inner spring. It is not necessary to remove the inner spring when measuring the outer spring gap.

(22) With the spring gaps properly determined, install and secure the end cap (81).

(23) Install the control lever adjusting screws.

(24) The covers and inspection cover with gasket can be installed after the governor has been tested and adjusted.

f. Governor Adjustments.

(1) Install the governor on a calibrated fuel injection pump which is mounted on a test stand. Reference to full load delivery in the following instructions is the maximum control rack setting and delivery used for calibration purposes.

(2) Move stop plate (68, fig. 20) to prevent interference with torque cam (50). Also retract bumper springs (70) with screw to prevent interference with fulcrum lever (41).

(3) Operate test stand at maximum governed full load speed as specified in paragraph 34h, holding operating lever (86) in full load position.

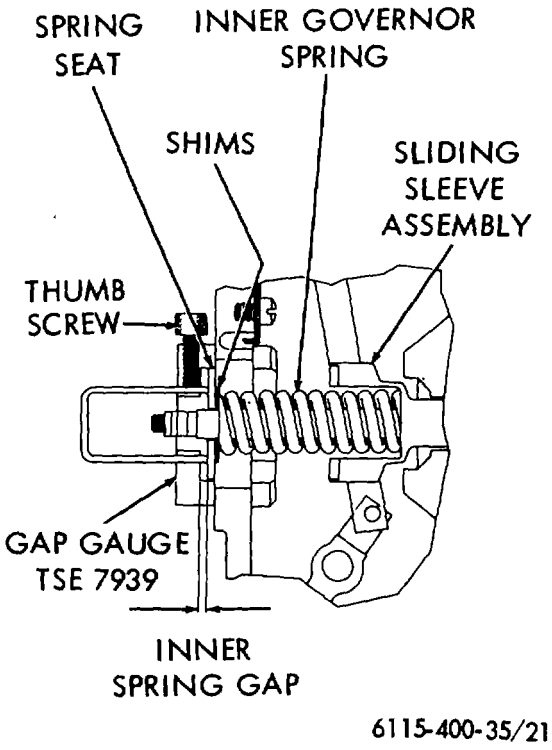


Figure 21. Measuring inner spring

(4) Adjust operating lever high idle speed screw until the desired full fuel quantity for full load, as specified in paragraph 34h, is obtained. Adjust screw upward for increased delivery and downward for reduced delivery.

Note. **When a governor is adjusted, there must be no rapid oscillations of the fulcrum lever (41). When this occurs, cause of fluctuations must be found and corrected before proceeding further.**

(5) If step 4 has been correctly established, then a slight increase in test stand rpm will start control rack moving toward the stop position, thus reducing the fuel delivery.

(6) Again operate test stand at governed full load rpm and adjust stop plate (68) to just contact cam (See fig. 22). Then inscribe line on the machined surface of governor housing with straight edge across front face of stop plate.

(7) Record fuel delivery taken at this setting and rpm.

(8) Check for torque control by reducing rpm to 2/3 of full load speed. Holding operating lever in full load position, an increased fuel delivery will result.

(9) With operating lever still in full load position, increase rpm to high idle rpm. The control rack should have moved into decreased fuel delivery position and reduced fuel approximately 1/4-1/5 of full load quantity. Record delivery for same number of strokes as taken at rated full load rpm.

(10) With pump operating at high idle rpm as set in step 9 (and operating lever in full load position) turn in adjusting screw (See fig. 22) until bumper spring just contacts the fulcrum lever. In the event that slight oscillation is present in the fulcrum lever at this higher rpm, screw in bumper spring screw in this position with lock nut and cap.

(11) The high and low idle setting can only be approximated on the test stand, as the actual idle settings must be made on the engine.

g. Installation. Refer to TM 5-6115-400-12.

36. Water Pump

a. General. A centrifugal-type water pump assembly is provided for circulating coolant through the engine and radiator. The pump shaft is supported in the pump bearing sleeve by a ball bearing on pulley end and a roller bearing on rear end of the bearing sleeve. The bearings are splash-lubricated by oil thrown from the engine gear train that enters through two openings in the pump bearing sleeve. Lip-type oil seals at each end of the bearing sleeve prevent oil from leaking to the outside and from entering the impeller compartment of the pump body. A spring-loaded coolant seal prevents coolant from seeping out of the impeller compartment. The tapered hub of the impeller is "pinned" to the rear of the pump shaft and is secured by a slotted nut and cotter pin.

b. Removal. Refer to TM 5-6115-400-12.

c. Disassembly and Inspection (Fig. 23).

(1) Clamp pulley hub in a vise as shown in figure 24, jaws of vise should be equipped with copper protectors.

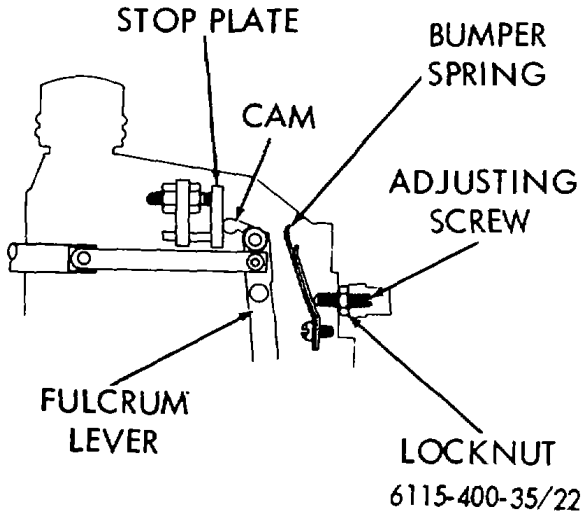


Figure 22. Governor bumper spring adjustment.

(2) Remove cotter pin and retaining nut from impeller end of shaft.

(3) Using a suitable bar-type puller remove impeller from the shaft.

Note. **Two 5/16 inch -18 NC tapped holes are provided in impeller for use of a puller. A shaft protector must be used with puller to protect end of pump shaft because of the amount of force required to shear the impeller retaining pin; this pin cannot be removed in any other way and must be sheared when removing the impeller.**

Extreme care should be taken to prevent damage to the ceramic sealing ring bonded to the impeller. This ring is an integral part of the impeller and is not serviced separately.

(4) Separate the pump body from bearing sleeve.

(5) The coolant and oil seals are now accessible. Drive coolant seal from pump body (fig. 25).

(6) Drive rear oil seal from pump body (fig. 25).

(7) Secure pulley hub in a vise and remove cotter pin. retaining nut and washer.

(8) Using a puller remove pulley hub from shaft.

(9) Position bearing sleeve in vise and, using a pinch bar, pry out front oil seal. The seal will be damaged during removal and a new seal must be used in assembling the pump.

(10) Using Truarc pliers, remove snap ring at the front ball bearing location.

(11) Using a soft-headed hammer and tapping from the rear of bearing sleeve with as little force as possible, drive shaft and ball bearing from the sleeve.

(12) Remove snap ring from its groove at rear roller bearing location. Drive roller bearing from the bearing sleeve as shown in figure 25.

(13) Remove Woodruff key from pump shaft. Using a press, force shaft from bearing.

(14) Press rear roller bearing race from pump shaft. Take care not to damage bearing race or shaft.

(15) Clean and inspect all parts thoroughly.

(16) If ceramic insert (bonded to front face of impeller) is scored or cracked, a new impeller assembly must be installed.

(17) Inspect carbon sealing face to coolant seal. If roughness or cracks are evident, coolant seal must be replaced. Inspect rear oil seal.

Note. **It is recommended that new coolant and oil seals be used in assembly to eliminate any possibility of reinstalling an original seal that may be defective or subject to failure (or leakage) shortly after installation.**

(18) Check bearings for looseness, roughness, bind, excessive wear or pitting and replace bearings if necessary.

(19) Make certain impeller vanes are not damaged or cracked. Replace impeller if necessary.

(20) Check pump shaft for wear at points in contact with the lips of rear oil seal and coolant seal. Replace shaft if necessary.

d. Reassembly.

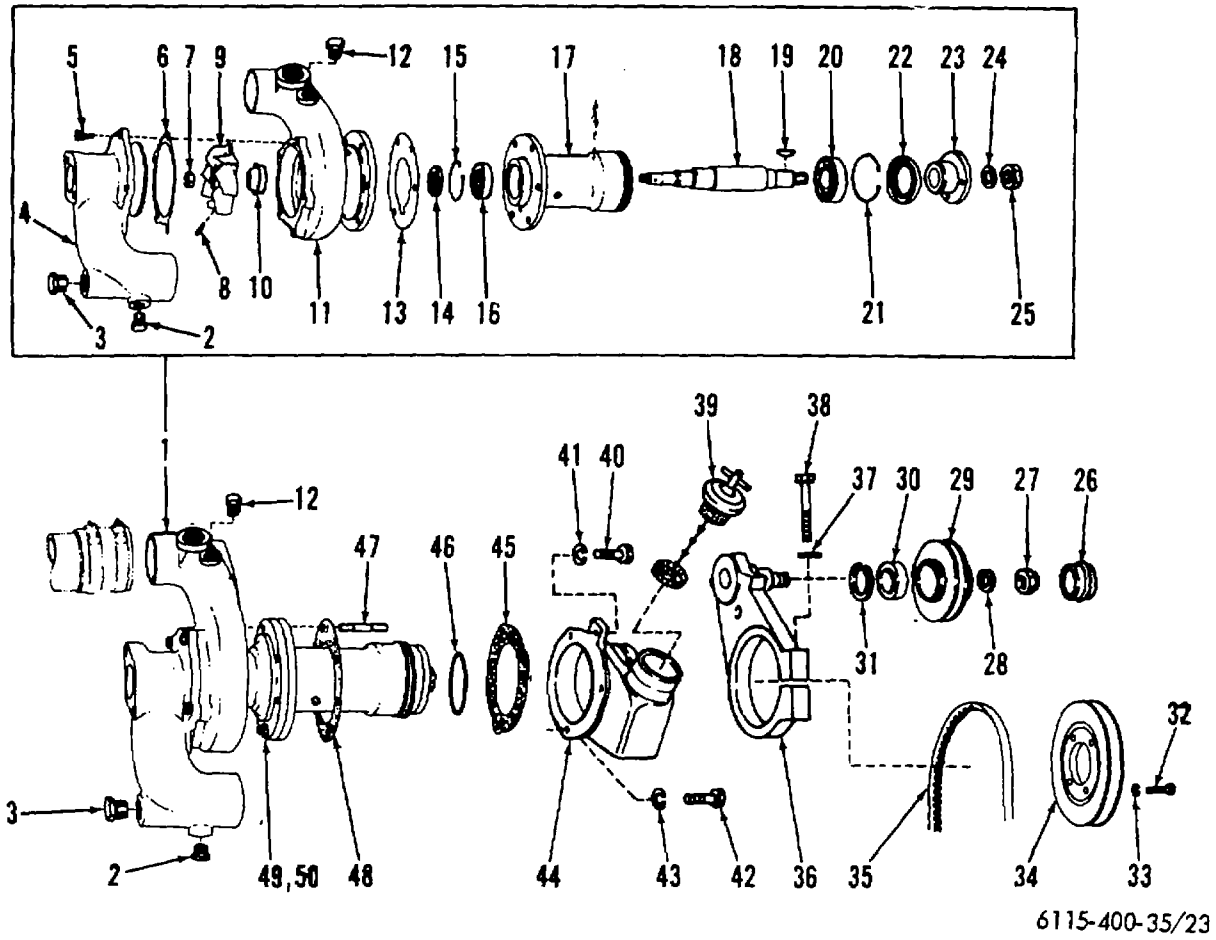
(1) Using tools as shown in figure 27, install rear oil seal in pump body, with sealing lip of seal facing installing tool.

(2) Using tools as shown in figure 27, install coolant seal in pump body, using care to prevent damage to the seal. Before installing, coat brass lip on the, outside diameter of the seal with a small amount of sealing compound.

Note**. Make certain carbon washer surface is wiped clean with an absorbent paper or lint-free cloth. If thorough cleaning cannot be accomplished this way, use a commercial solvent and then wipe clean.**

Caution**. Do not apply oil or grease to the carbon washer surface.**

(3) Press roller bearing-race only-onto shaft.



1	Water pump	18	Shaft	35	Belt
2	Plug	19	Key	36	Bracket assembly
3	Plug	20	Bearing	37	Lockwasher
4	Cover	21	Retaining ring	38	Screw
5	Screw	22	Seal	39	Closure assembly
6	Gasket	23	Hub	40	Screw
7	Nut	24	Washer	41	Washer
8	Pin	25	Nut	42	Screw
9	Impeller assembly	26	Cap	43	Lockwasher
10	Seal assembly	27	Nut	44	Support
11	Body	28	Washer	45	Gasket
12	Plug	29	Pulley	46	Packing
13	Gasket	30	Bearing	47	Stud
14	Seal	31	Retaining ring	48	Gasket
15	Retaining ring	32	Screw	49	Lockwasher
16	Bearing	33	Lockwasher	50	Nut
17	Sleeve	34	Pulley		

Figure 23. Water pump.

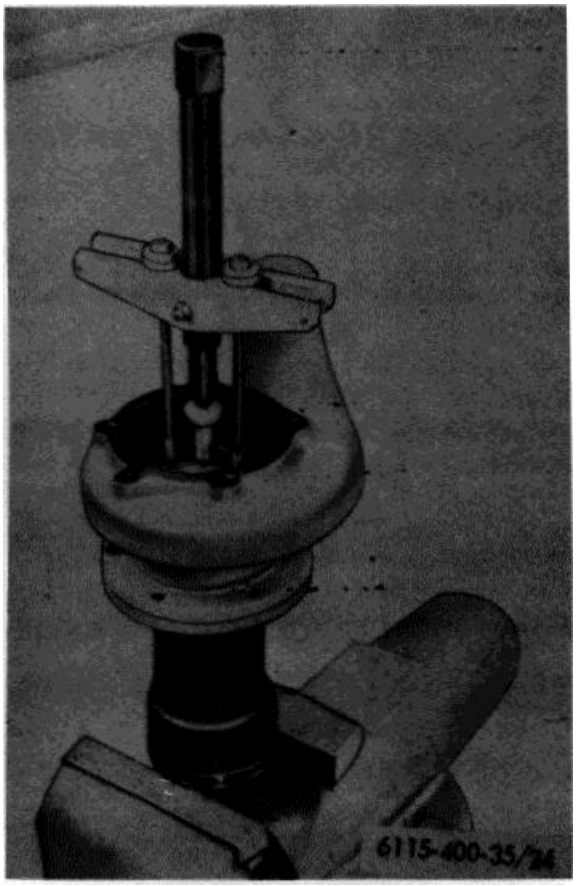


Figure 24. Pulling impeller from pump shaft.

(4) Press front ball bearing onto the shaft, positioning bearing against shoulder of the shaft. Install key in keyway of shaft.

(5) Using tools as shown in figure 27, install roller bearing in its bore in bearing sleeve. Install snap ring.

(6) Install pump shaft and ball bearing as an assembly into bearing sleeve by tapping on end of shaft with a soft hammer, using as little force as possible.

Caution:

Make sure that roller bearing race on shaft is alined with roller bearing before tapping shaft and ball bearing into position.

(7) Install snap ring.

(8) Install front oil seal by tapping seal into position with a soft hammer.

Note.

Lightly coat outer diameter of the seal with sealing compound before installing.

(9) Using tools as shown in figure 27, press pulley hub onto shaft making sure that key. is alined with keyway in pulley hub.

(10) Install washer and nut. Tighten nut to a torque of 50 ft. lbs. Aline nearest slot in nut with cross-drilled hole in shaft and install cotter pin.

(11) Using a new gasket, position pump body, with seals installed, on bearing sleeve, alining the drilled stud holes, and securing sleeve to body temporarily with a bolt and nut to facilitate easier installation of impeller on the pump shaft.

(12) If original impeller is to be reused, install impeller as follows:

(*a*) Drive the old retaining pin from impeller.

Note.

Make certain that ceramic sealing ring bonded to impeller is thoroughly cleaned before assembling. Use an absorbent paper or lint-free cloth for cleaning. If thorough cleaning cannot be accomplished this way, use a solvent and then wipe clean. DO NOT APPLY OIL OR GREASE TO THE CERAMIC SEALING RING.

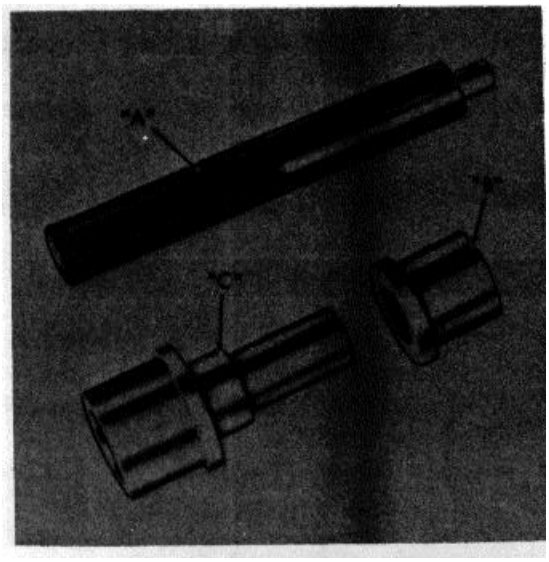
(*b*) Start impeller on the pump shaft so that drilled hole in impeller is turned 1800 from its original position and install impeller retaining nut; tighten nut to 30 ft. lbs.

torque and install cotter pin.

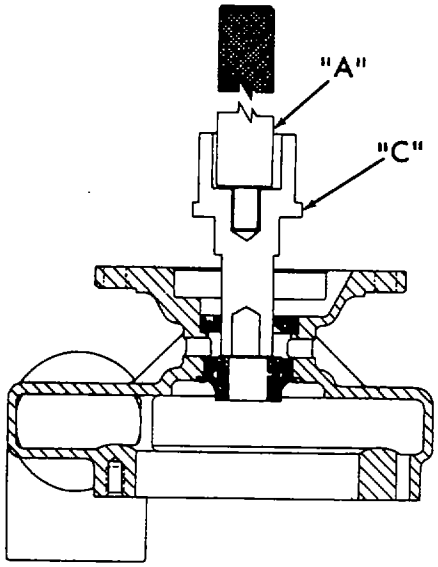
(*c*) Using a sharp 1/8 inch diameter drill inserted into drill hole in impeller, drill hole in shaft until total depth of the hole is 29/32 inch. Install groove pin so that outer end of pin is 1/16 inch below surface of impeller and stake (or peen) pin in place.

(13) If a new impeller is to be installed, install impeller as follows:

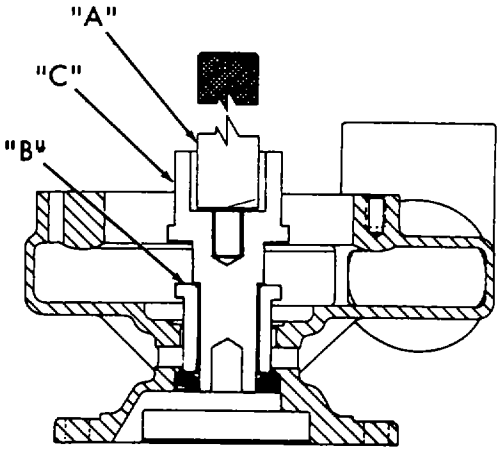
(*a*) Remove burrs from shaft bore of impeller and start impeller on shaft so that drilled hole in impeller is turned 180 from old groove pin location. Install impeller retaining nut, tighten to a torque of 30 ft. lbs. and install cotter pin.



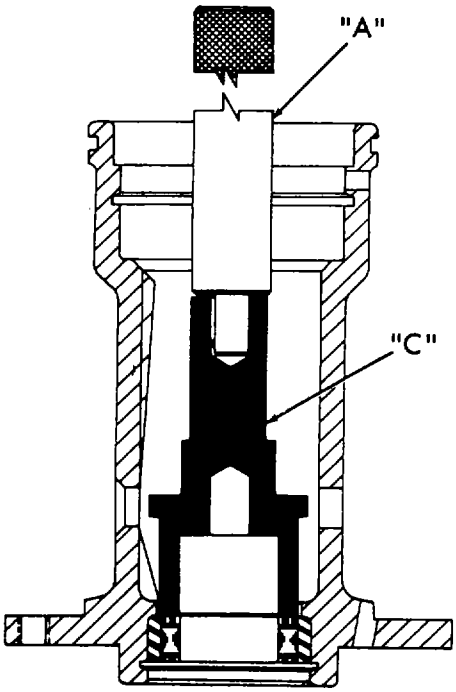
A. WATER PUMP SERVICE TOOLS



B. REMOVING COOLANT SEAL FROM PUMP BODY



C. REMOVING REAR OIL SEAL FROM PUMP BODY



D. REMOVING REAR ROLLER BEARING FROM BEARING SLEEVE

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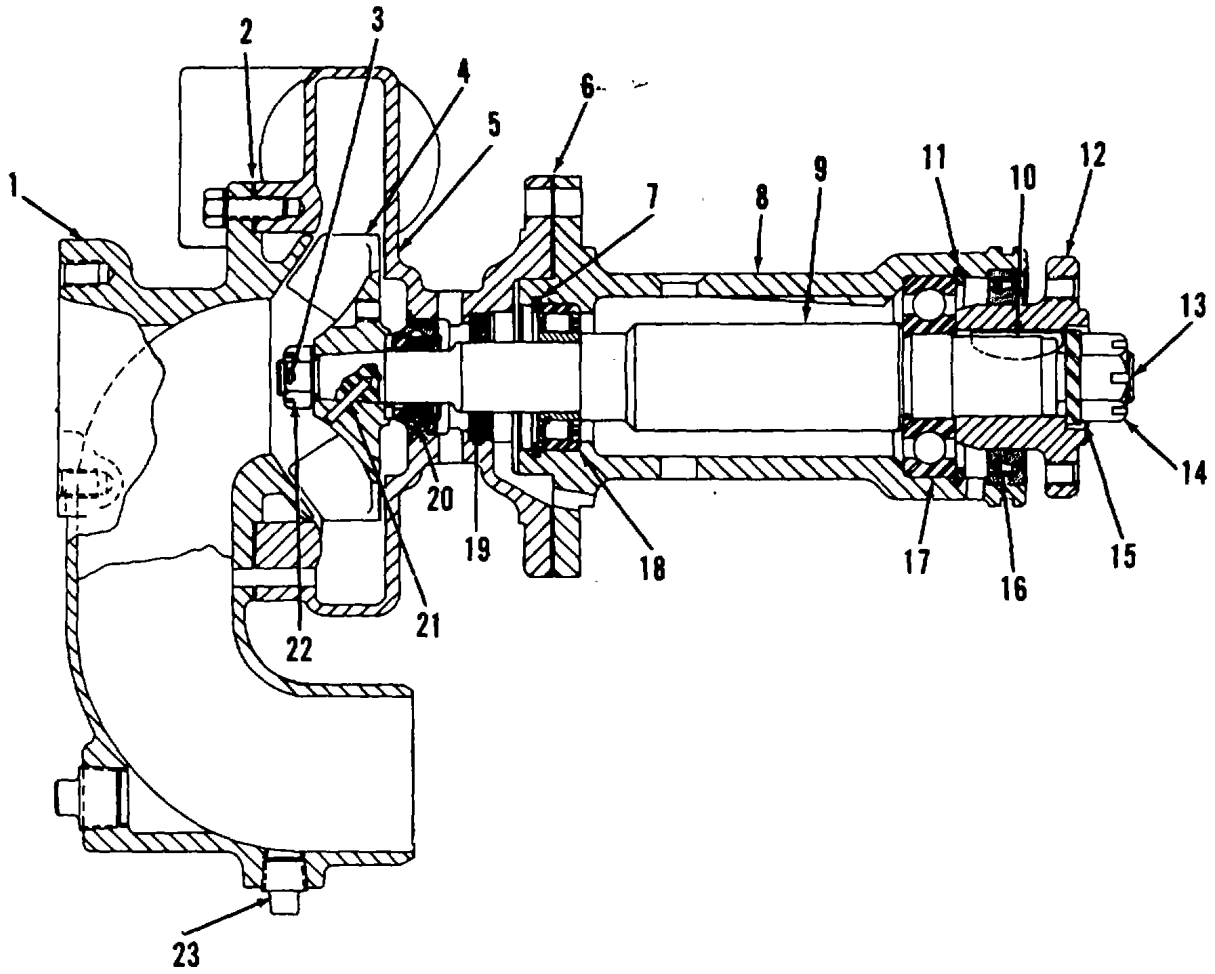
Figure 25. Water pump disassembly using service tools.



1. Water pump inlet cover
2. Cover gasket
3. Cotter pin
4. Impeller
5. Water pump body
6. Pump body gasket
7. Rear bearing snap ring
8. Bearing sleeve
9. Pump shaft
10. Pump shaft key
11. Front bearing snap ring
12. Pulley hub
13. Cotter pin
14. Pulley hub retaining nut
15. Hub retaining washer
16. Front oil seal
17. Front ball bearing
18. Rear roller bearing
19. Rear oil seal
20. Coolant seal
21. Impeller retaining pin
22. Impeller retaining nut
23. Pipe plug or drain cock

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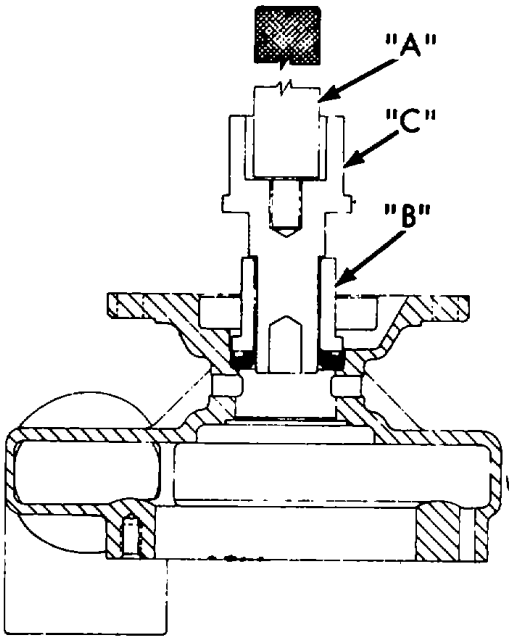
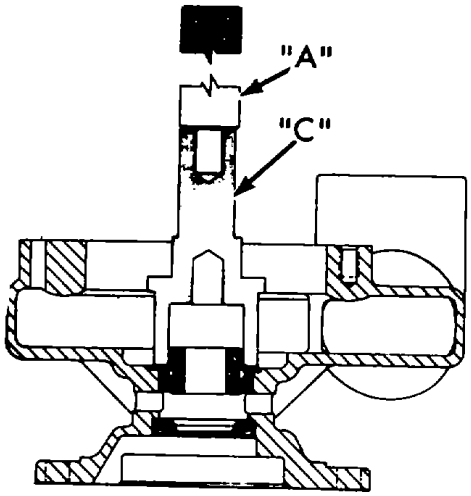
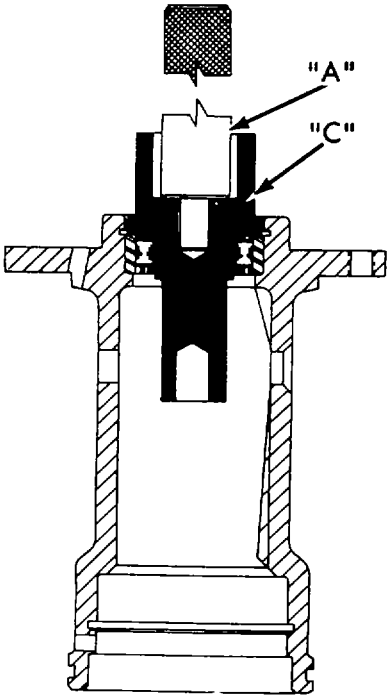
Figure 26. Water pump - sectional view.



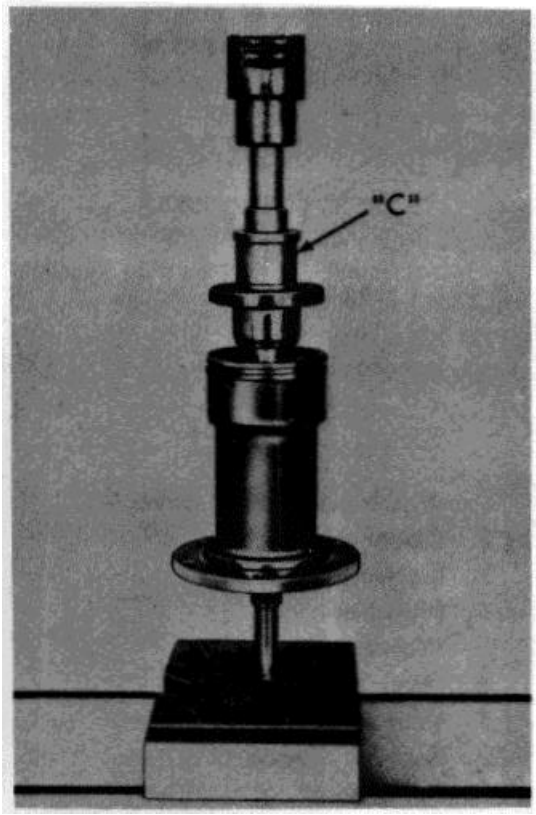
A. INSTALLING REAR OIL SEAL IN PUMP BODY



B. INSTALLING COOLANT SEAL IN PUMP BODY



C. INSTALLING REAR ROLLER BEARING IN BEARING SLEEVE



D. INSTALLING PULLEY HUB ON PUMP SHAFT.

Figure 27. Water pump reassembly.

Note.

If new impeller has a protective wax-like coating covering ceramic sealing ring, the coating must be removed before assembling impeller to shaft.

(*b*) Using a sharp 1/8 inch drill inserted into drilled hole in impeller, drill hole in shaft until total depth of the hole is 29/32 inch. Install groove pin so that outer end of pin is 1/16 inch below surface of impeller and stake (or peen) pin in place.

(14) Before proceeding to install water pump on engine, remove the nut and bolt (which had been installed temporarily).

Note.

The pump inlet cover and gasket are assembled to water pump assembly after bearing and pump body have been installed in the timing gear housing.

e. Water Pump Installation. Refer to TM 5-6115-400-12.

37. Fan Hub

a. Removal and Disassembly (see fig. 28).

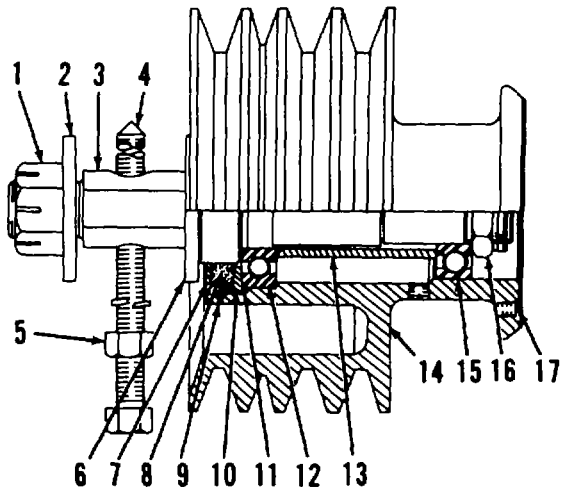
(1) Remove fan and fan belts.

(2) Remove spindle retaining nut and washer. Loosen locknut and back adjusting screw out of fan spindle.

(3) Pull fan hub assembly from its mounting bracket.

(4) Remove spindle washer, retainer snap ring, and turn sealing washer retainer out of fan pulley. Remove sealing washer, bearing retaining washer, and gasket from the fan pulley.

(5) Place fan hub assembly in a press, with fan end of pulley up, and press the spindle, bearings, and spacing sleeve from the fan pulley.



1. Spindle retaining nut
2. Plain washer
3. Spindle
4. Adjusting screw
5. Locknut
6. Spindle washer
7. Spindle sealing washer retainer
8. Spindle sealing washer
9. Retainer snap ring
10. Rear bearing retaining washer
11. Gasket
12. Rear ball bearing
13. Bearing spacing sleeve
14. Pulley
15. Front ball bearing
16. Bearing retaining nut
17. Gasket

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Figure 28. Fan hub details.

(6) Remove the retaining nut from the spindle. Press the spindle from the bearings.

b. Cleaning and Inspection. Wash all parts thoroughly in clean solvent or fuel and examine the parts for wear or damage. Rotate bearings by hand and check for looseness, roughness, or binding; replace bearings if necessary. Inspect fan pulley for wear; make certain that grooves are smooth and that the hub is not chipped or cracked. Discard sealing washer and gasket and install new ones when assembling.

c. Reassembly and Installation.

(1) Press rear ball bearing onto spindle.

(2) Place spacing sleeve in position, then front ball bearing onto spindle.

(3) Install flex-lok bearing retaining nut and tighten securely.

(4) Place pulley in a press, fan end of pulley down, and press spindle and bearing assembly into pulley.

Note.

While pressing spindle into pulley, pack area between bearings with clean ball and roller bearing lubricant. Use lubricant conforming to specification MIL-G-23827.

(5) Place a new gasket, bearing retaining washer, and a new sealing washer in position on the spindle. Turn sealing washer retainer into the pulley until hole in the retainer is aligned with hole in the pulley, then install retainer snap ring.

(6) Place washer in position on spindle.

(7) Insert spindle into bore of fan mounting bracket.

(8) Start the adjusting screw, with lockwasher and locknut into the spindle.

Install plain washer and retaining not on spindle but do not tighten at this time.

(9) Install fan belts and any other belts which may be driven by fan pulley. Turn adjusting screw in, until fan belts are properly adjusted, then lock adjusting screw with locknut. Tighten retaining nut securely.

(10) Install gasket, fan spacer, and fan.

38. Turbocharger

a. General.

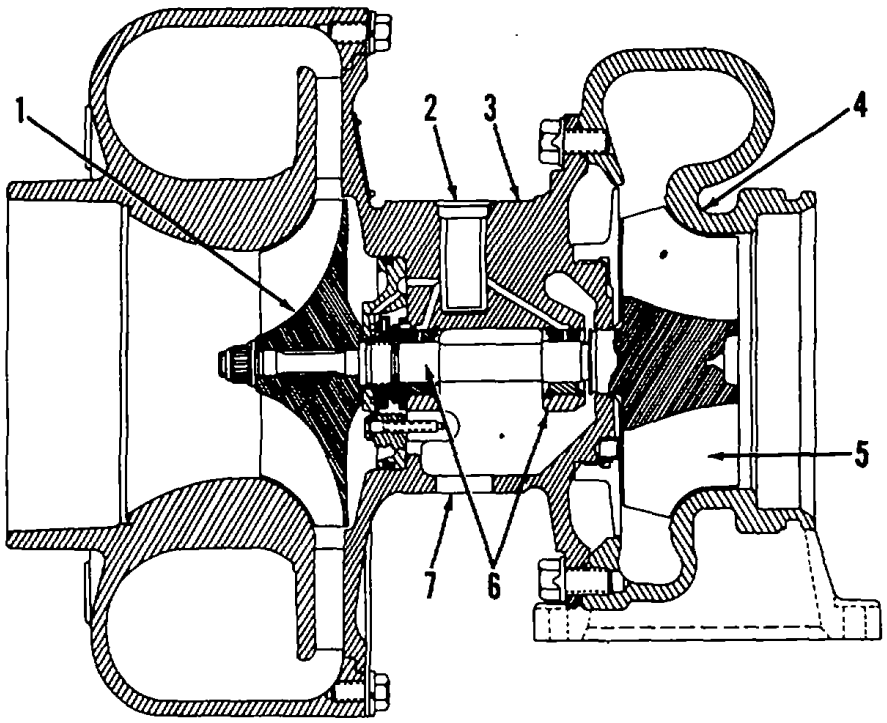
(1) The turbocharger consists of a radial inward flow turbine, center housing, and compressor. The turbine is located at the front of the center housing assembly and the compressor at the rear end. A shaft integral with the turbine wheel drives the compressor wheel. The shaft is supported in the bearing housing by sleeve type bearings. The rotating assembly consists of those parts which rotate while the turbocharger is in operation. The assembly consists of the turbine impeller and shaft, thrust ring, thrust spacer, compressor impeller, and impeller retaining nut. The compressor impeller and turbine impeller are individually balanced and may be serviced separately.

(2) Filtered engine oil is supplied under pressure through an external line. Oil is directed through passages from the center housing oil inlet to impeller shaft bearings, thrust ring, thrust bearing, and thrust plate. Oil returns by gravity to the oil pan through an external line extending from the bottom of the center housing to the side of the cylinder block. Oil is sealed from the compressor and turbine by seal arrangements at both ends of the center housing.

b. Two Thousand Hour Inspection and Service. A major inspection of the turbocharger should be made after each 2,000 hour period of operation. This inspection requires removal of the turbocharger from the engine, and removal of the compressor and turbine housings from the turbocharger. Perform the inspection as follows:

(1) Remove turbocharger from the engine. Refer to TM 5-6115-400-12.

(2) Place turbocharger on bench with shaft in horizontal position. Check for free rotation of the impellers. If they do not turn freely the trouble may be caused by carbon accumulation behind the turbine impeller, the impeller shaft bearings seized to the shaft, dirt in bearings, or by excessive bearing wear. Make repairs necessary to eliminate these conditions.



1. Compressor impeller
2. Oil inlet
3. Center housing assembly
4. Turbine housing
5. Turbine impeller and shaft assembly
6. Impeller shaft bearings
7. Oil outlet

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Figure 29. Turbocharger - sectional view.

(3) Remove the compressor and turbine housings. (Refer to para. d).

(4) Check turbine shaft radial movement as follows:

(*a*) Clamp the center housing compressor flange in a vise (fig. 30).

(*b*) Using two 3/8 inch X 1 1/8 inch capscrews, attach dial indicator adapter, Tool F, (2, fig. 30) to the center housing oil drain with plunger of Tool F, resting on the impeller shaft.

(*c*) Attach a magnetic or clamp type dial indicator to the dial indicator adapter base.

(*d*) Position contact point of dial indicator on plunge of the adapter.

Note.

For accurate indication, dial indicator stem end must be on same center line as plunger of the dial indicator adapter.

(*e*) Push rotating assembly toward indicator contact point and record the amount of movement.

(*f*) Pull the rotating assembly away from indicator contact point and again record the amount of movement.

(*g*) The difference between the two' measurements is the total impeller movement and should be .005 inch to .008 inch. Repeat this procedure several times before accepting a final reading.

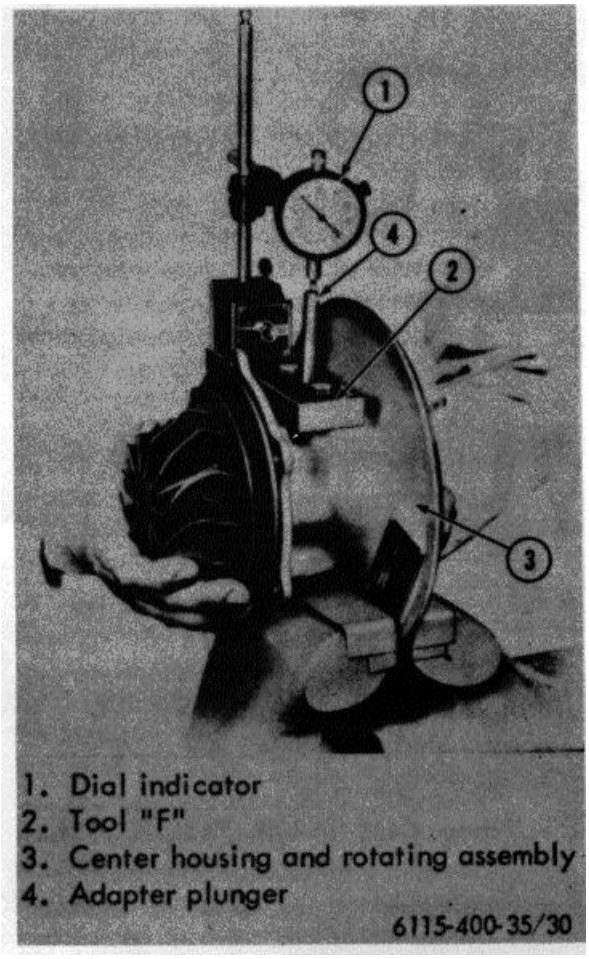


Figure 30. Checking turbine shaft radial movement.

(*h*) Radial movement in excess of .008 inch is an indication that the shaft or bearing is worn or that the bearing bore in the housing is worn. The unit must be disassembled and reconditioned.

Note.

Shaft radial movement can be checked without removing the turbocharger from the engine. Remove oil drain line from the center housing and follow the same procedure detailed in steps (b) through (h) above.

(5) Check shaft end play as follows:

(*a*) Position dial indicator so contact point is resting on the impeller shaft end.

(*b*) Move impeller to extreme UP position. Note and record the indication.

(*c*) Move impeller to extreme DOWN position. Note and record indication. The difference between indications is total end play.

(*d*) Permissible end play is .003 inch to .008 inch. End play more than .008 inch indicates that the thrust ring, thrust bearing, or bearing surface of the center housing thrust plate assembly is worn. If end play is less than .003 inch, carbon buildup behind the turbine impeller is indicated. In either case, the unit must be disassembled and the condition corrected.

(6) Remove the turbine housing. (Refer to paragraph *d*).

(7) Inspect the compressor housing, compressor impeller, turbine impeller, and turbine housing for dirt accumulations that impair turbocharger performance. Large, unevenly distributed accumulations of dirt on the impellers will disturb the precision balance of the rotating parts assembly. Refer to paragraph e for cleaning procedure.

(8) Make a thorough inspection of the compressor and turbine impellers. Wear on the outer and small diameters of the compressor impeller blades indicates extreme impeller shaft bearing and thrust bearing wear on the turbine side of the unit. Wear appearing on turbine impeller blades indicates undue wear of impeller shaft bearings. Broken or bent blades are an indication that large pieces of foreign material have gone through the compressor or turbine. A damaged blade(s) can throw the rotating assembly out of balance and shorten the life of the turbocharger. Do not attempt to repair a damaged impeller because total destruction of the turbocharger may result.

(9) If the turbocharger meets the above inspection specifications, it can be reassembled and considered satisfactory for further service.

(10) Install turbocharger on the engine. Refer to TM 5-6115-400-12.

Note.
If undue impeller shaft bearing wear or other damage is believed to have been caused by lack of lubrication, check the flow of oil to the turbocharger with the engine running. Minimum oil pressure at the turbocharger is 10 psi when oil temperature is 180° F.

c. Replacement Center Housing and Rotating Assembly. When complete disassembly of the turbocharger is not feasible, a replacement center housing and rotating parts assembly may be used (fig. 31). When replacing this unit it is only necessary to transfer the used turbine and compressor housings to the new center housings and rotating parts assembly. Follow the disassembly procedure outlined in paragraph d. Assemble by following the instructions in paragraph f.

d. Disassembly of Turbocharger. Disassembly of the Model T-1818 turbocharger can best be accomplished with the use of service tools listed in table 2. Clean the exterior with a non-caustic cleaning solvent. As parts are removed they should be placed in protective containers on a clean bench in the order of disassembly. Always handle the parts with care to prevent scratching the precision machined surfaces. Check turbine wheel shaft radial movement with a dial indicator and record the measurement obtained as this will be required later to determine amount of bearing bore wear in the bearing housing.

(1) Mark relative positions of compressor and turbine housings to the center housing (fig. 33A).

(2) Apply penetrating oil or diesel fuel to capscrews securing turbine housing to center housing.

(3) Remove capscrews, lockwashers, and clamps securing compressor housing to center housing. If necessary, tap compressor housing with a soft hammer and remove from center housing.

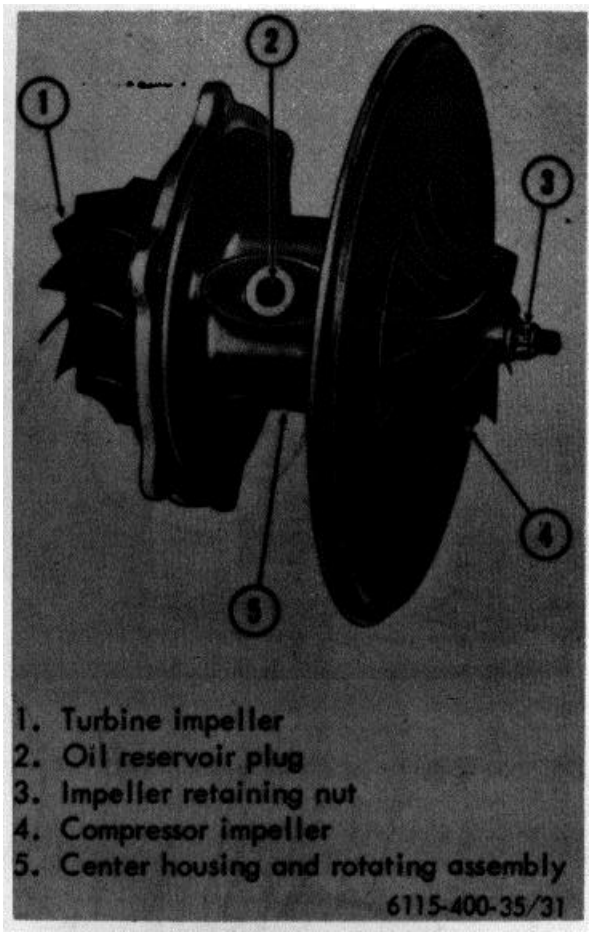
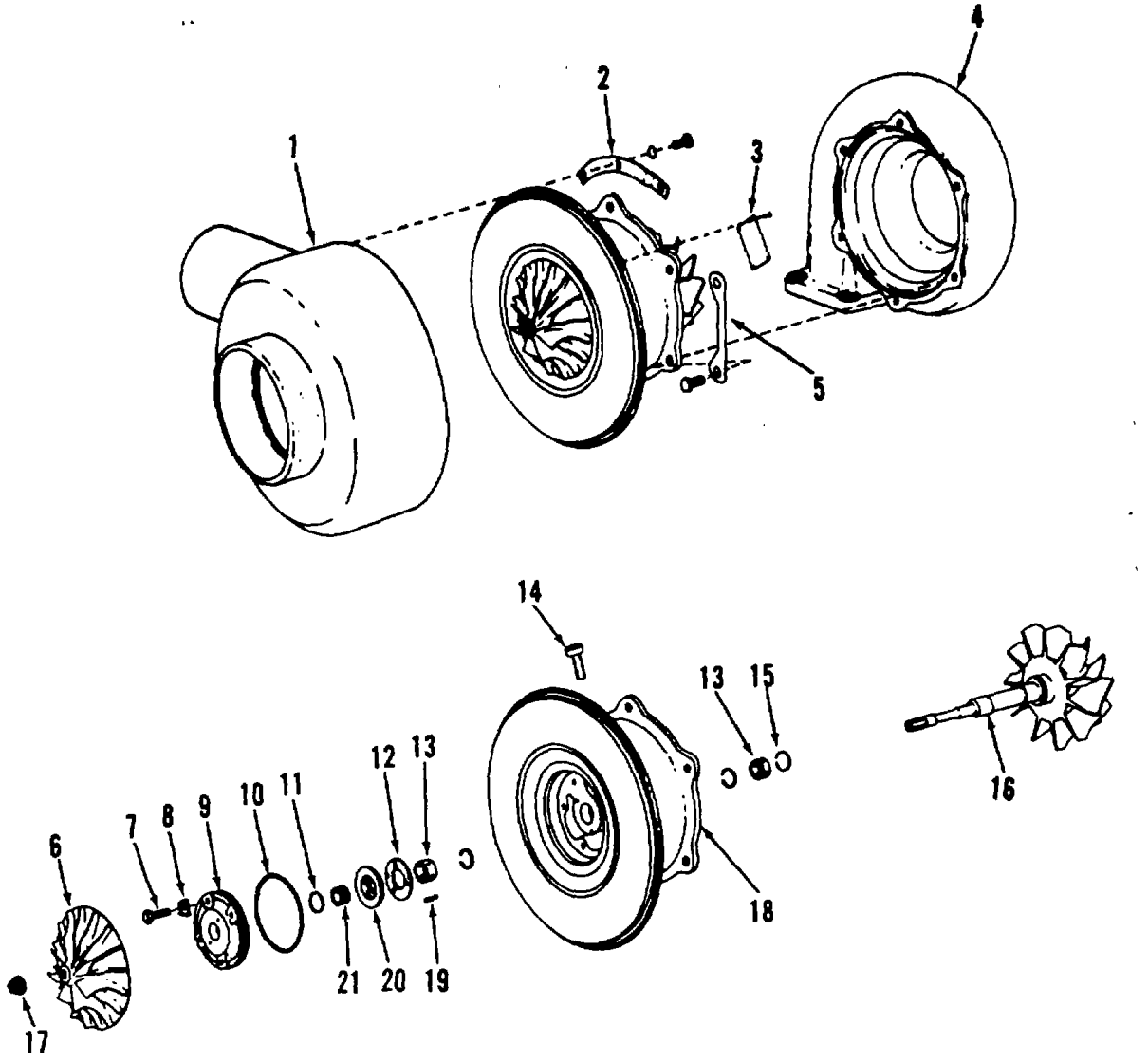


Figure 31. Center housing and rotating assembly

(4) Straighten tabs of lockplates and remove capscrews and lock plates securing turbine housing to center housing. If necessary, tap turbine housing with a soft hammer and remove from center housing.

(5) Record compressor and turbine shaft radial movement and the shaft end play. Follow procedure as outlined in paragraph b.

(6) Clamp holding fixture (tool A) in vise. Mount center housing and rotating assembly in holding fixture with turbine impeller downward Make certain the hexagon countersunk hole in turbine impeller goes over hexagon protrusion of holding fixture to prevent the shaft from turning.



1. Compressor housing assembly
2. Compressor housing clamp
3. Name plate
4. Turbine housing
5. Locking plate
6. Compressor impeller
7. Capscrew
8. Locking plate
9. Center housing thrust plate
10. Thrust plate preformed packing
11. Sealing ring
12. Thrust bearing
13. Impeller shaft bearing
14. Center housing oil reservoir plug
15. Snap ring
16. Turbine impeller and shaft
17. Impeller retaining nut
18. Center housing assembly
19. Center housing dowel pin
20. Thrust ring
21. Thrust spacer

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Figure 32. Turbocharger (exploded view).

Figure 33. Turbocharger disassembly.

Note.

Use a sliding tee handle and double universal with socket to remove locknut at the compressor impeller end of shaft. This method of nut removal will prevent the shaft from bending.

(7) Heat remainder of assembly in an oven or furnace in controlled temperature of 350° - 375°F for 10 minutes maximum. If oil bath is used, immerse the compressor impeller only. An electric deep fat fryer filled with sufficient oil to cover the impeller is ideal for the purpose. Position heat control to 350° - 375°F and heat the compressor impeller for 10 minutes maximum at this temperature.

Caution.

Be careful not to damage the impeller vanes. Do not overheat. Use asbestos gloves to protect hands from heat.

(8) Place assembly in an arbor press with the turbine wheel down. Use compressor impeller disassembly Tool B to press turbine and shaft from the compressor impeller (fig. 33B).

Caution.

Keep shaft centered with bearings until shaft is clear of the center housing. Do not drop the turbine wheel.

(9) Remove bearing from turbine end of center housing as follows:

(*a*) Bearings are retained with a snap ring. Use snap ring pliers and remove snap ring.

(*b*) Insert finger into bearing and remove bearing.

(10) Using a screwdriver, straighten tabs of the thrust plate retaining capscrews and lockplates. Remove capscrews and lockplates (fig. 33C). With a short length of 1/2 inch wooden dowel, carefully force the thrust plate and thrust spacer from the center housing. Remove performed packing from thrust plate.

Note.

The wooden dowel will prevent damage to the thrust ring located between the thrust plate and the inboard thrust bearing.

(11) Remove thrust spacer from the center housing thrust plate assembly.

(12) Remove sealing ring from the thrust spacer.

(13) Remove thrust bearing from dowel pins in the center housing.

(14) Remove impeller shaft bearing from bore in center housing.

(15) If oil passages in center housing are suspected of being clogged, remove oil reservoir plug from the center housing oil inlet and clean oil passages to the bearings (fig. 34). To remove oil reservoir plug:

(*a*) Thread I.D. of oil reservoir plug with a 1/2 inch-13 tap approximately 1/2 inch deep.

(*b*) Screw 1/2 inch-13 sliding hammer adapter into threads.

(*c*) Screw sliding hammer into adapter and bump out plug.

Caution.

After removing oil reservoir plug, make certain all metal chips from the tapping operation are removed from oil inlet and passages in the center housing assembly.

e. Cleaning. The turbocharger may occasionally require cleaning to keep both it and the engine operating efficiently. The cleaning interval is dependent upon operating conditions.

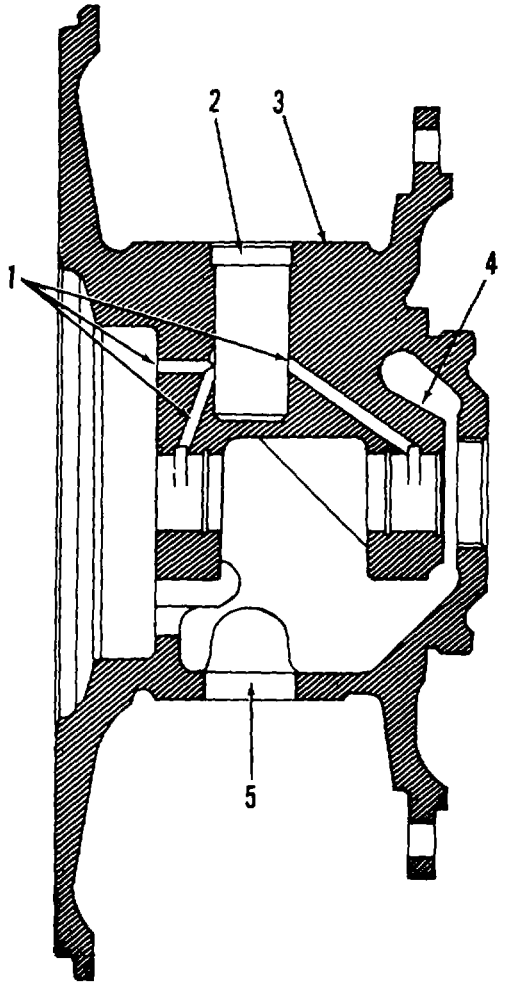
(1) Compressor End.

(*a*) Remove compressor housing as follows:

Mark relative position of compressor housing to bearing housing. Remove capscrews, lockwashers, clamps, and compressor housing.

(*b*) Rest unit on blocks in a container of cleaning fluid. The compressor impeller should be down and the shaft vertical.

(*c*) Using an approved metal cleaner, fill the container only enough to cover the compressor wheel.



1. Oil passages
2. Oil reservoir and plug
3. Center housing assembly
4. Drain annulus
5. Oil outlet

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Figure 34. Center housing - sectional view.

Caution.

Do not allow cleaning fluid to get into the bearing area. Never use caustic cleaning solution as this will damage certain parts. Use only a soft brush, plastic blade scraper and compressed air jet for removing deposits of dirt. Never use a wire brush or a steel blade scraper for this purpose.

(2) Turbine End and other parts.

(*a*) The turbocharger must be completely disassembled to satisfactorily clean the turbine end.

(*b*) Submerge and soak all parts in an approved metal cleaner. The cleaning solution should be agitated to do a satisfactory job, but take special care that parts are not allowed to strike each other.

(*c*) Make sure that all impeller blades are thoroughly cleaned. Deposits left on the blades will affect balance.

(*d*) Carefully inspect parts to specifications detailed in paragraph f.

(*e*) Using compressed air, blow out all oil passages/internal cavities in the center housing and center housing thrust plate assembly to make certain they are open and clean.

Note.

Bend a small screwdriver at right angles near its end so it can-be used as a scraper. The oil outlet (fig. 34) must be completely cleared of carbon so the lubricating oil from the bearing can escape without going around the turbine wheel.

f. Turbocharger Inspection. If lack of lubrication results in bearing seizure, or if impellers are damaged by foreign objects passing through the turbine or compressor, the resultant damage will be extensive and require replacement of the rotating parts or of both rotating parts and center housing. To properly assess the extent of damage/wear, it is recommended that the turbocharger be completely disassembled and all parts inspected at time of engine overhaul. In general, parts must not show signs of damage, corrosion, or deterioration. Threads must not be nicked, stripped, or crossed. Burnish or polish out minor surface damage using silicone carbide abrasive cloth for aluminum parts and crocus cloth for steel parts. At time of-- repair or overhaul, replace preformed packing, sealing ring, spiral lockring, and locking plates. Make certain all parts are thoroughly clean and work bench area is clean and free of any abrasive material before proceeding with inspection of individual parts.

(1) Center Housing Assembly. The center housing assembly must show no signs of contact with rotating parts. Oil passages must be clean and free of obstructions. Inspect bearing bores for scored surfaces and excessive wear. Using a micrometer and a telescoping gage, measure bearing bore diameter. The bearing bore of the center housing must not be out of round or exceed .9835 inch I.D. Using a straight edge and a feeler gage, check turbine shroud for distortion. Distortion must not exceed .005 inch.

Note.

The shroud is not a serviceable part If replacement is necessary, a center housing assembly, which includes the shroud, must be installed.

(2) Impeller Shaft Bearings. Replace bearings if they show signs of scoring, nicks, shellac deposits, or foreign material imbedded in the metal.

Measure bearing O.D. and I.D. with a micrometer. The dimensions of bearings are O.D., not less than .9785 inch, I.D. not more than .6272 inch.

(3) Thrust Bearing. The grooved side of the thrust bearing must not be scored or have any foreign material imbedded in its surface. Use a micrometer and measure overall thickness of the thrust bearing at three points, 1200 apart. The measurements obtained must not be less than .089 inch or vary more than .001 inch from one reading to the other.

(4) Center Housing Thrust Plate. Passages in the thrust plate assembly must be clean and free of obstructions. Blow out passages with compressed air. The bore for the sealing ring must not be scored or rough. The thrust plate bearing surface must not be scratched or scored. With a depth micrometer, measure the distance between the bearing surface and the opposite surface of the thrust plate at three points, 1200 apart (fig. 35). Readings obtained must not exceed .399 inch not vary more than .001 inch between measurements.

(5) Turbine and Compressor Housings.

Make certain that the turbine and compressor housings are clean and have no internal obstructions that could impede the flow of gases.

(6) Rotating Assembly. Every rotating part is balanced individually and can be replaced, without displacing overall balance of the assembly.

(*a*) Compressor Impeller. Inspect the blades and bore of the compressor impeller. Check impeller blade edges and the underside of the impeller wheel for indications of wear. Wear occurs at these points as a result of excessive bearing/thrust collar wear. Check impeller surfaces for excessive and unevenly distributed dirt accumulations. Such accumulations disturb the precision balance of the rotating assembly. Check to ensure that the impeller wheel bore is not scratched or scored.

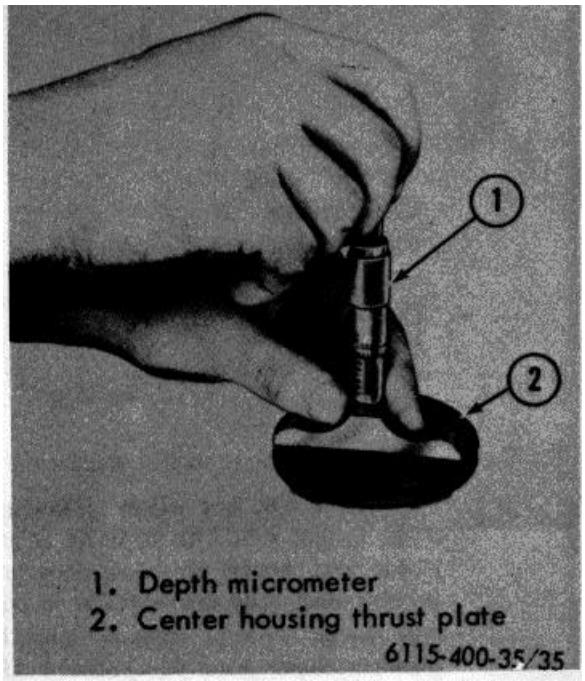


Figure 35. Checking center housing thrust plate bearing surface for wear.

(b) Thrust Spacer. Check the thrust spacer for indications of scoring and excessive wear. Surfaces of the sealing ring groove must be smooth and the walls must be parallel. Width of groove must not exceed .0715 inch.

(c) Thrust Ring. Make certain that all thrust ring (20, fig. 32) oil passages are open and clean and that thrust faces of the ring are not scored or warped. Measure overall thickness of the ring with a micrometer at three points, 1200 apart. Readings must not be less than .299 inch nor vary more than .001 inch between measurements.

(d) Turbine Impeller and Shaft. Check impeller for signs of wear. Check surfaces of impeller vanes for cracks and check edges of valve for indications of erosion. The shaft must not show signs of scoring, scratches of bearing seizure. Measure shaft journals with a micrometer. Journals must not be out of round and' diameter must not be less than .6245 inch.

(7) Turbine Impeller Shaft End Play. Shaft end play is predetermined by the finished machined parts that comprise the center housing and rotating parts. No shim pack is required to adjust end play before final assembly. If shaft end play exceeds .008 inch, excessive wear has taken place on one or both thrust surfaces of the thrust ring, the bearing surface of the center housing thrust plate assembly, or the thrust bearing. Shaft end play measuring less than .003 inch indicates that foreign material has accumulated between the impeller and center housing, or between the thrust ring faces and bearing surfaces in the center housing. Clean/replace all parts necessary to establish the specified end play of .003 inch to .008 inch.

(8) Shaft Radial Movement. Permissible radial movement of the turbine impeller shaft is .005 inch to .008 inch. Radial movement in excess of .008 inch indicates wear of shaft journals and I.D.'s of shaft bearings, shaft bearing O.D.'s and I.D.'s of center housing bearing bores. Refer to the shaft radial movement readings made during the 2,000 hour service inspection. Disassemble and replace either the impeller shaft bearings, center housing, or rotating shaft assembly to establish the specified radial movement of .005 inch to .008 inch.

g. Turbocharger Reassembly. The workbench area and tools must be kept clean at all times during turbocharger assembly operations to preclude the entrance of foreign material. All parts must be absolutely clean and free of nicks/burrs before they are installed in the turbocharger.

(1) Install the center housing oil reservoir plug if it was removed during cleaning operations.

(2) Install the two internal snap rings. To install snap rings use snap ring pliers.

Caution.
Use care to avoid scratching the center housing bore.

(3) Lubricate and install bearing in turbine end of housing. Install outside snap ring using snap ring pliers.

(4) Clamp holding fixture, Tool A, in a vise. Lubricate turbine impeller shaft journals. Insert hexagon countersunk hole in turbine wheel over hexagon stud in the holding fixture. With turbine end of center housing facing downward, guide housing onto shaft. Do not scuff or scratch bearing surfaces.

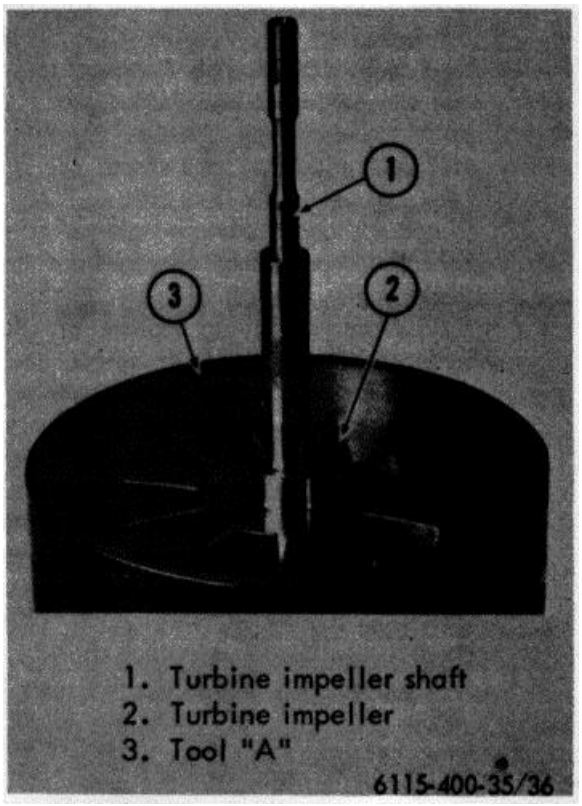


Figure 36. Turbine and shaft positioned in holding fixture

(5) Lubricate bearing for compressor end of assembly. Carefully guide impeller shaft bearing onto the shaft and into bore of the center housing assembly (fig. 37A).

(6) Install thrust bearing with hole and cutout in bearing aligned with center housing dowel pins. Bearing must be flat against the housing (fig. 37B).

(7) Install thrust ring on shaft, dished side up (fig. 37C).

(8) Install sealing ring on thrust spacer.

Carefully insert thrust spacer and sealing ring into the center housing thrust plate.

(9) Install lubricated preformed packing on center housing thrust plate. Align thrust plate oil hole with matching hole in the center housing. Insert thrust plate into center housing using care to avoid disturbing position of the thrust spacer (fig. 37E).

Caution.

If the thrust spacer moves out of position in the thrust plate and causes misalignment of the seal ring, repeat this step.

(10) Check hole alignment. Install lock plates and capscrews. Tighten capscrews to 30 to 40 in. lb. torque. Bend lock plate tabs to secure capscrews (fig. 37F).

(11) Heat compressor impeller in a furnace, oven, or hot oil bath at 350°F for 10 minutes maximum. Heated impeller wheel will readily slip onto shaft. Install heated impeller on shaft.

Caution.

Use asbestos gloves when handling the hot impeller. If the compressor impeller was not heated sufficiently or if it cooled too rapidly, the impeller may shrink on the shaft before it contacts the thrust spacer. Do not apply force. Refer to paragraph d, steps (7) and (8) for proper' impeller removal procedure.

(*a*) Bottom or seat compressor impeller by installing impeller locknut. Tighten to 150 to 160 in. lb. torque.

(*b*) Allow impeller to cool to 150°F or less and remove locknut. Inspect washer contact face of nut and hub of wheel. Both surfaces must be smooth and clean. Lubricate threads and contact face of nut.

(*c*) Reinstall the locknut. Position Tool H on the locknut. Mount a magnetic base or clamp type dial indicator on the center housing with the indicator contact point reseating on flat end surface of shaft (fig. 37H). Set dial indicator to ZERO. Insert sliding T-handle into upper end of Tool H. Tighten locknut until shaft length increases .006 inch to .007 inch.

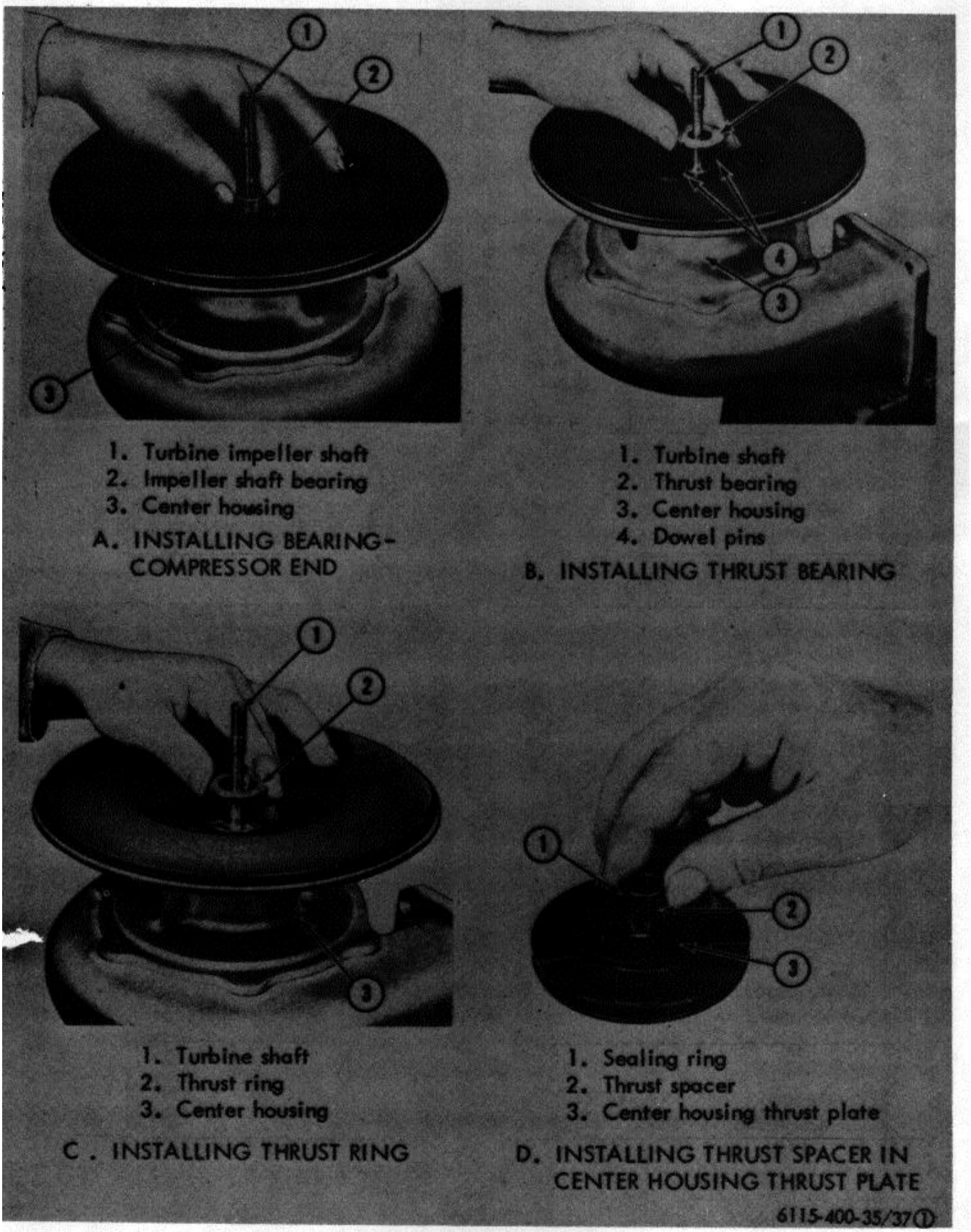


Figure 37 (1). Turbocharger reassembly.

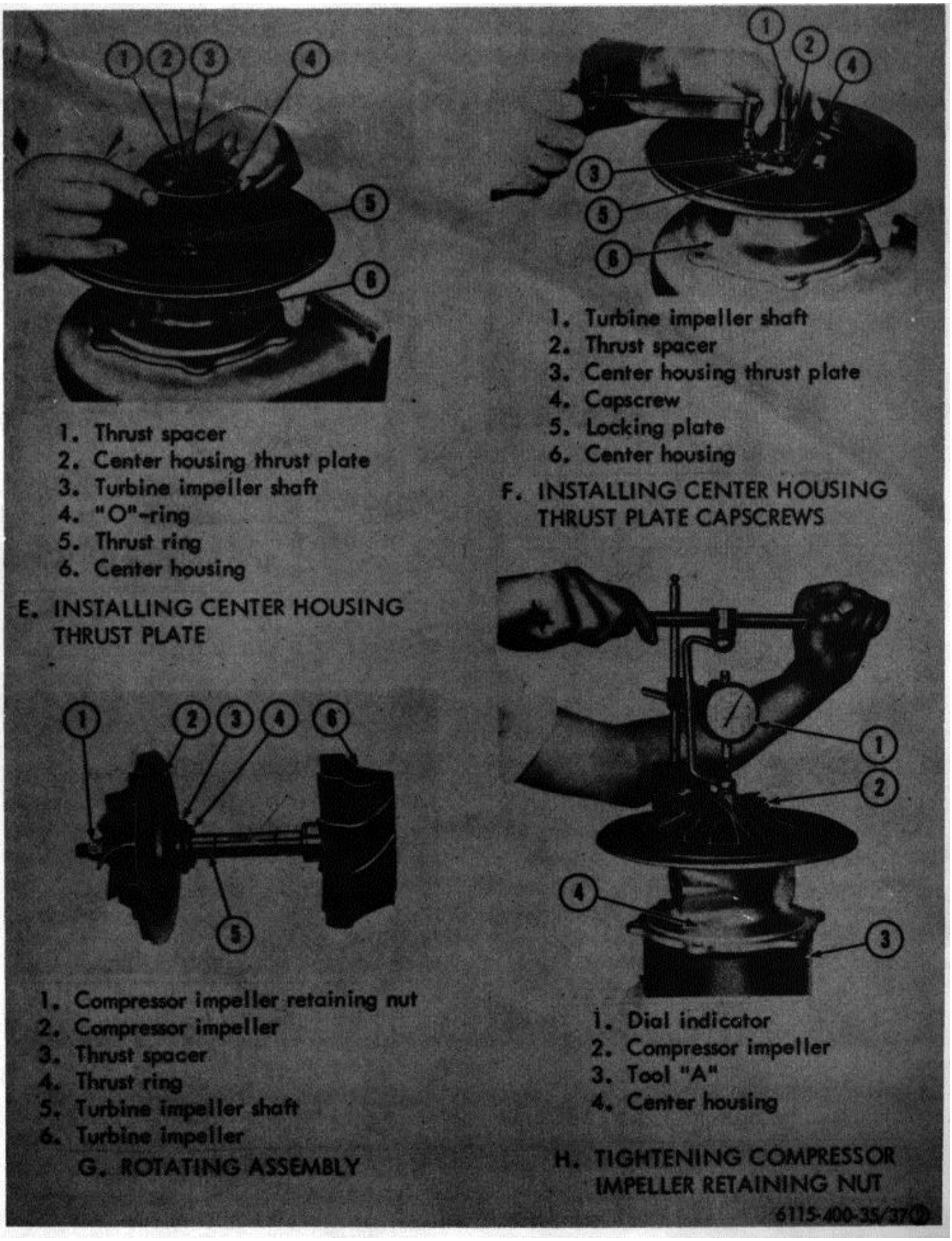


Figure 37 (2) - Continued.

Note

If tool H is not available to measure shaft stretch, an alternate method may be used. After reinstalling impeller nut and tightening to 18-20 in.-lb torque, continue to tighten the nut through an angle of 90°.

Caution.

Do not use a standard box wrench to tighten locknut because excessive side strain may bend the shaft. By using the sliding T-handle with Tool H and applying even turning force to both ends of the T-handle, the possibility of bending the shaft is eliminated.

(12) Apply a light coat of Super 300 Permatex compound to mating surfaces of the center housing and compressor housing. Position center housing on the compressor housing with assembly marks alined. Assemble these parts with care to keep compound from interior of the compressor housing. Apply a light coat of compound to threads of the retaining capscrews. Install compressor housing clamps, lockwashers, and capscrews. Tighten capscrews to 120 in. lb. torque.

(13) Position turbine housing on the center housing with assembly marks aligned. Apply a light coat of anti-seize compound to capscrew threads. Install locking plates and capscrews. Tighten capscrews to 170 in. lb. torque. Secure locking plate tabs against sides of capscrew heads.

(14) After completing turbocharger assembly, spin the impellers by hand.

The rotating assembly must spin freely with no indication of dragging or binding.

Note.

As a precautionary measure, recheck shaft radial movement and end play to ensure they are within specified limits.

(15) Cover all turbocharger openings to prevent entrance of foreign material. Remove covers as necessary during installation of the turbocharger.

h. Turbocharger Installation. Refer to TM 5-6115-400-12.

Section II. ENGINE COMPONENTS

39. General

The engine is a six-cylinder diesel with overhead valves. The engine components are fully described in the applicable paragraphs throughout this section.

40. Cylinder Heads

a. General. There are two cylinder heads, with each head covering three cylinders. Located in the cylinder heads, above each cylinder are two intake valves and valve guides, one intake valve bridge and bridge guide pin, two exhaust valves and valve guides, one exhaust valve bridge and bridge guide pin, a fuel injection nozzle, fuel injection nozzle sleeve, and two rocker arms. One rocker arm actuates the two intake valves through the intake valve bridge and the other rocker arm actuates the two exhaust valves through the exhaust valve bridge. The valves guides are pressed into the cylinder heads and hold the valve heads in accurate alignment with the valve seats. Valve rotators (roto-coil type) are provided in each valve assembly to effect rotation of the valves. All of the valve seat inserts are replaceable. See figure 38.

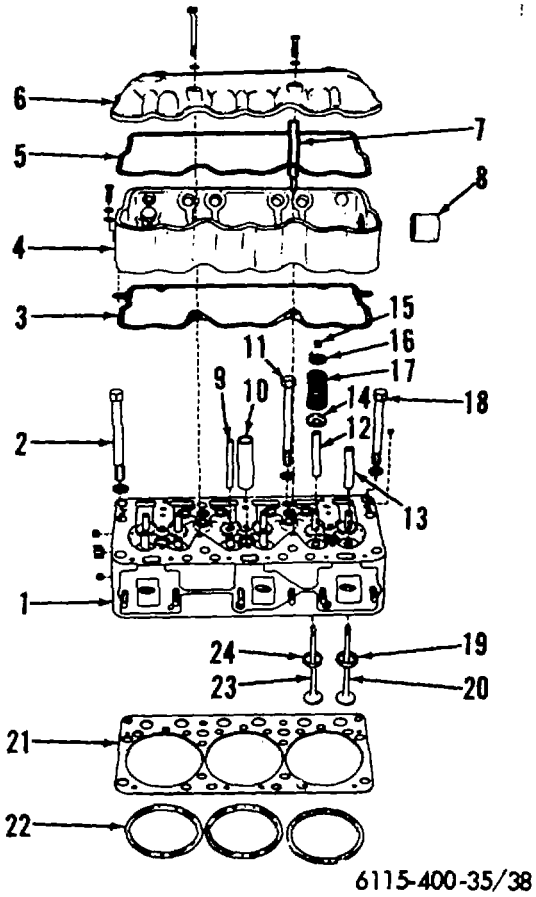
b. Removal.

(1) Drain cooling system.

(2) Remove or disconnect all components and assemblies necessary for access to the cylinder heads.

(3) Remove fuel return line assembly from connectors in the valve rocker housings and fuel filter head. Cap or plug all fuel line openings to prevent the entrance of dirt or dust.

(4) Remove valve rocker cover. Disconnect and remove fuel return manifold and fuel injection tubes.



1 Cylinder head
2 Capscrew (3/4 in. x 7 1/4 in.)
3 Housing gasket
4 Valve rocker cover
5 Cover gasket
6 Valve rocker cover
7 Extension bolt
8 Breather coupling
9 Valve bridge guide pin
10 Injection nozzle holder sleeve
11 Capscrew (5/8 in. x 7 in.)
12 Intake valve guide
13 Exhaust valve guide
14 Valve spring seat
15 Valve locks
16 Valve rotator
17 Valve spring
18 Capscrew (5/8 in. x 6 in.)
19 Exhaust valve seat insert
20 Exhaust valve
21 Cylinder head gasket
22 Cylinder sleeve gasket
23 Intake valve
24 Intake valve seat insert

Figure 38. Cylinder head assembly details.

(5) Remove nozzle holder clamps. and fuel injection nozzles. Remove. rocker arms and shaft (para 43). 'Remove valve bridges from the bridge guide pins. Withdraw push rods from the cylinder head.

(6) Disconnect upper ends of fuel injection lines from fuel line connectors in the rocker arm housing. Remove capscrews, plain washers, and lockwashers securing valve rocker housing to cylinder head and remove the valve rocker housing. Remove breather coupling.

(7) Remove cylinder head capscrews and washers. With a sling similar to the one shown in figure 39, remove the cylinder head. Remove cylinder head gaskets.

c. Cleaning and Inspection.

(1) Clean all parts with an approved solvent and dry thoroughly.

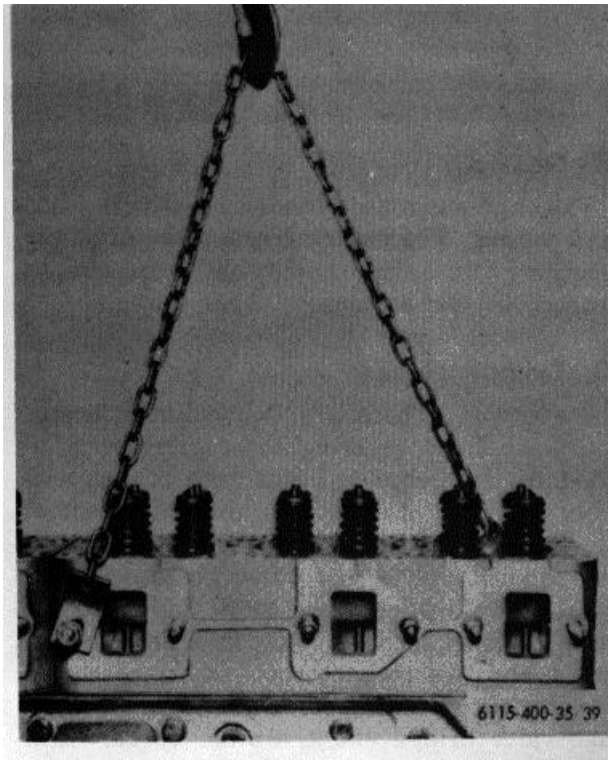


Figure 39. Removing cylinder head.

(2) Inspect cylinder heads and component parts for wear or damage. Repair or replace any worn or damaged parts. If cylinder heads are to be replaced, parts removed from old heads must be thoroughly inspected before installing them in the new heads. Make certain that the cored water and air passages, and drilled oil holes in the cylinder heads, are clean.

d. Installation.

(1) Make certain that machined surfaces of cylinder block and cylinder heads are thoroughly clean. New cylinder head gaskets must be used when installing cylinder heads.

(2) Make certain that the cylinder sleeve standout is within the specific limits.

The specified standout of each cylinder sleeve is .002 inch-.005 inch above top flat surface of cylinder head and the variation between the adjacent sleeves must not exceed .003 inch.

(3) Install the four cylinder head guide studs (fig. 40), finger tight, in the capscrew locations as shown.

(4) Position cylinder sleeve gaskets around the fire walls of cylinder sleeves with side marked "Cylinder Block Side" facing down. Place cylinder head gaskets in position with side marked "Top" facing up.

Note. Install gaskets dry and make certain head gaskets do not overlap cylinder sleeve gaskets.

(5) Position each cylinder head over guide studs and onto cylinder block. Aline manifold mounting surfaces with a straight edge.

(6) Lubricate threads of all cylinder head capscrews. Refer to figure 41, and install the various size capscrews in the locations indicated. The hardened steel washers must be in place under the head of each capscrew. After all the capscrews (except at guide stud locations) are in

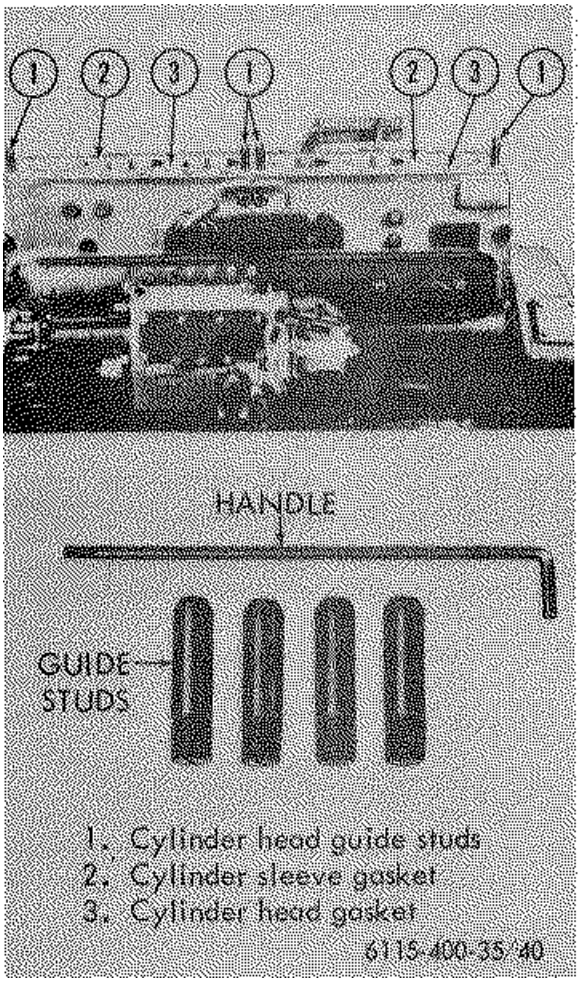


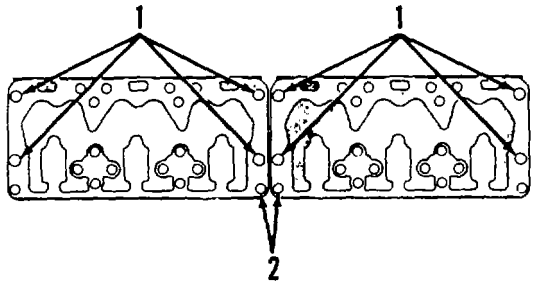
Figure 40. Cylinder head guide studs.

place and tightened sufficiently so that the cylinder heads cannot move, remove the four cylinder head guide studs, and install the remaining capscrews.

Caution

Before cylinder head capscrews are installed, make certain that there is not an excessive amount of oil, or any other liquid, in the capscrew holes in the cylinder block. Too much oil in any of these holes may cause a hydrostatic lock and crack the cylinder block when the capscrew is tightened.

(7) Tighten cylinder head capscrews to the specified torque following se-



1. Capscrews (3/4" NC x 7-1/4")
2. Capscrews (5/8" NC x 6")

NOTE

5/8" NC x 7" capscrews at all other locations. 6115-400-35/41

Figure 41. Cylinder head capscrew locations.

quence and instructions shown in figure 42. The specified torque is 180-185 ft. lbs. for the 5/8 inch capscrews and 260-275 ft. lbs. for the 3/4 inch capscrews.

(8) Install fuel injection nozzles, fuel lines, and covers. When installing the breather coupling (8, fig. 38) make certain it is in good condition, and properly positioned in grooves in valve rocker housings.

(9) Fill cooling system.

(10) Adjust valves. Refer to TM 5-6115400-12.

(11) Run engine until coolant reaches a minimum temperature of 1600 F, then again torque cylinder head capscrews and adjust the valve lash. Inspect engine for fuel, water, or oil leaks, and correct any leaks found.

41. Fuel Injection Nozzle-Holder Assembly

a. Description.

(1) Each cylinder of the engine is provided with a multi-hole, differential needle, hydraulically-lifted fuel injection nozzle-holder assembly. The function of each nozzle-holder is to direct the metered quantity of fuel,

received from the fuel injection pump, into the corresponding combustion chamber of the engine in a highly atomized, pre-determined spray pattern.

(2) Each fuel injection nozzle-holder consists of two assemblies: the holder assembly and nozzle assembly. The holder assembly is used to hold the nozzle in its correct position in the cylinder head and to provide a means of conducting fuel to the nozzle. See figure 43.

(3) The nozzle consists of a nozzle valve and a nozzle valve body, in which are located four equally spaced spray orifices. The nozzle valve body has orifices of .425 mm (.0167 in.) and may be identified by the numbers "837" on the valve body.

b. Service. The fuel injection nozzle-holder assemblies should be removed after approximately every 2,000 hours of operation, tested and adjusted if necessary. The nozzle-holder assembly, when properly adjusted, should require an opening pressure of 2900 psi to raise the nozzle valve from its seat. To compensate for initial set of a new nozzle spindle spring, the specified popping pressure of a new nozzle-holder is 3100-3150 psi.

When adjusting popping pressure of a new nozzle-holder or a rebuilt nozzle-holder in which a new spindle spring has been installed, the initial popping pressure should be set at 3100-3150 psi.

c. Fuel Injection Nozzle-Holder Removal.

Refer to TM 5-6115-400-12.

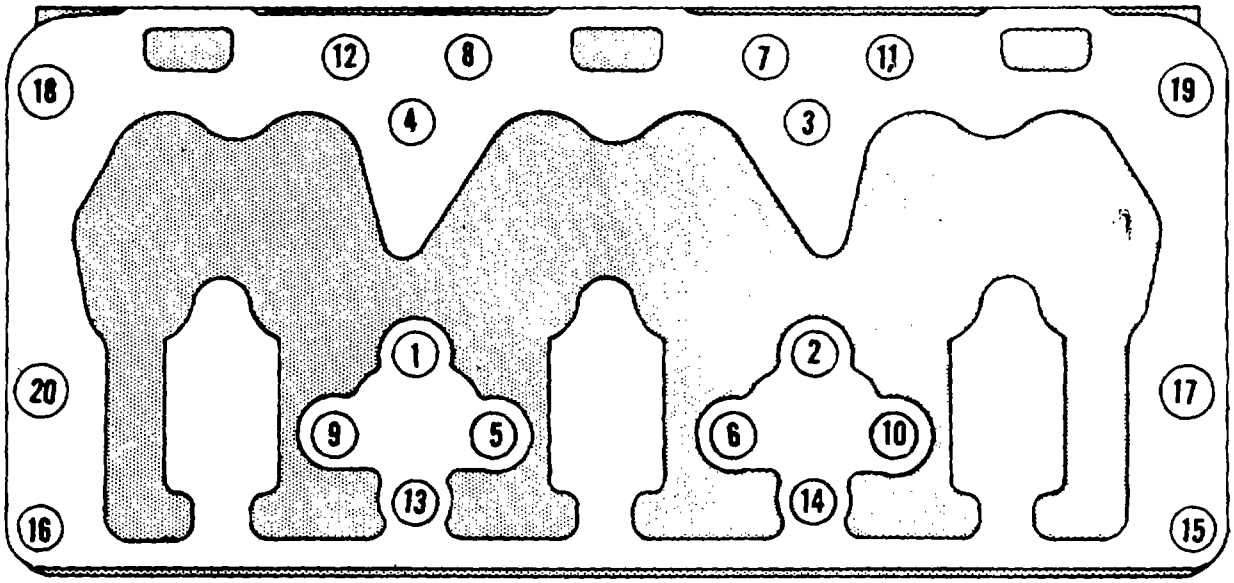
d. Testing and Adjusting Fuel Injection Nozzle-Holder. To test and properly adjust the fuel injection nozzles, a nozzle tester similar to the one illustrated in figure 44 is required. Test and adjust each nozzle as follows:

Warning

Keep hands away from the nozzle tip when popping a nozzle. The finely automized fuel from the nozzle tip is ejected with such force that it will penetrate the skin and cause blood poisoning.

(1) Bolt or clamp nozzle tester to a work bench.

Capscrews in locations 18, 20, 19, and 17, are 3/4" diameter, all others 5/8" diameter.



RECOMMENDED CYLINDER HEAD RETAINING CAPSCREW TORQUE

5/8" capscrews - 180-185 lbs. ft. (With lubricated threads)
3/4" capscrews - 260-275 lbs. ft. (With lubricated threads)

INSTRUCTIONS

1. **Align cylinder head manifold mounting surfaces**
2. **Tighten capscrews in numerical sequence to 1/2 specified torque.**
3. **Tighten capscrews in numerical sequence to full specified torque.**
4. **Again tighten capscrews in numerical sequence to full specified torque.**
5. **Run engine until water temperature reaches minimum 160F and again tighten capscrews to full specified torque.**

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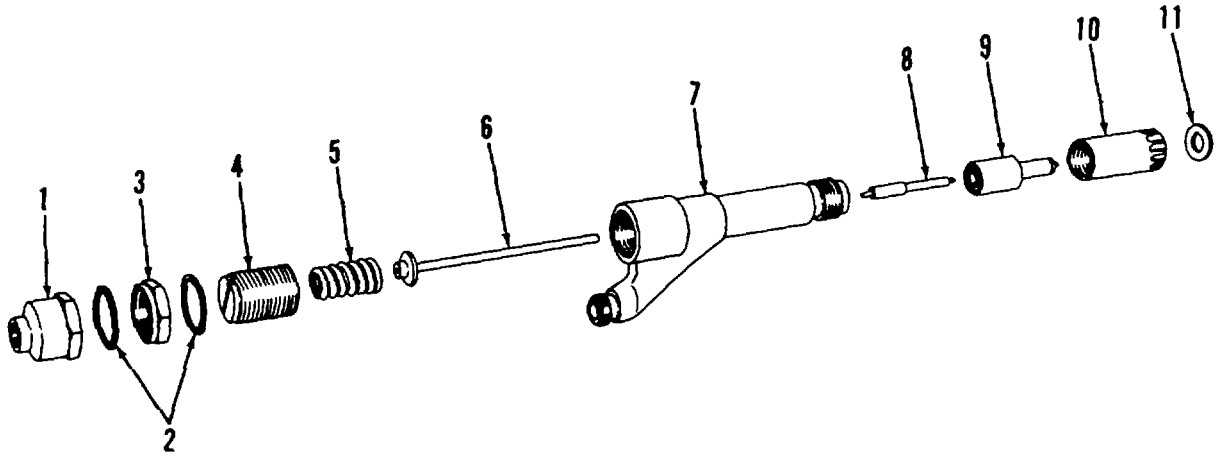
Figure 42. Cylinder head capscrew torque sequence.

(2) Turn the valve handle of the nozzle tester to the open position. Loosen the tester filler cap to prevent an air lock in the tester. Operate the tester handle until fuel flows from end of tester fuel line, then close the tester valve.

(3) Install and connect fuel injection nozzle holder to the nozzle tester. Install spray collector over valve end of the nozzle.

(4) Open the nozzle tester valve. Operate tester handle a few quick strokes and observe popping pressure of the fuel injection nozzle as indicated by the nozzle tester pressure gauge. (Specified popping pressure is 2,900 psi.)



1. Protection cup
2. Gasket
3. Pressure adjusting screw locknut
4. Pressure adjusting screw
5. Spindle spring
6. Spindle
7. Holder body
8. Nozzle valve
9. Nozzle valve body
10. Nozzle retaining nut
11. Nozzle holder gasket

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Figure 43. Fuel injection nozzle holder assembly.

Note

The original fuel injection nozzle-holder assemblies have the opening nozzle pressure set higher at the factory to compensate for the initial set of the spindle spring.

(5) Adjust the fuel injection nozzle to obtain the specified popping pressure (if necessary) as follows:

(a) Remove the protection cap (1, fig.43) from the upper end of the fuel injection nozzle and loosen the adjusting screw locknut (3).

(b) While operating the tester handle, turn the pressure adjusting screw (4) IN to increase or OUT to decrease the popping pressure until the specified pressure is obtained. At this time, hold the adjusting screw from turning and tighten the adjusting screw locknut (3).

(6) Dry the tip of the fuel injection nozzle. Operate the tester handle slowly until the pressure is approximately 200 pounds below the popping pressure and observe the top of the nozzle for fuel leakage. If the nozzle does not leak or dribble, the nozzle valve is seating properly on its seat in the valve body. If drops of fuel collect at a pressure of approximately 200 pounds or less below the popping pressure, the nozzle valve is not seating properly in the valve body; the valve body and valve must be removed for cleaning and inspection.

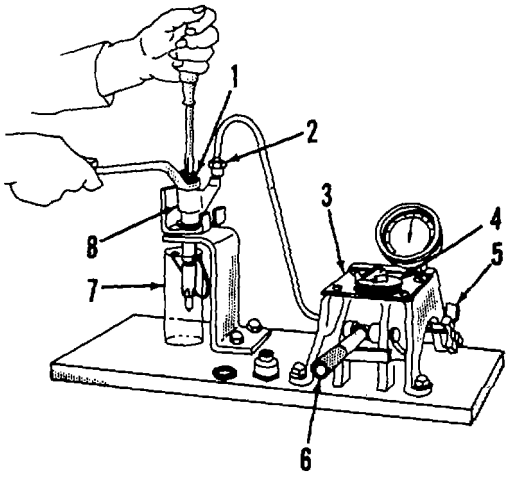
(7) If the fuel injection nozzle proved satisfactory when subjected to the leakage test above, operate the tester handle at a speed of approximately 100 strokes per minute and observe the nozzle spray pattern.

(8) The nozzle tip has four equally spaced holes (fig. 45). The size and spacing of these holes determine the

spray pattern. If fuel is being discharged evenly through all four holes in the nozzle tip at the specified popping pressure, the spray pattern is considered satisfactory. If fuel is not being discharged evenly from all four holes in the nozzle tip, a plugged hole or holes is indicated; then the nozzle must be removed and cleaned, using a .016" diameter wire (fig. 46).

e. Fuel Injection Nozzle Holder Cleaning and Inspection.

(1) Before starting the disassembly of a fuel injection nozzle holder, it is of the utmost importance to have a clean work bench, clean washing



1. Pressure adjusting screw
2. Adjusting screw locknut
3. Nozzle tester
4. Filler cap
5. Valve handle
6. Tester handle
7. Spray collector
8. Nozzle-holder assembly

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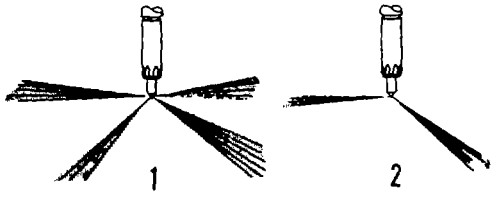
Figure 44. Adjusting popping pressure.



1. Acceptable spray pattern
2. Nonacceptable spray pattern

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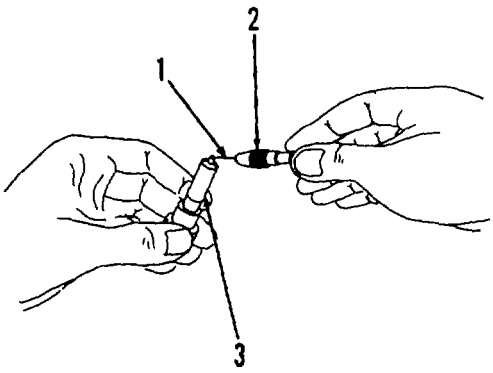
Figure 45. Nozzle spray patterns.



1. Wire
2. Chuck
3. Valve body

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Figure 46. Cleaning nozzle orifices.

fluid containers, clean tools, and clean hands. Cleanliness is emphasized because injection nozzle service troubles are, in most instances, due to dirt entering the nozzles. Use clean paper on the work bench and as the nozzle holder is disassembled, place the components in a container of clean diesel fuel as a protection against dirt and corrosion.

(2) When more than one fuel injection nozzle holder is disassembled, keep parts of each separate. Complete disassembly of the fuel injection nozzle holder is seldom necessary. In most cases only disassembly and cleaning of the nozzle. valve body and valve is required to place the nozzle holder in good operational condition. The nozzle valve and nozzle valve body are mated parts, and must be kept together; if replacement of either part is necessary, both parts must be replaced as matched sets.

(3) Nozzle Valve Body and Valve Disassembly, Cleaning, and Assembly (fig. 43).

(a) Clamp nozzle holder body in a vise having copper jaws or similar protective material.

(b) Remove protection cap (1, fig. 43) and gasket from upper end of nozzle holder. Loosen pressure adjusting screw locknut (3) and turn pressure adjusting screw out sufficiently to release spring tension on spindle spring.

(c) Loosen and remove the nozzle retaining nut (10). Remove the nozzle valve body (7) and nozzle valve (8) from the retaining nut.

Start the nut back onto the holder body to protect the lapped end of the holder body.

(d) Withdraw the valve from the valve body and place them in carbon and rust remover solution for cleaning. Normally, the valve can easily be withdrawn from the valve body, however, in some cases it may be necessary to soak the valve body and valve in the carbon and rust remover solution before the valve can be withdrawn. After removing the parts from the solution, immediately place them in clean diesel fuel for neutralizing. Always handle the parts care fully to protect the lapped surfaces.

Caution

Do not allow the solution to get on the hands or body; use tweezers or the basket method to handle the parts. For faster and better cleaning results, the carbon and rust remover should be heated to approximately 200°F. The parts generally can be separated in two or three minutes; however, for stubborn cases they can be left in the solution longer.

(e) The valve seat and the seat in the valve body are originally ground to slightly different angles to provide a line contact seat between the two parts. Practically all the wear occurs in the seat in the valve body. The valve should never be lapped to the seat in the valve body.

(f) Using a magnifying glass, inspect condition of seat in the valve body.

If the seat is damaged or worn in any way to prevent proper seating of the valve, the nozzle assembly must be replaced. Examine the lapped bore in valve body for any signs of scoring. If scoring is apparent, the nozzle assembly must be replaced.

(g) The outer surfaces of the valve body may be cleaned with a brass wire brush. Do not scrape carbon from the surface around the orifices in tip of valve body with any hard object as damage may result.

(h) Using a .016 inch wire, clean the four orifices in the valve body tip.

(i) Visually inspect the condition of the valve, preferably with aid of a magnifying glass. The lapped surface (large O.D.) of the valve must be smooth and free of signs of scoring. Also, the valve must not show any wear or damage at seat location. If the valve is damaged in any way, the nozzle assembly must be replaced.

(j) Thoroughly rinse the valve and valve body in clean diesel fuel or calibrating oil. The valve must fit freely in the valve body. To check this fit, lift valve about one third of its length out of the body. The valve should slide down to its seat without aid when assembly is held at a 45°angle. If the fit of the valve in the valve body is unsatisfactory, the valve may be cleaned and polished with 1,000G lapping compound and castor oil used on tissue paper. The valve may be held by its stem in a revolving chuck for this cleaning operation. An orange stick or round toothpick will be helpful in cleaning the valve. Hard or sharp tools, emery cloth, crocus cloth, jeweler's rouge, grinding compounds, or other abrasives should never be used in cleaning.

(k) Thoroughly rinse the valve in clean diesel fuel before installing it in the valve body.

(l) Examine the flat sealing surface of the valve body (surface which contacts lower end of the holder body) and make certain surface is clean and free of scratches. This surface may be lapped, if necessary, using 1,000G lapping compound, castor oil, and a lapping block as shown in figure 47. After lapping, remove all traces of lapping compound with clean diesel fuel.

(m) Make certain that the bottom flat sealing surface of the nozzle holder body is clean and in good condition. Rinse the valve and valve body in clean diesel fuel, then insert valve into position in the valve body. Place the valve body and valve in position on the end of the nozzle holder body and center the valve body with the holder body. Install and tighten the nut to a torque of 60-80 ft. lbs.

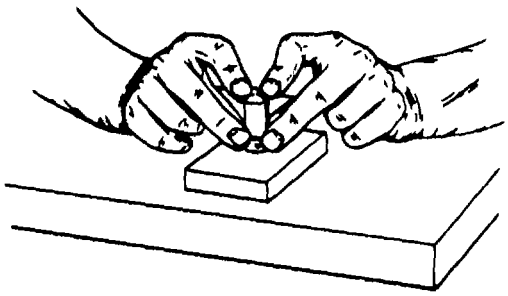

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Figure 47. Lapping fuel injection nozzle valve body.

Note

It is important that the valve body be centered in the nozzle retaining nut. Use care while tightening the nozzle retaining nut so that the valve body remains centered in the nut.

(n) Test and adjust the fuel injection nozzle. Refer to preceding paragraph *d*.

(4) Nozzle Holder Disassembly, Cleaning, and Assembly (fig. 43). If malfunctioning of the fuel injection nozzle holder was not corrected by removal and cleaning of the nozzle valve body and valve, disassemble and clean the nozzle holder as follows:

(a) Clamp nozzle holder assembly in a copper-jawed vise and remove the protection cap and gasket from upper end of nozzle holder. Loosen and remove the pressure adjusting screw locknut and gasket.

(b) Remove pressure adjusting screw, spindle spring, and spindle.

(c) Remove nozzle retaining nut, nozzle valve body, and nozzle valve.

(d) Place all parts in clean diesel fuel.

Using filtered compressed air, blow out the fuel passages in the holder body.

(e) Visually inspect the parts for damage or wear; replace necessary parts. Examine the flat sealing

surface of holder body (surface which contacts upper end of valve body) and make certain the surface is clean and free from scratches. This surface should be lapped if necessary, using 1,000G lapping compound, castor oil, and a lapping block. When lapping (fig. 47) use care to keep the nozzle holder body square with the lapping block to assure contact with the entire area being resurfaced. After lapping, remove all traces of the lapping compound with clean diesel fuel and dry with filtered compressed air.

(f) Examine the spindle spring. If the spring is scratched or pitted, it must be replaced. Also, the spring must be replaced if the ends have worn. Always replace questionable springs.

(g) Rinse spindle in clean fuel and insert it into holder body. Place the spindle spring in position on spindle. Install pressure adjusting screw, pressure adjusting screw locknut and gasket, protection cap and gasket-do not tighten at this time.

(h) Install nozzle valve, valve body, and nozzle retaining nut. Tighten nut to a torque of 60-80 ft. lbs.

(i) Test and adjust the fuel injection nozzle holder assembly as instructed in paragraph d.

(j) Tighten the protection cap to a torque of 60-75 ft. lbs.

42. Fuel Injection Nozzle Holder Sleeves

a. General. The bore in the cylinder head for each fuel injection nozzle holder extends directly through the cylinder head water jacket.' To facilitate removal of the nozzle holder for servicing, without loss of coolant, a stainless steel nozzle holder sleeve is pressed into the cylinder heads at each nozzle bore. The sleeve forms a water-tight receptacle for the nozzle holder. The coolant in the cylinder head flows around the stainless steel sleeve and helps to cool the nozzle holder.

b. Fuel Injection Nozzle Holder Sleeve Removal. Whenever the cylinder heads are removed from the engine, the nozzle holder sleeve should be thoroughly cleaned (fig. 48) and inspected. If sleeve condition warrants replacement, proceed as follows:

(1) Using tools similar to the ones shown in figure 48, screw the 7/8 inch tap down into the nozzle holder sleeve.

(2) Insert driving rod through the nozzle tip hole in bottom of the cylinder head; using a hammer, drive sleeve out of the cylinder head.

c. Fuel Injection Nozzle Holder Sleeve Installation (fig. 48).

(1) Thoroughly clean the bore in the cylinder head for injection nozzle holder sleeve.

(2) Clean new nozzle holder sleeve with a solvent and dry. Apply sealant to the sleeve at top and bottom outside surfaces which contact the head. Use grade A "Loctite Sealant" or equivalent.

(3) Install sleeve in position in cylinder head with sleeve end having the large O.D. toward the top. Using tools similar to those shown in figure 48, drive sleeve into position in cylinder head until it bottoms solidly in the bore.

43. Rocker Arms and Shafts

a. General. The four different types of rocker arms installed on an engine are marked on top with raised letters so they may be removed and replaced in their original or an interchangeable position on the rocker shaft assemblies. The rocker arms for the intake valves are marked either "1-2-4-5 Int. R.H." or "3-6 Int. L.H." Rocker arms for the exhaust valves are marked "1-2-4-5-Exh. L.H." or "3-6 Exh. R.H." The rocker arms, having slightly different angles, allow centralized contact on the valve mechanism.

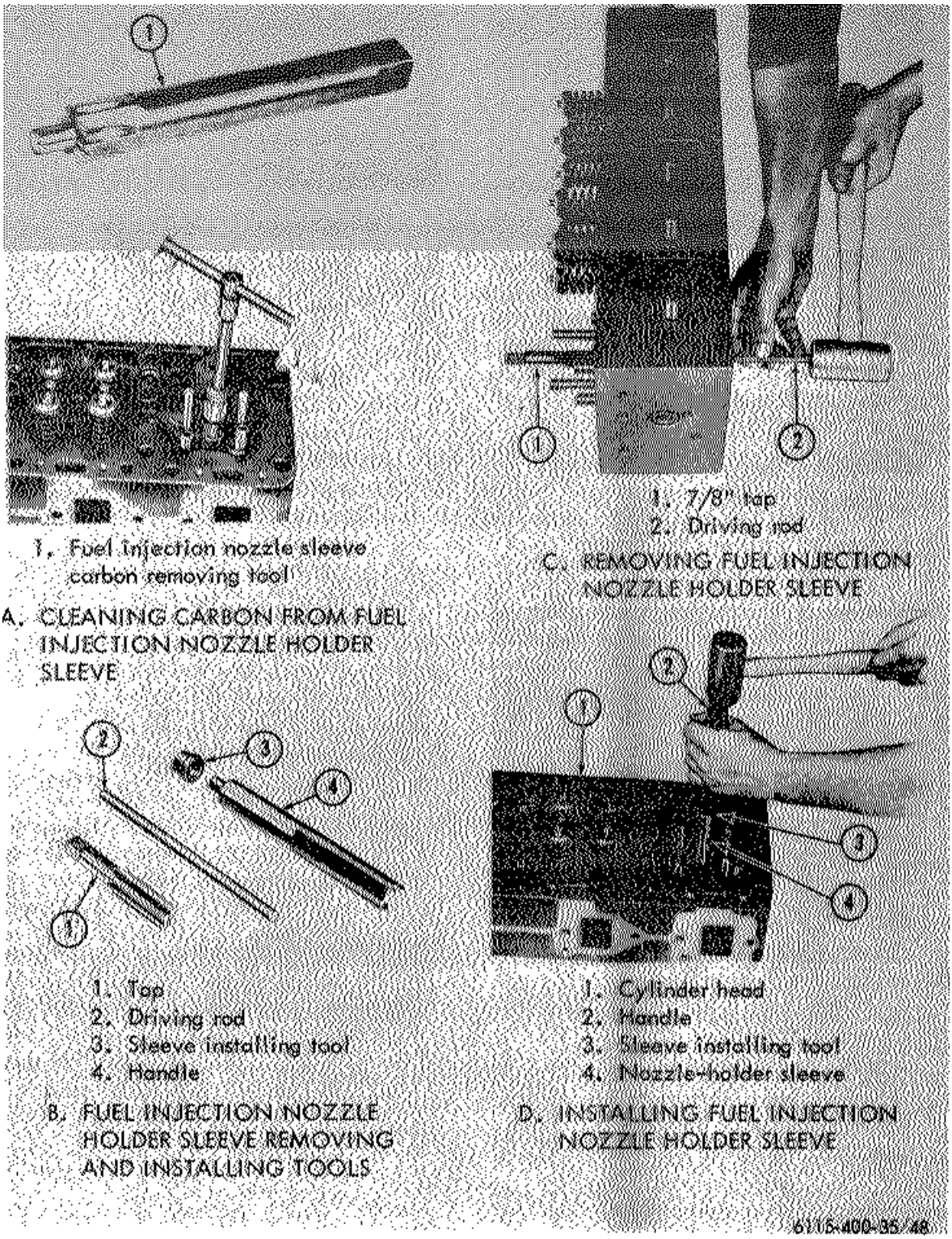


Figure 48. Fuel injection nozzle holder sleves.

Caution

If rocker arms are not marked as described, it is imperative that extra precautions be taken when disassembling or assembling rocker arms to their shafts to be sure they are installed in their correct locations. Since there is very little visual difference in the rocker arms and to prevent the possibility of the rocker arms being mixed and improperly reinstalled, each rocker shaft assembly should be kept separate and rocker arms punched or marked in some way before removal from their relative shafts so they may be assembled in the same position. Failure to correctly locate rocker arms will cause interference of rocker arms with the fuel injection lines and will not allow centralized contact with the valve bridge assemblies.

b. Removal.

(1) Remove the valve rocker cover.

(2) Disconnect and remove fuel return manifold (fig. 49) and fuel injection tubes. Remove the valve rocker housing if desired.

(3) Remove nuts and plain washers securing fuel injection nozzle holder clamps and remove the clamps. Remove rocker shaft bracket stud nuts and lockwashers attaching the right side of rocker shaft brackets to the cylinder head. Remove capscrews and lockwashers attaching the left side of brackets to the cylinder head and remove rocker shaft brackets, shaft, and rocker arms as an assembly.

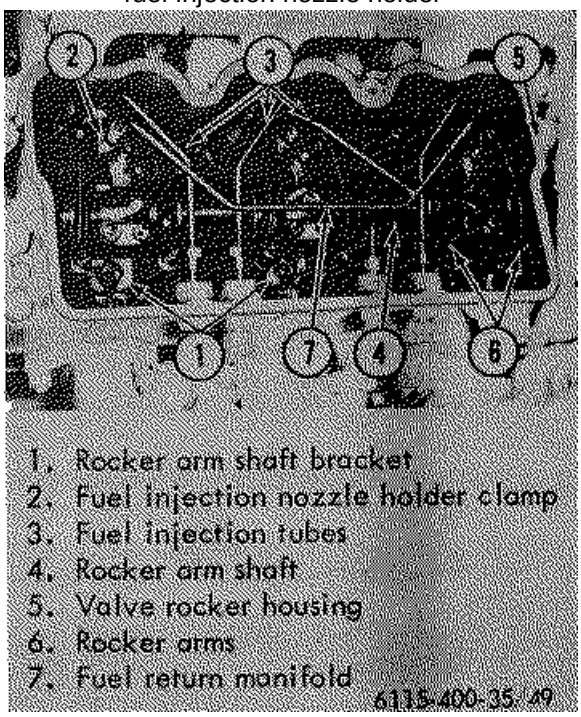


Figure 49. Rocker arms, shafts, and brackets.

c. Disassembly. Remove snap ring at each end of rocker shaft. After loosening the 5/16 inch capscrews in rocker shaft brackets, and the 1/4 inch centering capscrew in the middle bracket, slide rocker arms, brackets, rocker arm retainers, and spring retainers from the shaft.

d. Cleaning and Inspection.

(1) Steel inserts are provided on ends of rocker arms and contact the valve bridges during opening and closing of the valves. The inserts are designed so that a minimum of side thrust is exerted on the valve mechanism during operation. Normally, the inserts will wear very little; however, if they become worn, the rocker arms must be replaced since inserts cannot be serviced separately.

(2) Inspect rocker arm bushings for wear. The specified clearance between shaft and bushings is .001 inch-.0025 inch and must not exceed .005 inch. If bushings are excessively worn, remove bushings and install new bushings using tools as shown in figure 50. After bushings are installed an oil hole must be drilled in the bushing in line with oil hole in rocker arm. A burnishing tool (fig. 50) must be pressed through the bushing to establish the specified .001 inch-.0025 inch clearance with the shaft. After burnishing, file bushing so that it is flush with sides of the rocker arm and remove all burrs with a scraper.

(3) Inspect rocker arm shaft for wear and replace if necessary. Clean oil holes in rocker arms and rocker arm

shaft with solvent, a small wire, and compressed air.

e. Reassembly.

(1) Lubricate rocker arm bushings and shaft with clean oil and install rocker arms (fig. 51) rocker arm retainers, springs, and rocker arm shaft brackets on the shaft. Install snap rings at each end of shaft.

(2) Aline center hole in rocker arm shaft with centering capscrews and tighten the capscrew. Tighten clamping capscrews, only on middle bracket, to a torque of 18-20 ft. lbs. Do not tighten clamping capscrews on either end bracket.

f. Installation.

(1) Place rocker arm assembly over rocker arm shaft bracket studs and position the assembly on cylinder head. The rocker arm assemblies are interchangeable and can be installed on either cylinder head.

(2) Install stud nuts and lockwashers and bracket retaining capscrews and lockwashers. Tighten capscrew and nut, only at center bracket location, to a torque of 68-73 ft. lbs. Do not tighten capscrews or nuts on either end bracket.

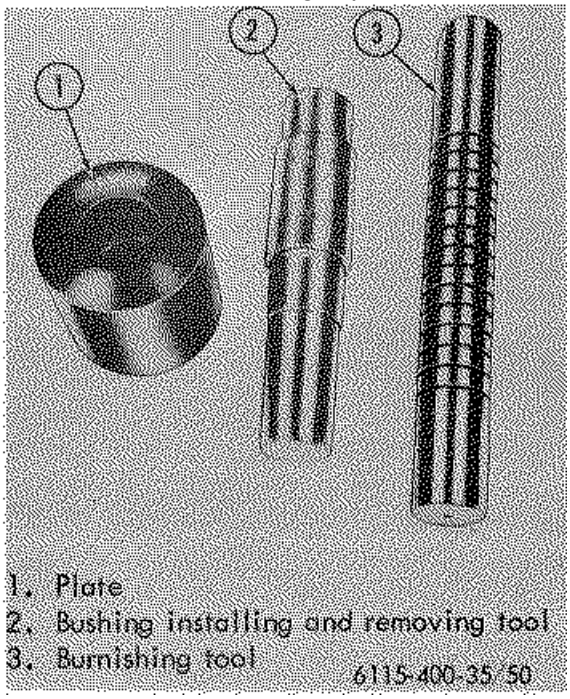


Figure 50. Rocker a arm bushing service tool set.

(3) Using a feeler gage, check clearance between the end rocker arms and the end brackets (fig. 51). The specified clearance is .002 inch.005 inch. Tap brackets forward or back until the specified clearance is obtained, then tighten bracket retaining capscrew and nut to a torque of 68-73 ft. lbs. and clamping capscrews to a torque of 18-20 ft. lbs, After all capscrews and nuts are tightened to the proper torque, recheck the end play, and readjust if necessary.

(4) Install fuel injection nozzle holder clamps (fig. 49), plain washers, and nuts. Tighten nuts to a torque of 21-24 ft. lbs.

(5) Adjust the valves (TM 5-6115-400-12). After adjusting valves, recheck rocker arm clearance (fig. 51) and readjust if necessary.

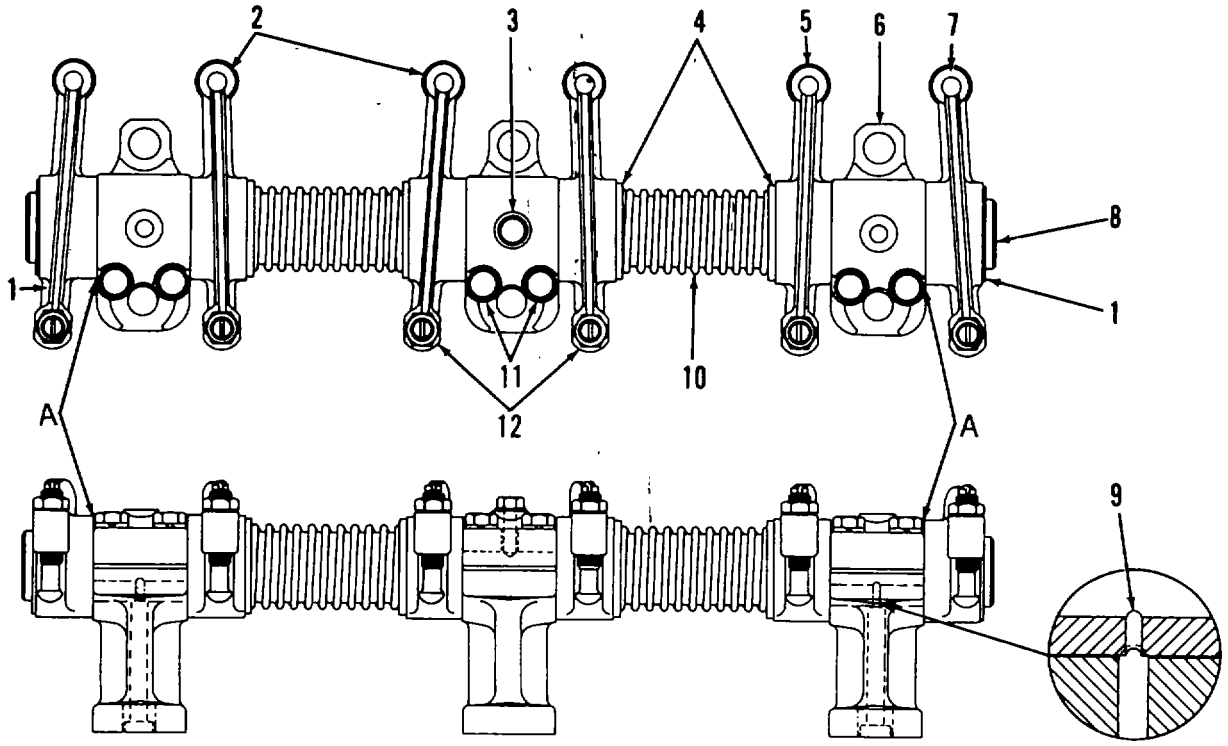
44. Push Rods and Valve Lifters

a. Removal and Inspection.

(1) Remove rocker arm assemblies. Refer to paragraph 43.

(2) Withdraw push rods. Inspect both ends of signs of wear; polish out any nicks or scores. If push rods are bent, twisted, or damaged, they must be replaced.

(3) Remove capscrews, plain washers, and sealing washers attaching valve lifter covers to cylinder block and remove the covers. Remove locking wire, capscrews, and plain washers securing valve lifter brackets to the cylinder block and remove the valve lifters from each valve bracket (fig. 52). Remove valve lifter brackets from cylinder block.



1. Snap ring
2. Rocker arm (1-2-4-5 exhaust L.H.)
3. Rocker arm shaft centering capscrew (1/4" NC x 3/4")
4. Rocker arm retainer
5. Rocker arm (3-6 Intake L.H.)
6. Rocker arm shaft bracket
7. Rocker arm (3-6 exhaust R.H.)
8. Rocker arm shaft
9. Restricted oil passage in rocker arm shaft
10. Rocker arm shaft spring
11. Rocker arm shaft clamping capscrew (5/16" NC x 1-1/4")
12. Rocker arm (1-2-4-5 intake R.H.)

A. .002"-.005" end clearance

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Figure 51. Rocker arm assembly.

Caution

When removing valve lifter bracket, use care to prevent valve lifter bracket hollow dowels from falling into the oil pan.

(4) Inspect flat surface of valve lifters for wear and replace any worn valve lifters.

b. Installation.

(1) The valve lifter brackets are marked "FRONT" and "REAR" and must be installed in their proper locations.

(2) Lubricate valve lifters with clean oil and install lifters and lifter brackets by a direct reversal of removal procedure. Tighten the lifter bracket attaching capscrews to a torque of 68-73 ft. lbs. and lock with locking wire.

(3) Install push rods with cup end to the top. Make certain push rods are seated properly in the valve lifters.

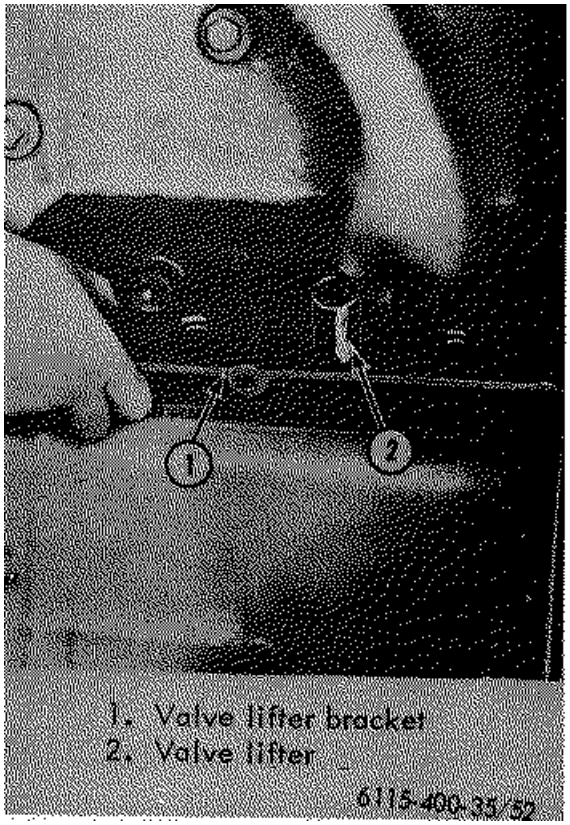


Figure 52. Removing valve lifter from bracket.

45. Valves, Bridges, Springs, Rotators, Guides, and Seat Inserts

a. Valve Bridges.

(1) Removal.

(a) Remove rocker arm assembly (para 43).

(b) Lift valve bridges (fig. 53) off bridge guide pins.

(2) Cleaning and Inspection. Clean bridges in a cleaning solvent. Using a wire, clean oil hole located in end of cross member opposite the adjusting screw. Inspect the hardened insert in top of bridge for wear. Replace insert if necessary. The specified bore in valve bridge guide is .4995 inch-.5000 inch and specified O.D. of bridge guide pin is .4970 inch-.4975 inch. If total clearance between bridge and guide pin exceeds .006 inch, replace bridge and/or guide pin. The bridge must slide freely on guide pin.

(3) Valve Bridge Installation.

(a) Install valve bridges in position on bridge guide pins and valve stems.

(b) Install rocker arm assembly (para 43).

b. Valve Bridle Guide Pins.

(1) Removal.

(a) Remove cylinder head from engine (para 40).

(b) Remove valve bridge.

(c) Break bridge guide pin (fig. 54) off as close to cylinder head as possible, using a 1/2 inch pipe and bending pin back and forth until it breaks.

(d) Using a 5/16 inch drill, drill a hole approximately 3/4 inch deep in the center of portion of guide pin remaining in cylinder head, then tap the hole with a 3/8 inch NC tap. Using a 3/8 inch NC

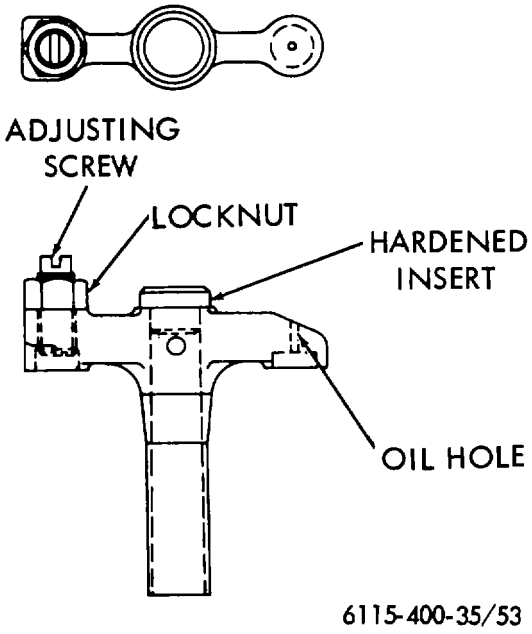


Figure 53. Valve bridge.

adapter on a slide hammer puller,; pull pin from cylinder head.

(2) Installation. Using a press, press a new guide pin into cylinder head until top of pin stands out 2 inches above top flat machined surface of the cylinder head or 2 11/16 inches above counterbore at which guide pin is located. The guide pin bore in the cylinder head is .4945 inch.4960 inch.

c. Valve Springs and Rotators.

(1) Removal. The intake and exhaust valve springs and rotators may be removed without removing the cylinder heads from the engine. The valve spring and damper assembly (3, fig.55) is serviced as a unit. To remove the valve springs without removing the cylinder heads, proceed as follows:

(a) Remove valve rocker cover. Disconnect and remove fuel return manifold and the fuel injection' tubes. Remove valve rocker housing. Loosen rocker arm adjusting screw in the valve rocker arms sufficiently so rocker arms may be moved to one side. Remove valve bridges (para a above).

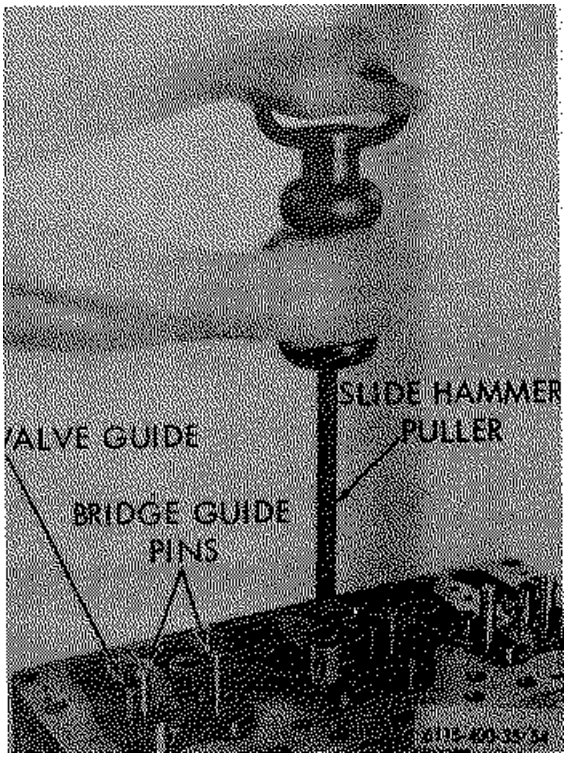


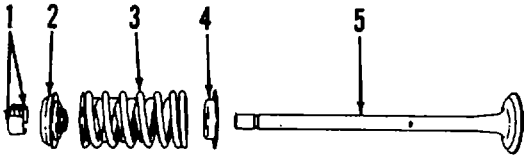
Figure 54. Removing valve bridge guide pin.

(b) Make certain that the piston in cylinder from which valve springs are to be removed, is at top dead center. Using a suitable spring compressing tool, remove spring retainer locks (1, fig. 55) and carefully release tension on valve spring. Remove valve spring, rotator, and spring seat.

(2) Inspection.

(a) Inspect valve springs. Both intake and exhaust valve springs should have a load of 50-63 lbs. when compressed to a length of 2 13/64 inches and a load of 136-150 lbs. when compressed to a length of"1 21/32 inches. Install a new Spring when old spring is 5% under or over the specified load limits.

(b) After engine is running, remove valve rocker covers and visually observe valve rotators. If any rotators are not rotating, they must be replaced.



1. Valve spring retainer locks
2. Valve rotator
3. Valve spring and damper assembly
4. Valve spring seat
5. Valve

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Figure 55. Valve and valve components.

(3) Installation. Install valve spring seat, valve spring, valve rotator, and valve spring retainer locks using a direct reversal of removal procedure. When installing the valve spring, the end of the spring having the coils closer together should be installed next to the cylinder head.

d. Valves and Valve Guides.

(1) Removal.

(a) Remove cylinder heads (refer to para 40).

(b) Remove valve springs. Remove valves from cylinder heads. Place valves in a rack as they are removed from cylinder heads so they can be identified and reinstalled in their original locations.

(c) The valve guides may be removed by pressing them out through the bottom of the cylinder head, using a valve guide removing tool similar to the one shown in figure 56.

(2) Clean and Inspection.

(a) Clean carbon from valves and valve seats. Clean carbon from valve guides using a valve guide cleaning tool (nylon brush).

Caution

Do not use a metal cutting type cleaning tool.

(b) Replace intake and exhaust valves if they are cracked, bent, burned, or stems are worn. The specified O.D. of both intake and exhaust valve stems is .3715 inch-.3720 inch. The specified I.D. of the intake valve guide is .373 inch giving a stem-to-guide clearance of .001 inch-.0015 inch. The specified I.D. of the exhaust valve guide is .374 inch giving a stemto-guide clearance of .002 inch.0025 inch. Replace valve and/or guide if clearance exceeds .0055 inch.

(3) Installation.

(a) The intake and exhaust valve guides are the same length but

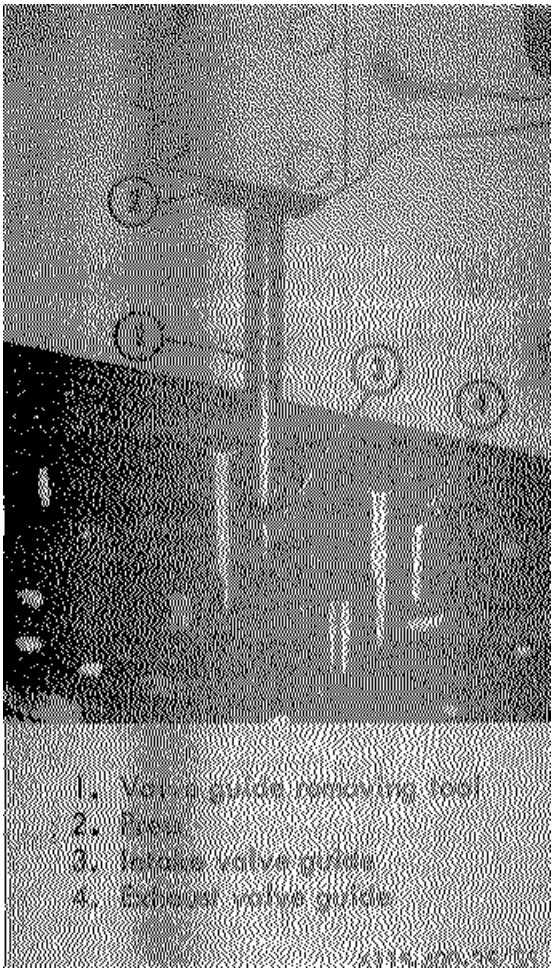


Figure 56. Removing intake valve guides.

differ in other dimensions; they are not interchangeable. New guides must be installed with tapered end of guide at top of cylinder head. The spiral thread (internal oil groove) cut into the bore must be to the top of cylinder head on exhaust valve guides and to the bottom on intake valve guides.

(b) Press valve guides into position from bottom of cylinder head with a guide installing tool, consisting of a stop plate, pilot, exhaust valve guide adapter, and an intake valve guide adapter. The adapters establish proper protrusion of guides above the cylinder head. To

use the tool, place cylinder head in a press with head gasket surface up. Assemble guide installing tool by screwing pilot into stop plate. Install adapter, exhaust or intake on the pilot. Install valve guide on the pilot with bottom end (end not tapered) against the adapter. Insert installing tool and guide into guide bore in cylinder head and press downward until stop plate rests on head gasket surface of cylinder.

Note

To eliminate the possibility of scuffing guide or bore in the cylinder head, coat outside surface of guide with a mixture of white lead and lubricating oil before pressing guide into position.

(c) After pressing valve guides into position, check the distance from top of guide to counterbore in cylinder head. This dimension must be .721 inch-.736 inch (47/64 inch) on intake valve guide and 1.346 inch-1.361 inch (1 23/64 inch) on exhaust valve guide (fig. 57)

(d) The bore of intake valve guides is .373 inch-.3735 inch and exhaust valve guides .3732 inch-.3742 inch. The interference fit of guides in the cylinder is .0005 inch -.002 inch. The guide bore will close approximately .001 inch when installed with maximum interference fit. To resize intake valve guides after installation, use a .372 inch valve guide reamer first and follow with a .373 inch valve guide reamer (fig. 58). Resize exhaust valve guide by first using a .373 inch reamer followed by a .374 inch reamer to complete the operation.

Note

Intake and exhaust valve guides installed in production and service replacement cylinder heads at the factory are sized with a "bearingizing" tool. However, service replacement valve guides are not "bearingized" and must be reamed after installation in cylinder head. Do not ream guides installed in service replacement cylinder heads.

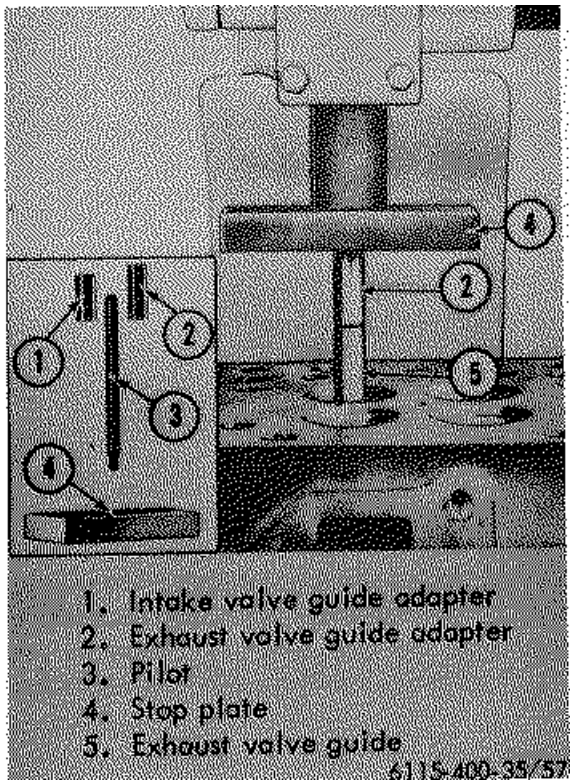


Figure 57. Installing exhaust valve guide.

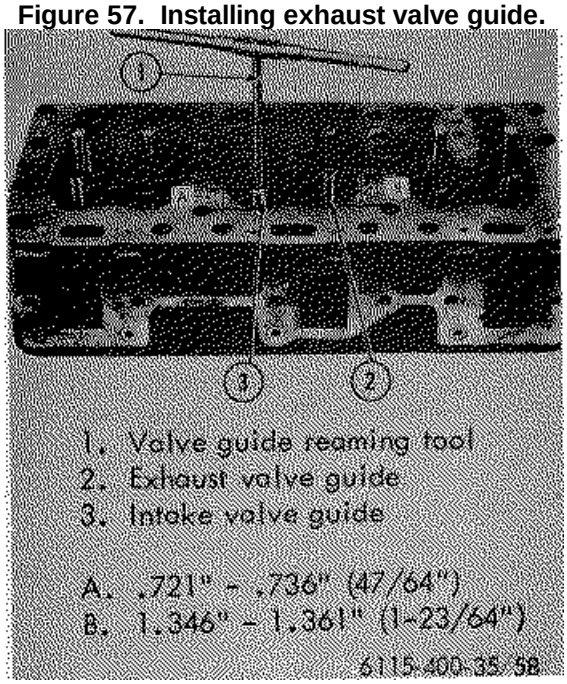


Figure 58. Reaming intake valve guide.

e. Valve Seat Inserts.

(1) Removal. Inspect the valve seat inserts. If they are loose, cracked or pitted, new inserts must be installed. The valve seat inserts are a press fit in the cylinder head. Remove valve seat inserts by electric welding three small beads on inside circumference of the insert as shown in figure 59. Allow insert to cool, then lift out or pry out with a bar.

Caution

Do not weld in encircled area (fig. 59). Protect machined surfaces from arc splatter.

(2) Installation.

(a) It is imperative that the original press fit be maintained between new inserts and insert bores in the cylinder head. If insert bores in cylinder head are damaged or worn enough so that the recommended press fit cannot be obtained when installing new standard size valve seat inserts, the bores must be machined .005 inch larger than their original I.D. and .005 inch oversize valve seat inserts must be installed. Refer to table 2.1 for O.D. of valve seat inserts and corresponding I.D. of bores in cylinder head. The dimensions shown in table 2.1 provide an interference fit of .002 inch to .004 inch for intake valve seat inserts and .002 inch to .0035 inch for exhaust valve seat inserts.

Table 2.1. Valve Insert Dimensions

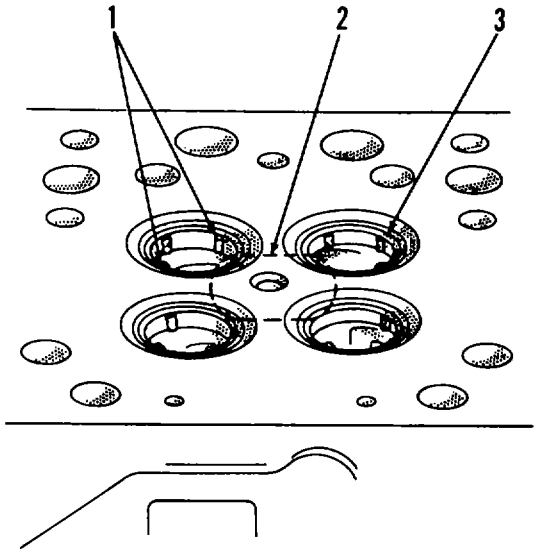
Valve Seat Insert	O.D. of New Insert	Insert Bore in Cylinder Head
Standard Size-Intake	1.6445 inch-1.6455 inch	1.6415 inch-1.6425 inch
.005 inch Oversize-Intake	1.6495 inch-1.6505 inch	1.6465 inch-1.6475 inch
Standard Size-Exhaust	1.6105 inch-1.6110 inch	1.6075 inch-1.6085 inch
.005 Oversize-Exhaust	1.6155 inch-1.6160 inch	1.6125 inch-1.6135 inch

(b) Make certain valve seat counterbores in cylinder head are clean, free of burrs, and of the correct size to assure the specified interference fit (refer to table).

(c) Chill inserts for 2 to 4 minutes in a dry ice container or cold box.

(d) Place cylinder head bottom side up on a bench. Thoroughly clean counterbores for the inserts with compressed air and start an insert into the counterbore (valve seat side up). Inserts must be started in place "true" with the counterbore in the cylinder heads.

(e) Using a valve seat insert installing tool, drive insert down tightly into counterbore. This operation must be done quickly while insert is cold.



1. Weld beads
2. Do not weld in encircled area
3. Valve seat insert

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Figure 59. Beads welded on valve seat inserts.

(f) After the inserts have been installed, the exhaust valve seat inserts must be staked to eliminate the possibility of the insert loosening in its bore. It is not necessary to stake the intake valve seat inserts. Using a center punch and hammer, stake each exhaust valve seat insert at 3 points approximately 1200 apart, as illustrated in figures 60 and 61, being careful not to stake in the semi-circled area (fig. 61). Do not use old staking points.

(g) It will be necessary to refinish valve seat inserts with a grinder (refer to following para).

f. Valve Face and Valve Seat Grinding.

(1) Before installing either new valves or valves used previously, valve seats in cylinder heads should be inspected for proper valve seating. If previously used valves are to be reinstalled, valve stems should be cleaned and valve faces ground to their specified angles of 45° for exhaust valve and 30° for intake valve. When re-facing valves, remove all evidence of pitting and grooving. The valve guide should be cleaned

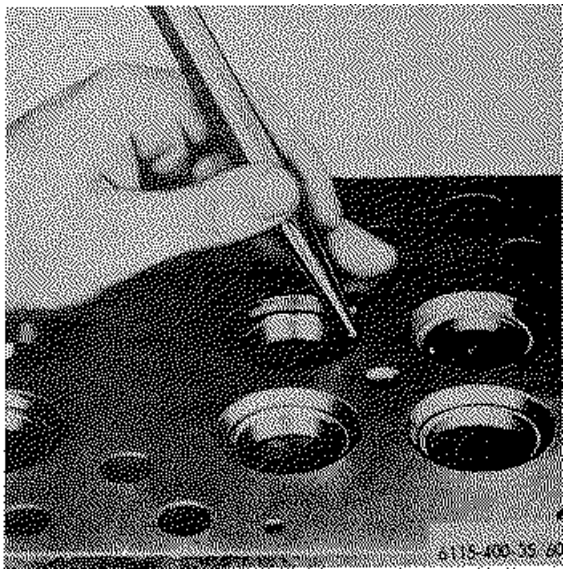
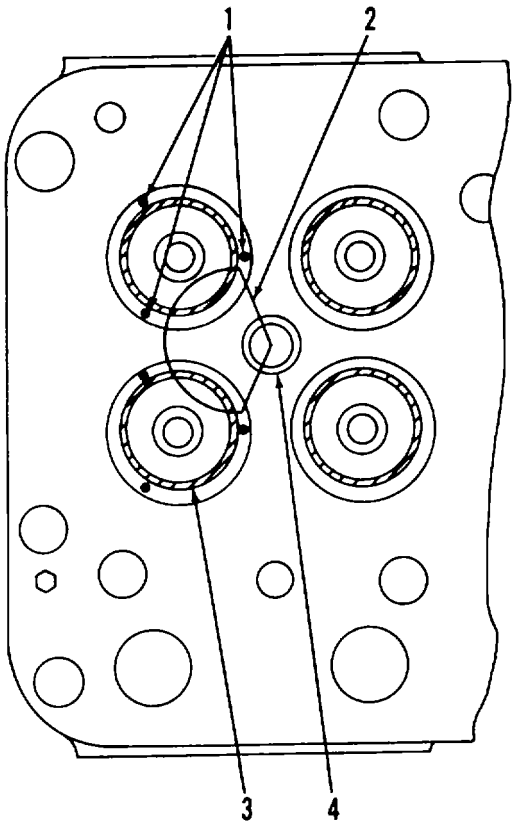


Figure 60. Staking exhaust valve seat inserts.



1. Staking points
2. Do not stake in this area
3. Exhaust valve seat insert
4. Hole for fuel injection nozzle tip

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Figure 61. Exhaust valve seat inserts staking points.

with a nylon brush. If bore in valve guide is worn oblong, or if valve head is warped relative to valve stem, the necessary parts must be replaced.

(2) When new valve seat inserts are installed, or previously used inserts re-seated, refinishing must be done with a valve seat grinder set.

Note

It is important that the valve grinder set be used according to the manufacturer's directions.

The usual equipment used with the valve seat grinder set includes the following items:

(a) Valve seat grinder.
(b) Dial gauge.
(c) Tool pilot.
(d) Four grinding wheels: 15^0, 30^0, 45^0, and 60^0.

(3) The cutting face of the stone must be maintained at the correct angle and in proper condition by frequent dressing with a diamond wheel dresser. The frequency of dressing will be determined by condition of the seats and amount of metal required to be removed during the grinding operation.

(4) By grinding valve face and insert seat at slightly different angles, a fine line contact of the face and seat is obtained, thus eliminating the need to lap the seating surfaces with grinding compound.

(5) The difference of angles is termed "interference angle" and is usually $1/2^0$ to $1\ 1/2^0$. The angle of the insert seat is made greater than that of the valve face, so as to assure contact at the top of insert seat. Thus, for the 450 exhaust valve face angle and a 1^0 interference angle, the insert seat grinder wheel must be dressed to grind the insert seat at an angle of 460. Likewise, the insert seat for the intake valve must be ground at 31^0. This is a positive interference angle. A negative angle, as illustrated in figure 62, must be avoided. The first step in reconditioning the insert is to grind the seat, removing only enough metal to produce a pit-free continuous seat. After seat has been ground, use a dial gauge to check concentricity of the seat relative to the valve guide. The total run-out of a good seat should not exceed .002 inch total indicator reading.

(6) To determine seat contact in relation to insert and valve face, wipe a thin film of Prussian Blue on the valve face and bounce the valve once on the valve seat. A thin, continuous line must be evident on the valve face, otherwise further grinding is required.

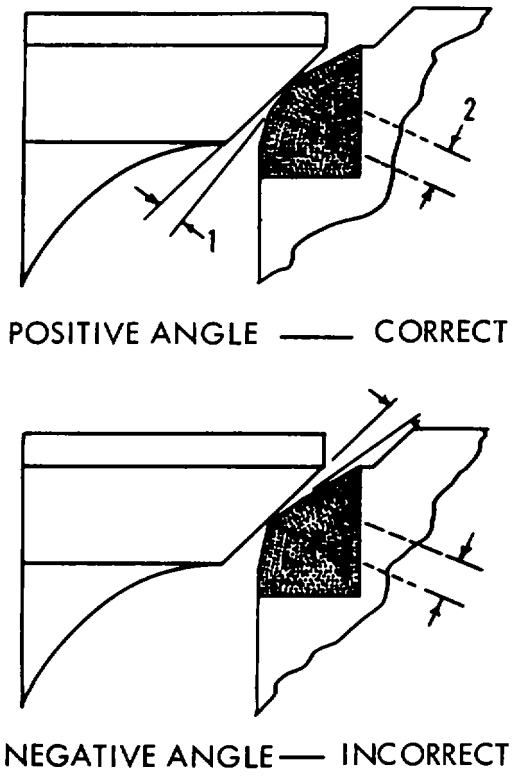


Figure 62. Interference angle.

Note

Do not revolve valve while checking seat.

The specified width of the valve seat on the insert is 3/32 inch for the exhaust and 1/16 inch for the intake (fig. 62). If the seats are too wide or too narrow they must be ground to the specified width using the appropriate angle grinding wheels.

Caution

After valves are installed in cylinder head, make certain valve heads are set in a minimum of .064 inch from the cylinder head gasket surface, otherwise serious damage will result. If valve stand-in is less than .064 inch, the valve seat on the insert must be ground lower until the specified stand-in is obtained.

46. Accessory Drive

a. General.

(1) The accessory drive is pressure lubricated from the engine main oil gallery by an oil line located inside the timing gear housing.

(2) The accessory drive upper shaft (7, fig. 63) is driven at 1 1/2 times crankshaft speed and drives the auxiliary drive gear (12) at twice the crankshaft speed. The lower shaft (27) is driven at 1/2 crankshaft speed.' (3) The upper shaft (7) drives the overspeed governor and the auxiliary gear (12) drives the hydraulic pump which provides hydraulic pressure to the electric governor actuator. The lower shaft (27) drives the fuel injection pump.

b. Removal (fig. 64).

(1) Remove overspeed governor. Refer to TM 5-6115-400-12.

(2) Remove hydraulic pump and hydraulic tank.

(3) Remove fuel injection pump. Refer to TM 5-6115-400-12.

(4) Remove the capscrews attaching accessory drive to timing gear housing and remove accessory drive and gasket from the engine.

c. Disassembly.

(1) Remove the clamping capscrew and lockwasher from fuel injection pump drive coupling hub; remove coupling and woodruff key from accessory drive lower shaft.

(2) Remove capscrews securing cover to housing and remove cover (21, fig. 65) and gasket. Remove overspeed governor drive adapter (24) and gasket from cover.

(3) Remove cotter pin and nut (29) from upper shaft. Using a puller tool, pull auxiliary shaft driving gear (30) from shaft.

(4) Press upper shaft from upper shaft gear (15). Remove woodruff key, high profile key (3), rear thrust washer, laminated shims, and front thrust washer (5).

(5) Press upper shaft from drive gear (4). Remove woodruff key.

Note. Do not press on end of shaft; use a sleeve that will contact large shoulder of shaft.

(6) Remove self-locking nut, plain washer, and packing from auxiliary shaft (19). Press shaft, gear, rear thrust plate, and bushing from the housing. Remove front thrust washer (13).

(7) Remove cotter pin and nut, front thrust washer, and laminated shim from lower shaft (28); remove shaft and gear from housing. Remove rear thrust washer (33) from dowel pins.

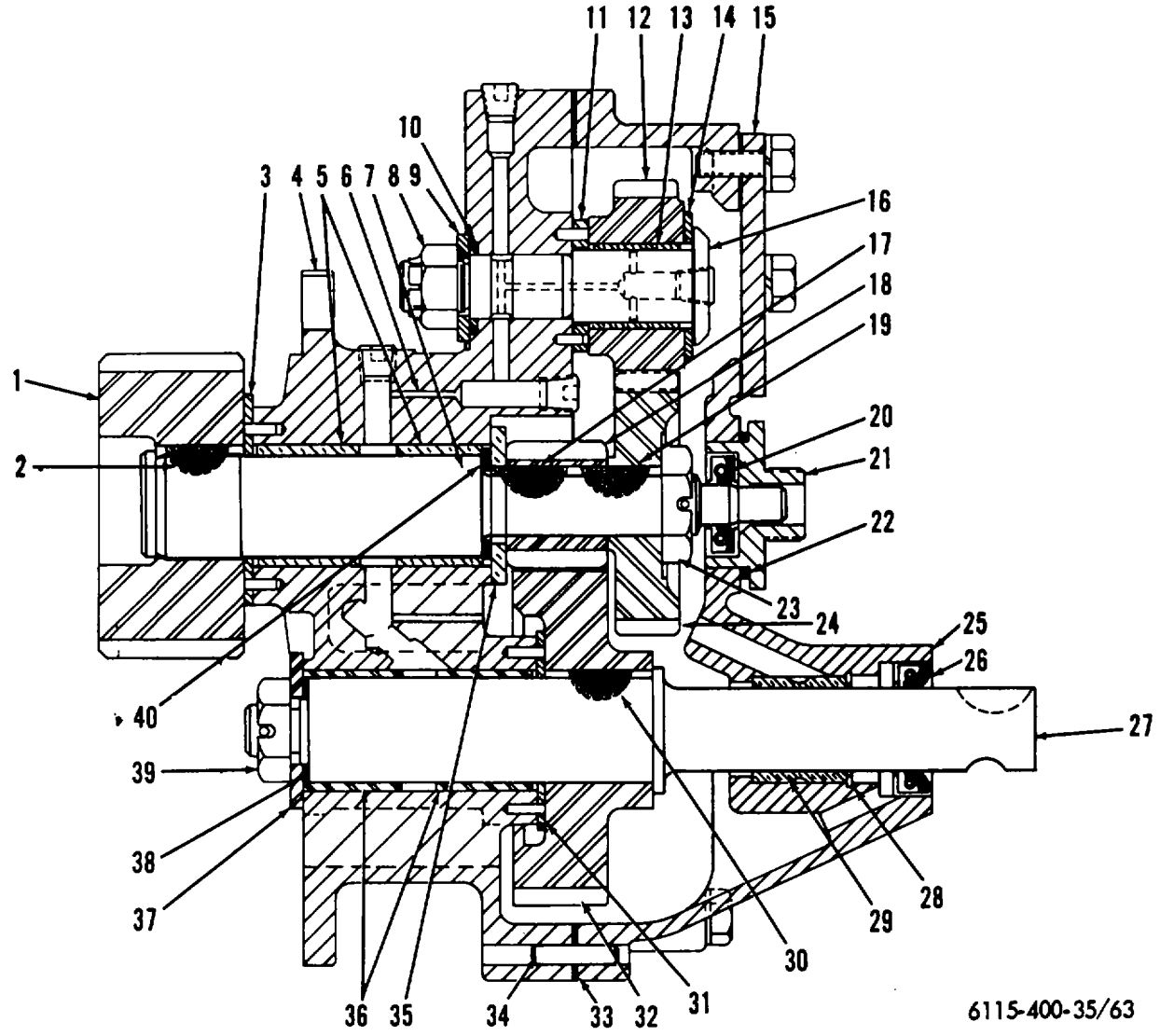
With threaded end of shaft upward, press shaft from lower shaft gear and remove woodruff key.

d. Accessory Drive Inspection. Thoroughly clean all parts. Inspect gears, thrust washers, and shafts for wear, cracks, or roughness. Replace worn or damaged parts. If bushings in housing or cover are worn, they may be pressed out and new ones installed as described in the following paragraph.

e. Reassembly (fig. 65).

(1) If the old bushings were removed from housing, install new bushings making certain the oil grooves in upper set of bushings are down and oil grooves in lower set of bushings are up. Press bushings in from each face of housing so ends of bushing are 1/32 inch in from each face of housing.

(2) The I.D. of the bushings after assembly should be 1.2495 inch1.2507 inch. The bushings are the



1	Drive gear	15	Shipping cover	29	Bushing
2	Woodruff key	16	Auxiliary shaft	30	Woodruff key
3	Front thrust washer	17	High profile key	31	Rear thrust washer
4	Housing	18	Upper shaft key	32	Lower shaft gear
5	Bushings	19	Woodruff key	33	Gasket
6	Oil restrictor	20	Oil seal	34	Dowel pin
7	Upper shaft	21	Overspeed governor drive adapter	35	Rear thrust washer
8	Nut	22	Gasket	36	Bushings
9	Washer	23	Nut	37	Front thrust washer
10	Preformed packing	24	Auxiliary shaft drive gear	38	Laminated shim
11	Front thrust washer	25	Cover	39	Nut
12	Auxiliary gear	26	Oil seal	40	Two laminated shims
13	Bushing	27	Lower shaft		
14	Rear thrust plate	28	Snap ring		

Figure 63. Accessory drive.

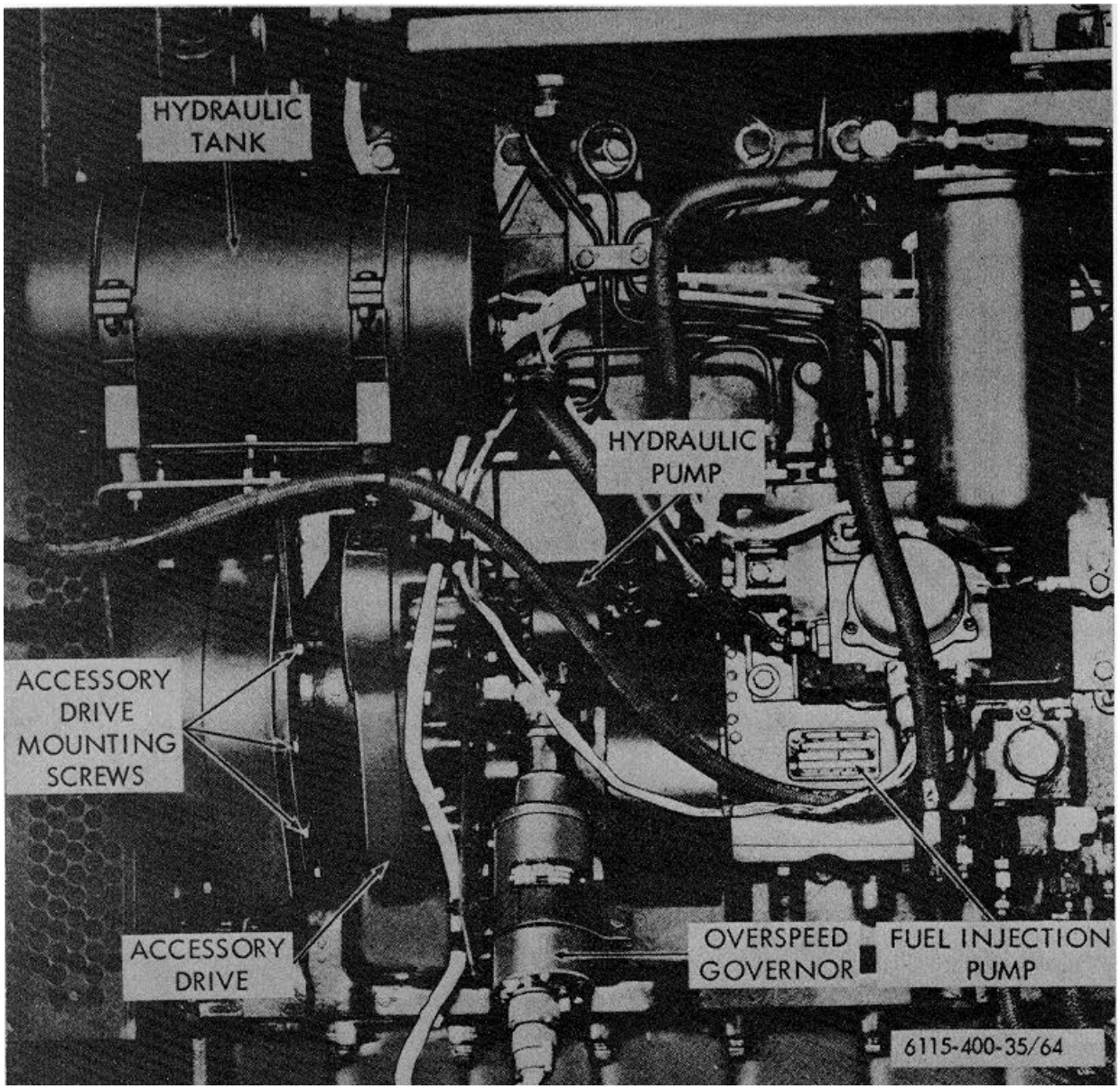
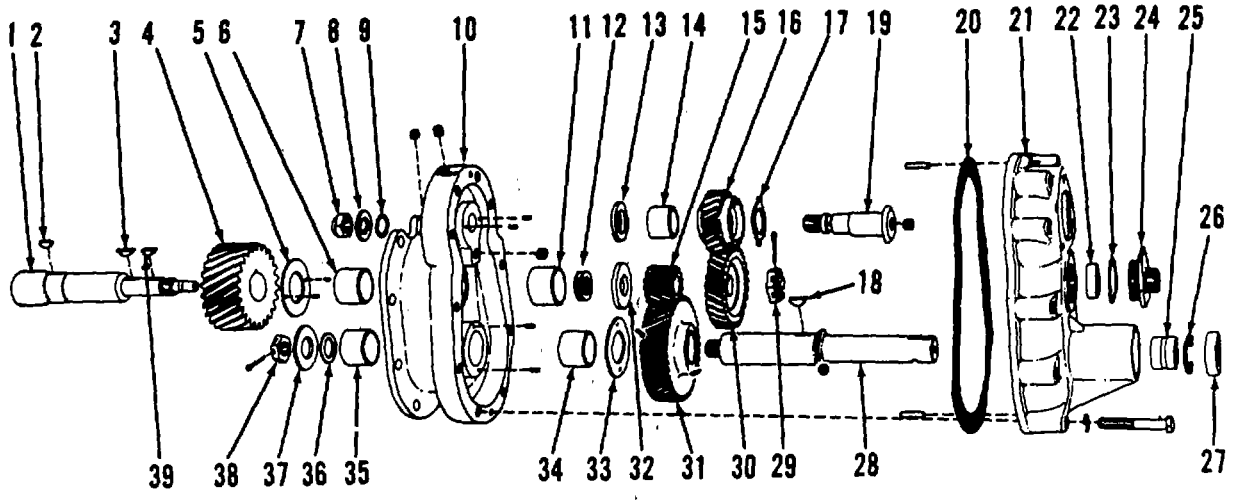


Figure 64. Accessory drive removal.

precision type and do not require sizing after being installed. The specified diameter of the upper and lower shafts at the bushing locations is 1.247 inch-1.248 inch.

(8) Install a woodruff key in keyway on large diameter of upper shaft (1). Position drive gear (4) on bed plate of press with counterbored face of gear up, and press upper shaft into gear until the flange on shaft is tight against the counterbore in gear.

(4) Install the upper shaft from thrust washer (5) in position on dowel pins in housing and insert the upper shaft, with gear, into housing. Rotate the shaft in the housing to be sure it turns freely. Lubricate the bushings and thrust washer.



1. Upper shaft
2. Woodruff key
3. High profile key
4. Drive gear
5. Front thrust washer
6. Bushing
7. Nut
8. Washer
9. Preformed packing
10. Housing
11. Bushing
12. Two laminated shims
13. Front thrust washer
14. Bushing
15. Upper shaft gear
16. Auxiliary gear
17. Rear thrust plate
18. Woodruff key
19. Auxiliary shaft
20. Gasket
21. Cover
22. Oil seal
23. Gasket
24. Drive adapter
25. Bushing
26. Snap ring
27. Oil-seal
28. Lower shaft
29. Nut
30. Auxiliary shaft driving gear
31. Lower shaft gear
32. Rear thrust washer
33. Rear thrust washer
34. Bushing
35. Bushing
36. Laminated shim
37. Front thrust washer
38. Nut
39. Woodruff key

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Figure 65. Accessory drive-exploded view.

(5) Install the two laminated shims (12), rear thrust washer, high profile key (8), and remaining woodruff key on shaft.

(6) Support splined end of upper shaft on bed plate of press and press upper shaft gear (15) onto upper shaft until it is tight against the rear thrust washer.

(7) Using a feeler gage, check the end clearance between the drive gear (4) and the front thrust washer (5). The

specified clearance is .002 inch-.005 inch. If the clearance is not within this range, press the upper shaft from the upper shaft gear (15) and add or remove shims (12) as necessary to obtain the specified clearance.

Note. Do not install the auxiliary shaft driving gear at this time.

(8) Install woodruff key in keyway of lower shaft (28). With the hub end of the lower shaft gear facing the flange on shaft, press gear (31) into position on shaft.

(9) Lubricate bushings in housing with clean oil. Position rear thrust washer on dowel pins in housing. Rotate the shaft in the housing to be sure it turns freely.

(10) Install the laminated shim (86), front thrust washer (37), and nut on the lower shaft. Tighten the nut securely and check the end play of the lower shaft; add or remove shims to obtain .002 inch-.005 inch end play. Tighten nut to 75-85 ft. lbs. torque and secure with cotter pin.

(11) Support the splined end of up/per shaft (1) on bed plate of a press; place the auxiliary shaft driving gear (30) on the shaft with hub end of gear down; press gear on shaft until it is tight against upper shaft gear (15). Tighten nut to 125-135 ft. lbs. torque and secure with cotter pin.

(12) Inspect bushing (14) in auxiliary gear (15). The specified I.D. of a new bushing (installed) is .8745 inch-.8755 inch and the O.D. of the auxiliary shaft at the bushing location is .872 inch—.873 inch. Replace any worn or damaged parts. If a new bushing is installed in the gear, the bushing must be reamed to the specified I.D.

(13) Support housing in a press as shown in figure 66. Install front thrust washer (13, fig. 65) over the dowel pins in housing with oil grooves

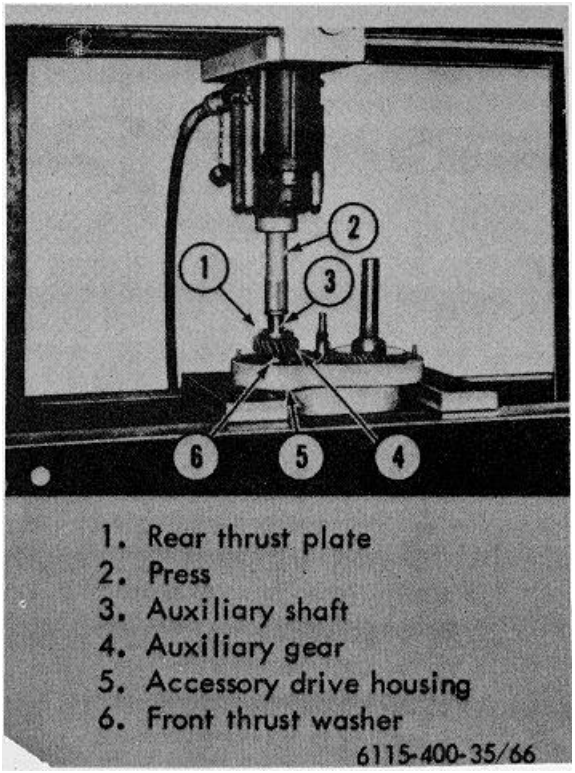


Figure 66. Installing auxiliary gear and shaft in housing.

in washer facing up. Place auxiliary gear (16) in position on front thrust washer with slotted hub of gear facing up. Position rear thrust plate (17) with tangs of plate in slots of gear hub and bronze face of plate facing up. Insert auxiliary shaft through the gear and into the bore in housing. Press shaft into position in housing. Remove housing from press. Position a new performed packing over front end of shaft. Install washer and self-locking nut (7) and tighten nut to a torque of 75-85 ft. lbs.

(14) Check clearance between auxiliary gear and front thrust washer with a feeler gage. The specified clearance should be .006 inch-.015 inch. If clearance exceeds .020 inch replace front thrust washer, gear, and/or rear thrust plate.

(15) Inspect bushing (25) in lower shaft bore of the cover. The specified I.D.

of a new bushing (installed is 1.0015 inch-1.0027 inch, and the O.D. of lower shaft at the bushing location is .999 inch-1.000 inch. If bushing is worn it may be replaced as follows:

(*a*) Remove lower shaft oil seal (27) from the cover.

(*b*) Remove bushing retaining snap ring (26) and drive old bushing out toward snap ring end of the bore.

(*c*) Using a suitable installing tool, drive or press a new bushing into position in cover until it is tight against the shoulder in the bore. Make certain oil hole in bushing is to the bottom when installed. Install bushing retaining snap ring.

***Note*. The bushing is the precision type and does not require sizing after being installed.**

(16) Install a new oil seal in the drive adapter (24) and a new oil seal in the lower bore of the cover with the sealing lip of the seal directed toward the inside of the cover.

***Note*. Coat the O.D. of the seals with a small amount of sealant.**

(17) Using a new gasket, attach the cover to housing with capscrews and lockwashers. Tighten capscrews securely.

(18) Using a new gasket, install the drive adapter, drive cover nut, and gasket.

f. Accessory Drive Installation. The accessory drive must be timed to the engine so that the keyway (fig. 67) is properly positioned for installation and timing of the fuel injection pump. Install the accessory drive on the engine as follows:

(1) Use barring tool to rotate engine until the #1 piston is on its compression stroke and the engine flywheel timing pointer registers 34 degrees BTDC for start of fuel injection into the #1 cylinder.

(2) The accessory drive is properly timed to the engine when the keyway (fig. 67) in the lower shaft is to the top and in line with an imaginary centerline between the lower shaft and slightly to the left of the center of the drive adapter when the accessory drive assembly is secured in position on the timing gear housing.

***Note.* When starting the accessory drive into the timing gear housing, it will be necessary to position the keyway slightly left of the centerline. This is to compensate for the gear angle which causes the lower shaft to rotate clockwise as the accessory drive is moved forward into position.**

This is a trial and error method and must be repeated until the keyway in the lower shaft is to the top and on the imaginary centerline between the lower shaft and the overspeed governor drive adapter as shown in figure 67 when engine is positioned as described in the preceding step.

(3) Install the woodruff key in the accessory drive lower shaft and install the fuel injection pump drive coupling hub on the shaft: Secure the coupling to the shaft with the clamping capscrew and lockwasher.

(4) Install and time the fuel injection pump (refer to TM 5-6115-400-12).

47. Crankshaft Pulley and Damper

a. General. The vibration damper (fig. 68) consists of two identical vibration dampers which are attached to the crankshaft pulley. Each consists of a metal ring enclosed in a fluid tight outer case but separated from contact with the, case by a thin wall of viscous liquid that tends to dampen the torsional vibrations of the crankshaft. This damper should give no trouble, but it must be given proper care. It must not be dropped or struck with a hammer or similar object. Doing so can upset its balance. For the dampers to function properly, they are aligned with the crankshaft pulley by dowel pins and fastened securely to the pulley with capscrews and locking wire.

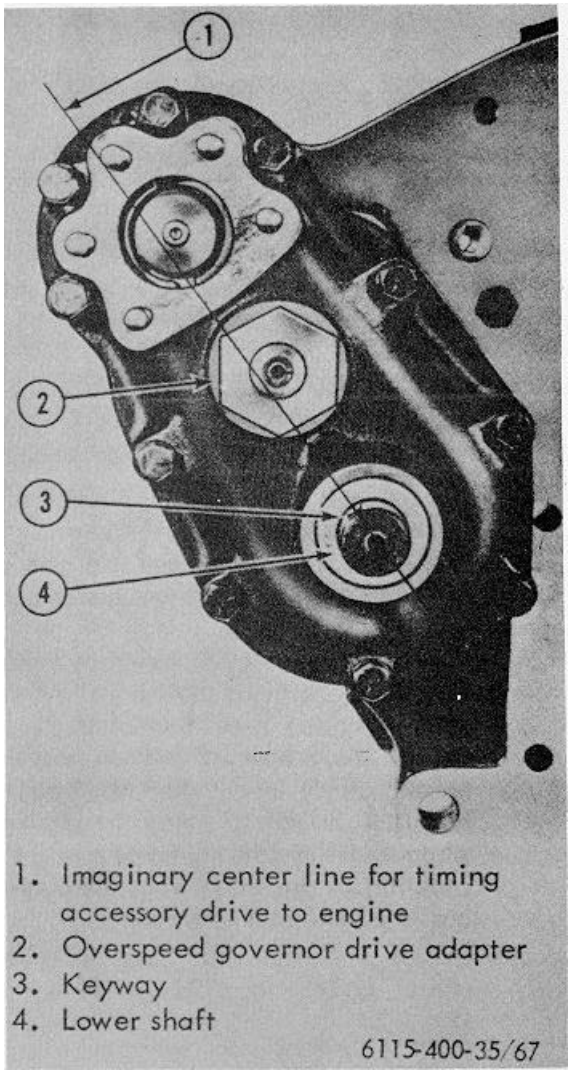


Figure 67. Accessory drive installation.

Caution. Do not, under any circumstances, fasten any type of additional pulleys or drive anything with the front crankshaft pulley/vibration damper that is not installed at the factory. Crankshaft breakage can occur if this precaution is not adhered to.

b. Removal.

(1) Remove radiator or other components necessary for the crankshaft pulley/vibration damper removal.

(2) Release tension on fan and water pump drive belts; remove belts.

(3) Loosen crankshaft pulley retaining capscrew and turn out approximately 1/2 inch.

(4) Remove two opposite capscrews and install a puller tool as shown in figure 69.

(5) Tighten puller forcing screw. To assist in loosening pulley hub from crankshaft, strike puller forcing screw with hammer.

(6) Remove puller tools, crankshaft pulley retaining capscrew, washer, crankshaft pulley/vibration damper, and square-cut key.

Caution. If, for any reason, the crankshaft/pulley vibration damper is disassembled from the crankshaft pulley, identify the rear vibration damper's position in regards to the keyway so it is assembled to its original position. Always install the rear vibration damper to the crankshaft pulley with the timing marks to the keyway side of the pulley.

c. Installation.

(1) Install the crankshaft pulley/vibration damper square-cut key into the crankshaft keyway.

(2) Install pulley, washer, and pulley retaining capscrew. Tighten the capscrew to a torque of 250-260 ft. lbs.

48. Engine Front Mounting Bracket and Timing Gear Housing Cover

a. General.

(1) The timing gear housing cover encloses the timing gear housing and gear train. An opening at the right side of the cover, aligned with a similar opening in the timing gear housing, is provided for mounting the water pump assembly.

(2) The unitized crankshaft front oil seal is located in the timing gear housing cover. The unitized seal is made up of an inner part which fits tight on the crankshaft, and the outer part which is tight in the front cover.

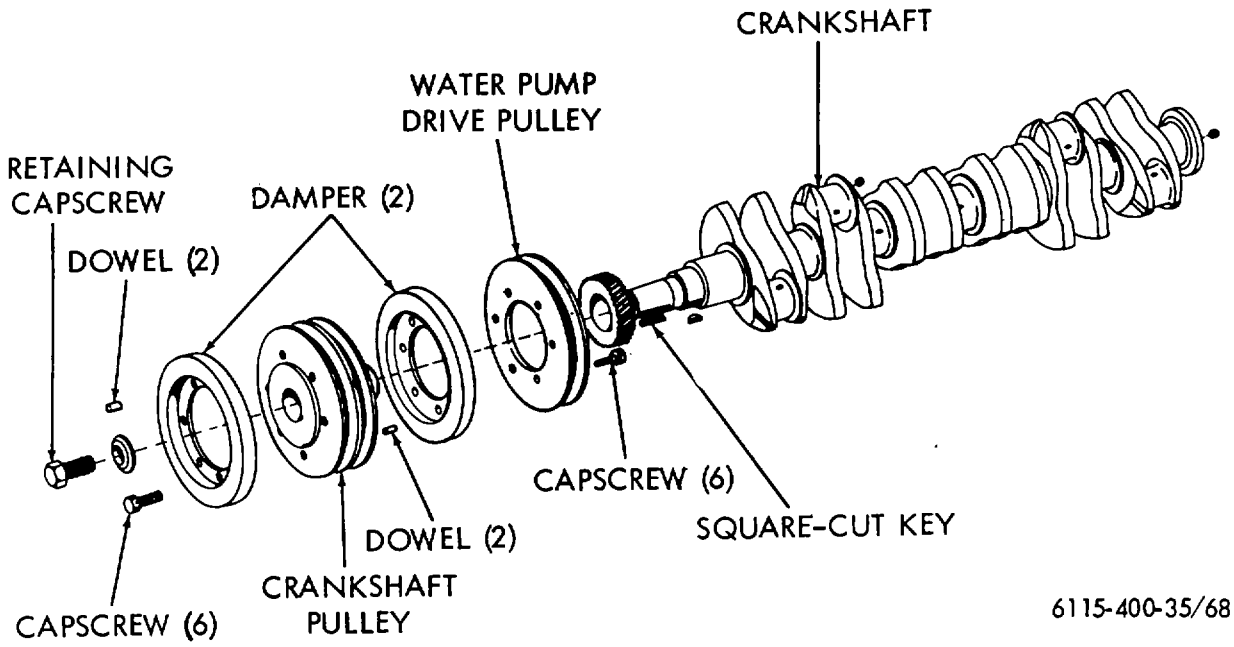


Figure 68. Crankshaft pulley and vibration dampers.

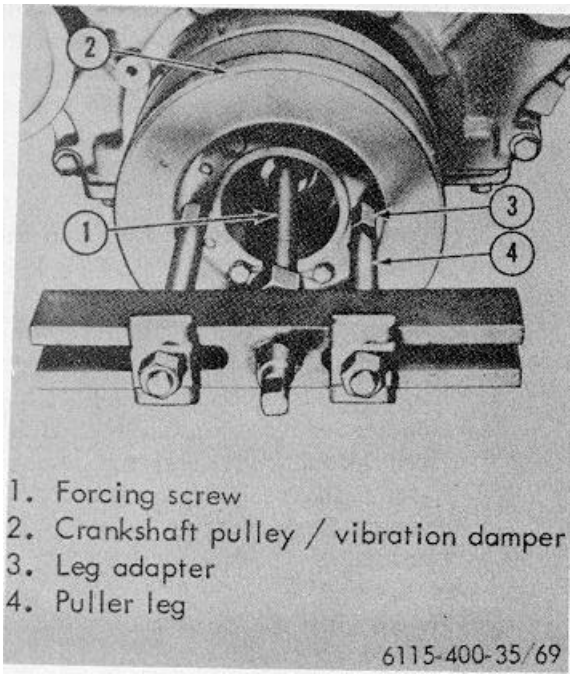


Figure 69. Removing crankshaft pulley/vibration damper.

(3) Sealing is accomplished by an internal contact (spring loaded) of the inner and outer parts of the seal, and the two parts are so constructed that they form a single assembly.

Note. **Install a new oil seal each time the engine is disassembled.**

b. Engine Front Mounting Bracket.

(1) Removal.

(*a*) Remove crankshaft pulley (para 47).

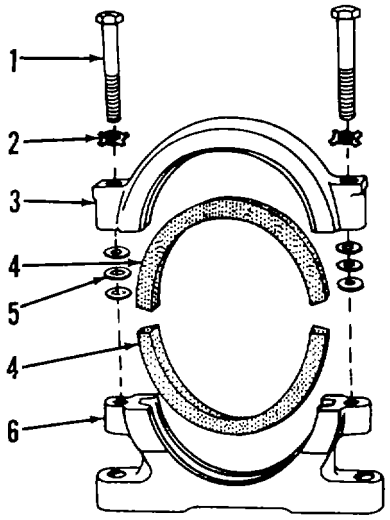
(*b*) Remove capscrews (1, fig. 70) and remove cap (3).

(*c*) Raise front of engine slightly and support with blocks, or chain and hoist.

(*d*) Remove bracket (6) from frame.

(2) Cleaning and Inspection.

(*a*) The bracket assembly is provided with liners; if the material has become hard or deteriorated, new liners must be installed.



1. Capscrews
2. Lockwashers
3. Bracket cap
4. Liners
5. Shimming washers
6. Bracket

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Figure 70. Engine front mounting bracket-with liners.

(*b*) Remove the old liners and carefully clean the grooves in the bracket and cap.

(3) Installation.

(*a*) Install new liners, making certain that the liner ends are flush with the ends of the grooves in bracket and cap.

(*b*) Install bracket on frame. Install bracket securing hardware-do not tighten at this time.

(*c*) Lower engine into position on bracket and install bracket cap and securing capscrews.

(*d*) Tighten bracket cap securing capscrews evenly to a torque of 95-105 ft. lbs. Determine the amount of shimming washers necessary to fill the gap between ends of the bracket and cap.

(*e*) Remove capscrews and install shimming washers to equal the gap.

Note. Shimming washers are 1/32 inch thick and must be evenly distributed on both sides of bracket.

(*f*) Reinstall capscrew and torque to 95-105 ft. lbs.

Note. The bracket assembly must be a tight fit on trunnion to avoid "bearing out" the liners.

c. Timing Gear Housing Cover.

(1) Removal.

(*a*) Remove crankshaft pulley/vibration damper (para 47).

(*b*) Remove engine front mounting bracket.

(*c*) Remove fan, fan hub, and fan hub mounting bracket.

(*d*) Remove water pump pulley, water pump belt idler, and idler support bracket, and filler pipe support.

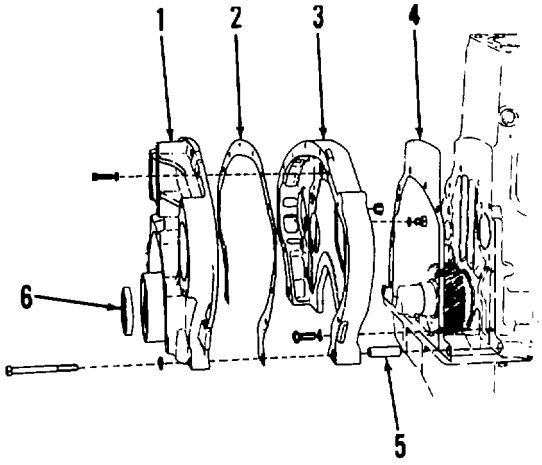
(*e*) Remove capscrews securing the oil pan to timing gear housing cover. To facilitate removal and installation of timing gear housing cover, it is possible to loosen the oil pan capscrews enough to lower front end of the oil pan; however, it is recommended that the oil pan be removed and all gaskets replaced.

(*f*) Remove capscrews securing timing gear housing cover to timing gear housing and jar cover loose with a soft-headed hammer; pry cover from locating dowels and remove it from engine being careful not to damage front portion of oil pan gasket.

(2) Installation.

(*a*) Before installing cover, install a new crankshaft front oil seal (refer to para d. following).

(*b*) Remove burrs from keyway in crankshaft, using a fine-cut mill



1. Timing gear housing cover
2. Cover gasket
3. Timing gear housing
4. Housing gasket
5. Dowel
6. Crankshaft front oil seal

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Figure 71. Timing gear housing and cover.

file or stone to prevent damaging the inner layer of rubber of the crankshaft front oil seal.

(*c*) Coat crankshaft lightly with lubricating oil.

(*d*) Cement a new cover gasket to the timing gear housing cover.

(*e*) Using a reversal of the removal procedure, install the timing gear housing cover and components. Torque the 1/2 inch capscrews to 68-73 ft. lbs. and the 3/8 inch capscrews to 28-33 ft. lbs.

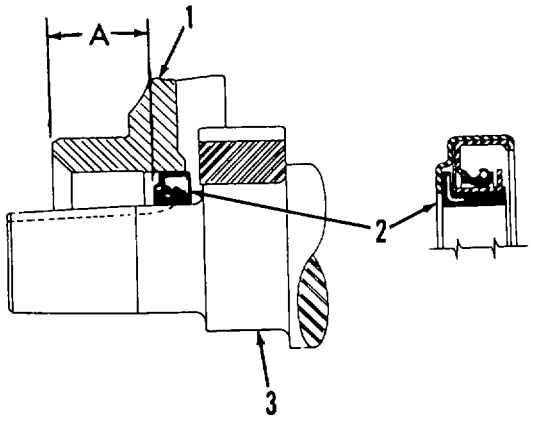
d. Crankshaft Front Oil Seal.

(1) Removal.

(a) Remove timing gear housing cover from engine.

(b) Clean the bore in the cover to receive a new seal.

(2) Installation. The O.D. of the seal has a layer of red-colored sealant which forms a seal between the O.D.



1. Timing gear housing cover
2. Seal
3. Crankshaft
A. 2-5/32" - 2-11/64"

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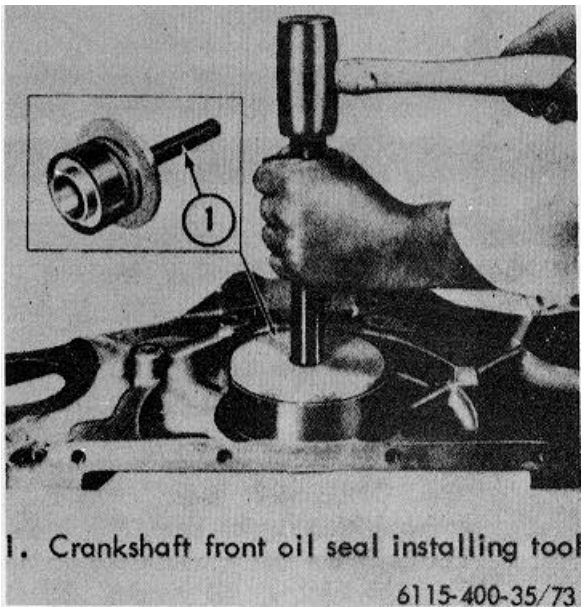
Figure 72. Crankshaft front oil seal location.



1. Crankshaft front oil seal installing tool

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Figure 73. Installing crankshaft front oil seal

of seal and the bore in the cover, eliminating the need for putting a sealing compound on O.D. of seal

prior to pressing it into the cover. The seal I.D, has a layer of rubber compound to prevent oil leakage between the seal and the crankshaft.

(*a*) Place cover on a flat surface with the front side to the top as shown ,in figure 73.

(*b*) Position seal in cover with open side of seal facing down and positioned squarely in bore of cover.

***Caution*. Make certain seal is not cocked in cover bore.**

(*c*) Drive or press seal into cover bore the specified distance of 2 5/32 inches-2 11/64 inches, as shown in figure 72. Using the service tool as shown will properly position the seal the correct distance in the cover bore, and will place the driving force on the outer edge of the seal.

***Caution*. Do not press on open face of seal or seal damage will result.**

(*d*) After seal is positioned in cover, insert fingers into inner part of seal and check for rotation. If seal was installed properly, the inner part will turn with a firm feel to the fingers.

49. Gear Train and Timing Gear Housing

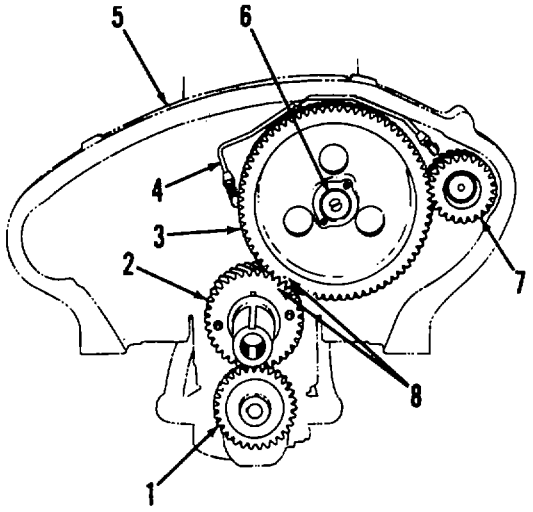
a. General.

(1) Located in the timing gear housing at the front end of the engine is a completely enclosed train of four helical gears as shown in figure 74. The crankshaft gear, which is pressed and keyed onto the crankshaft, drives the camshaft gear and the lubricating oil pump driving gear. The camshaft gear drives the accessory drive gear. The gear train is splash-lubricated by oil thrown by the gears, and also by oil returning to the oil pan from the accessory drive and the camshaft gear.

(2) The gear train will run quietly if the gears and bearings are in good condition. The specified backlash between mating gears is given in Table I. As the gears or the bearings wear, the backlash will increase and the gear train may become noisy. New parts should be installed when the bachlash between any two mating gears exceeds .020 inch.

(3) The gear train may be exposed by removing the timing gear housing cover as described in paragraph 48.

b. Camshaft Gear Removal and Installation. To prevent possible damage to the flywheel housing when installing the camshaft gear, it is recommended that the camshaft be removed from the engine before removing the gear. Refer to paragraph 55. If gear is to be



1. Engine oil pump drive gear
2. Crankshaft gear
3. Camshaft gear
4. Accessory drive lubricating oil line
5. Timing gear housing
6. Snap ring
7. Accessory drive gear
8. Timing marks

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Figure 74. Gear train.

removed and installed in the engine, proceed as follows:

(1) Remove the gear retaining snap ring.

(2) Using suitable puller tools, remove the gear.

(3) Before installing the gear, examine the thrust plate for signs of wear and replace if necessary. Make certain that woodruff key is in place on the camshaft.

(4) Heat gear in oil to a temperature of approximately 300°F. Coat camshaft, at gear location, with a mixture of white lead and oil and press gear onto camshaft.

***Caution*. Use asbestos gloves when handling the heated gear.**

(5) Install gear retaining snap ring.

c. Crankshaft Gear Removal and Installation. Refer to paragraph 60.

d. Accessory Drive Gear Removal and installation. Refer to paragraph 46.

e. Oil Pump Drive Gear Removal and Installation. Refer to paragraph 51.

f. Timing Gear Housing Removal and Installation.

(1) Drain the cooling system. Remove the timing gear housing cover (para 48).

***Note*. The water pump may or may not be removed, as desired, however, if the water pump is not removed, remove the nuts and lockwashers securing the water pump to the timing gear housing.**

(2) Remove the camshaft and camshaft gear.

(3) Remove the fuel injection pump and then remove the accessory drive.

(4) Remove the accessory drive lubricating oil line and fittings. Remove the pipe nipple with the restrictor if so equipped.

(5) Remove capscrews securing timing gear housing to cylinder block and remove housing.

***Note*. If oil pan was not removed be extremely careful not to damage oil pan gaskets.**

(6) Before reinstalling the housing, clean it in cleaning solvent and inspect it for cracks and other damage.

(7) Cement a new gasket to the housing, coat hollow dowels with white lead, and install the housing. Install retaining capscrews and lockwashers and torque to 68-73 ft. lbs.

(8) Complete the rest of the installation by a direct reversal of the removal procedure, using new gaskets and parts where required and making the proper adjustments.

50. Oil Pan

a. General. The engine oil pan includes two sections, the upper oil pan (3, fig. 75) and the lower oil pan (15). The lower oil pan assembly includes a heating element (14) which can be connected to winterization heaters.

b. Removal.

(1) Drain oil from engine. Refer to TM 5-6115-400-12.

(2) Remove fuel tank (TM 5-6115-400-12) or remove engine from generator set (para 28).

(3) If generator set is equipped with winterization heaters, disconnect connecting lines from heating element assembly.

(4) Remove lower oil pan by removing screws (18 and 19, fig. 75).

(5) Remove upper oil pan by removing screws securing the oil pan to the flywheel housing and to the engine block. Jar the oil pan to remove it from the engine.

Note. Take care not to damage the preformed packing in the front of flywheel housing.

c. Cleaning and Inspection.

(1) Wash all parts and clean gasket sealing surfaces.

(2) Inspect pans for cracks or other damage and make certain the preformed packing in the front of flywheel housing is in perfect condition.

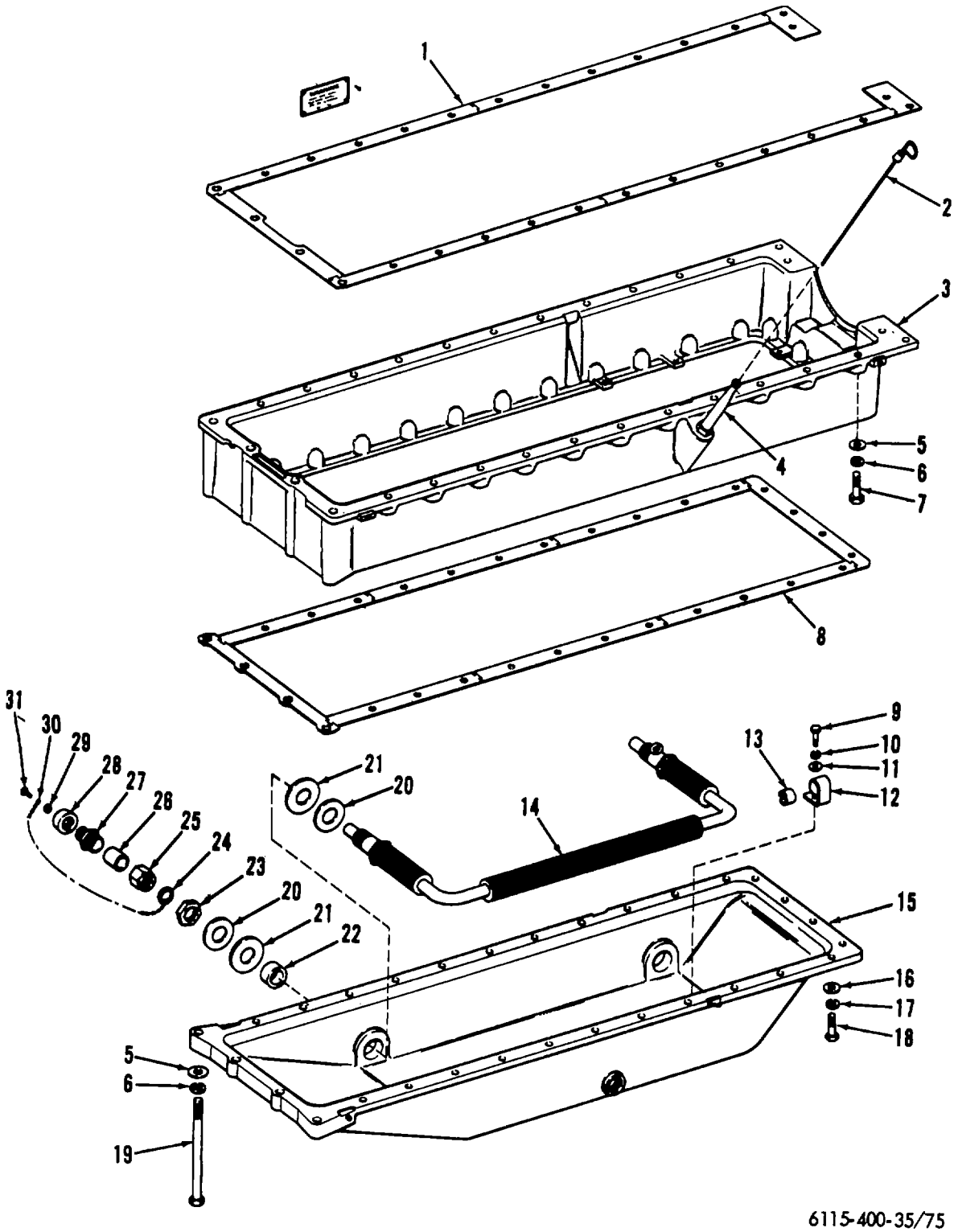


Figure 75. Oil pans and level gage.

1 Gasket assembly
2 Level gage
3 Pan
4 Adapter
5 Washer
6 Lockwasher
7 Screw
8 Gasket
9 Screw
10 Lockwasher
11 Washer
12 Clip
13 Liner
14 Element assembly
15 Pan
16 Washer
17 Lockwasher
18 Screw
19 Screw
20 Washer
21 Gasket
22 Sleeve
23 Nut
24 Retaining ring
26 Nut
26 Sleeve
27 Connector
28 Capscrew
29 Nut
30 Chain
31 Screw

Figure 75-Continued.

d. Installation.

(1) Cement new gaskets to front and side rails of pans.

(2) For ease of installing the upper pan, make guide studs and screw them into the side rails of the cylinder block. Also have available a greased sheet of shim stock larger than the rear area of the pan. The greased sheet of shim stock is to be placed against the preformed packing, in the lower half of the flywheel housing, to protect the seal from being damaged when the pan is installed.

(3) Mount the pan on the guide studs, Hold the pan in position by inserting a capscrew and lockwasher near each corner, but do not tighten to the extent that the pan cannot be shifted. Carefully ease out the greased sheet of shim stock protecting the preformed packing in the flywheel housing.

(4) Remove the guide studs. Install the capscrews and lockwashers which hold the rear flange of the oil pan to the flywheel housing and tighten the rear corner capscrews and the two upper capscrews in the flywheel housing alternately until secure.

(5) Install the balance of the capscrews in the oil pan and tighten all capscrews securely to a torque of 45-50 ft. lbs.

(6) Install lower oil pan.

51. Oil Pump

a. General. Pump gears are keyed and pressed onto their respective shafts and are not serviced separately. The pump driving gear is keyed and pressed onto the upper shaft and is retained by a roll pin.

b. Removal.

(1) Drain the engine oil. Refer to TM 5-6115-400-12.

(2) Remove the oil pan (para 50).

(3) Remove the pump suction tube (12, fig. 76) and screen as an assembly.

(4) Remove the oil pump discharge tube (25) and oil pressure relief valve (3) as an assembly.

(5) Remove the oil pump from the front main bearing.

c. Disassembly and Inspection.

(1) Wash the pump assembly.

(2) Remove the roll pin securing the pump driving gear to the upper shaft.

(3) Pull the driving gear (15, fig. 77) from the shaft with a gear puller.

Remove the key from the shaft and clean any burrs from the shaft with a stone or file.

(4) Remove the locking wires, capscrews, and lockwashers securing the cover assembly (3) to the pump housing. Tap the cover lightly to loosen it from the dowel pins and remove the cover and gasket.

(5) Inspect the pump gear teeth, the inside of the pump body, and the inner face of the cover for wear or scoring. The gear teeth, the inside of the pump body, and the inner face of the cover must be smooth, having no scratches, score marks, or rough spots.

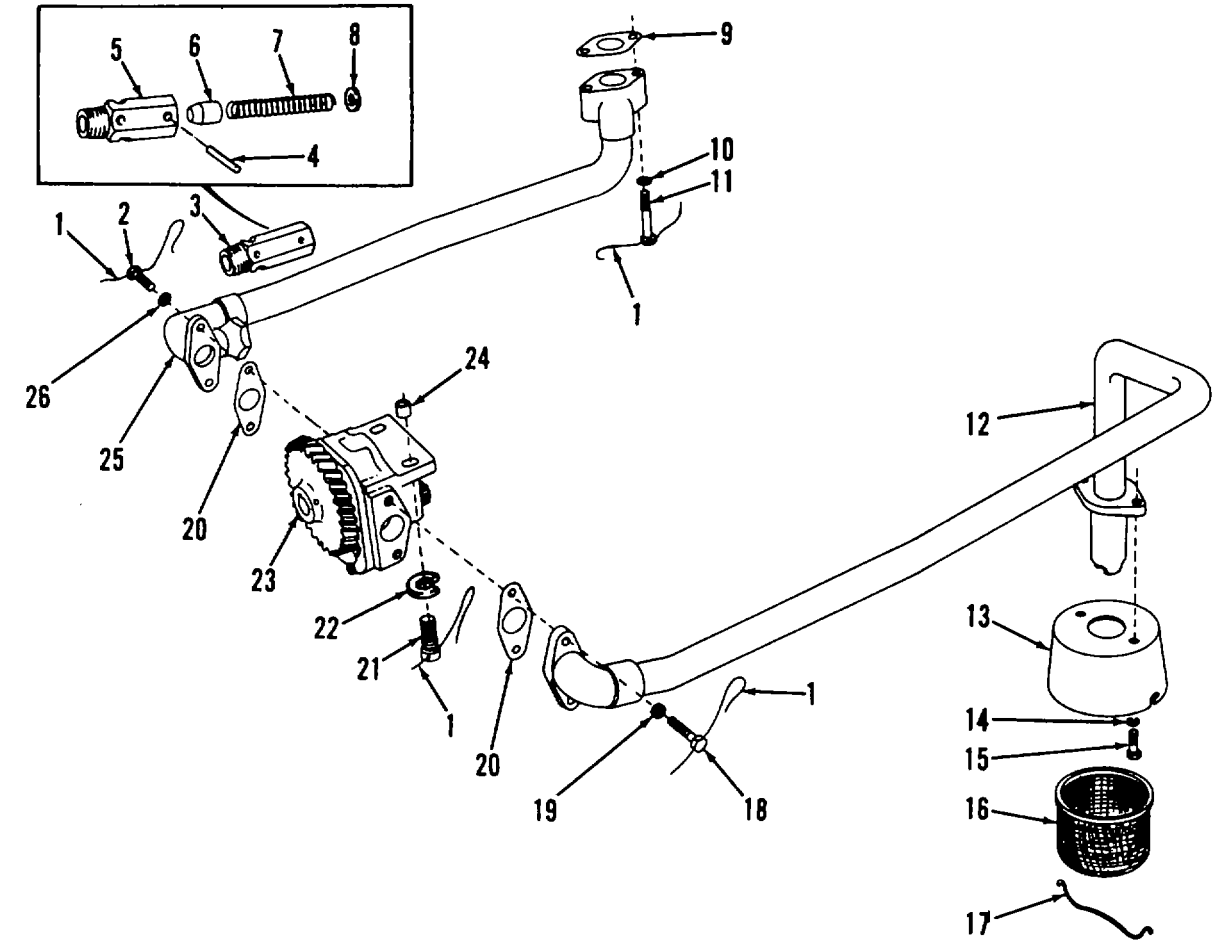


Figure 76. Oil pump and tubing.

(6) To properly check the radial clearance between the gear teeth and the pump body (fig. 78) it is necessary to use two feeler gauges with like thickness of feelers in each gauge. This method will centralize the gear in the body and the gear shaft in the bushing(s), permitting a true indication of the radial clearance and/or wear to be obtained. The radial clearance between pump gears and pump body should be .002 inch-.003 inch.

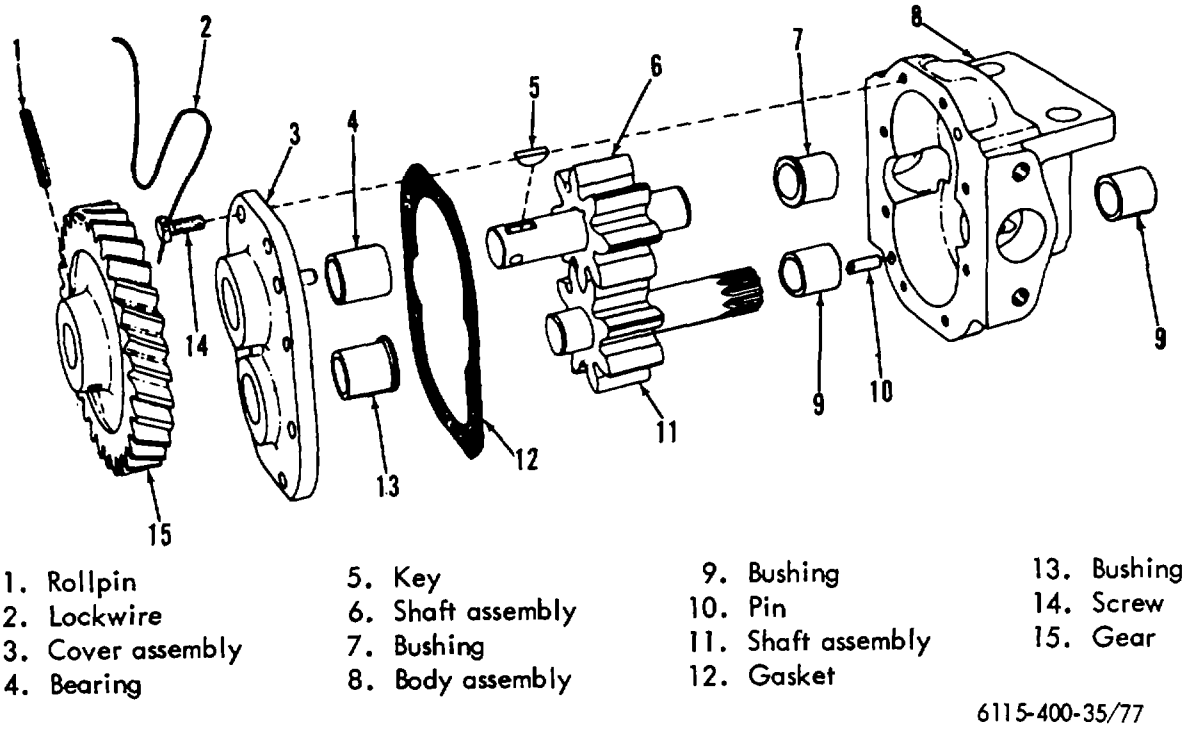


Figure 77. Oil pump-exploded view.

When the radial clearance exceeds .005 inch it will be necessary to replace worn parts.

(7) Remove upper shaft and gear assembly (6, fig. 77).

(8) Remove any burrs from splined end of the lower shaft and remove shaft and gear assembly from the pump body.

(9) The maximum allowable end clearance of the gears to the pump body is .007 inch. The clearance may be checked as follows:

(*a*) Measure the thickness of the gears with a micrometer. Make note of the figure.

(*b*) Place a new gasket on the cover face of the pump body. Place a depth micrometer in position on the gasket, and pressing firmly measure the depth of the counterbore at a point of gear contact.

(c) Subtract the gear thickness from the depth micrometer reading. The difference is the end clearance of the gears.

(10) Inspect the pump cover bushings and pump body bushings for wear or scoring and replace if necessary. The specified clearance between upper and lower shafts and the bushings is .0015 inch-.003 inch. After installing new bushings in the pump body and in the pump cover, the bushings should be reamed to .7495 inch-.7505 inch. The specified diameter of the upper and lower shafts at the bushing locations is .7475 inch -.7480 inch.

(11) Install the plain bushing in the upper shaft bore and the flanged bushing in the lower shaft bore in the pump cover. The two bushings must be flush with or below the machined inner surface of the pump cover.

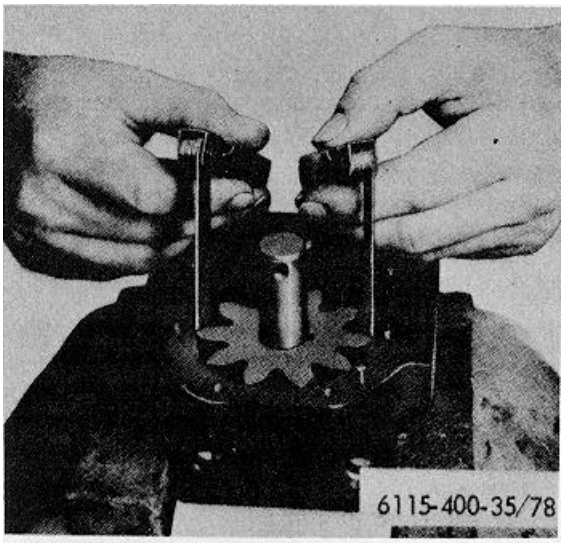


Figure 78. Checking radial clearance between gear teeth and pump body.

Three bushings are installed in the pump body bores; the flanged bushing in the upper shaft bore and the two plain bushings in the lower shaft bore. The upper shaft bushing must be installed so inner end (gear end) of the inner bushing is 1/32 inch in from the inner machined face of the body; the outer end of outer bushing should be located 1/32 inch in from outer face of the pump body.

(12) Remove, disassemble, and inspect the pressure relief valve (3, fig. 76).

The piston must slide smoothly in the bore of the valve body. When the piston or bore of the valve body shows excessive wear or roughness, a new valve assembly must be installed.

(13) Clean valve parts, reassemble, and reinstall the valve in the pump discharge tube.

(14) Remove and clean the oil screen and reinstall in the oil screen cover.

d. Assembly (fig. 77).

(1) Lubricate the bushings and shaft and gear assemblies with clean engine oil.

(2) Install lower shaft and gear assembly in the pump body, inserting splined end of the shaft through the pump body bushings.

(3) Install upper shaft and gear assembly in the pump body, with end of the shaft containing the keyway facing toward the cover end.

(4) Install the pump cover and gasket in position on the pump body and dowel pins; secure with capscrews and locking wires.

***Note*. It is recommended that a new cover gasket he used.**

(5) Install the key in the keyway of the upper shaft. The interference fit between the pump driving gear and the upper shaft is .001 inch-.0025 inch. Heat the pump driving gear in lubricating oil to a temperature of approximately 260°F. Coat shaft, at gear location, with a mixture of white lead and oil; press gear into position on the shaft.

***Note*. When installing the driving gear onto the shaft, press gear onto shaft only far enough to aline the holes for the roll pin.**

(6) The specified clearance between the driving gear and front machined face of the cover is .010 inch-.029 inch. Install the roll pin in position in the driving gear and shaft. Secure by peening the gear hub over each end of the pin.

e. Installation. All attaching capscrews, used on the oil pump and associated tubing, are drilled head capscrews and MUST be locked with locking wire after they are installed and tightened to the proper torque. This will prevent their working loose and causing possible serious damage to the engine.
See figure 76.

(1) Position the oil pump under the front main bearing cap and turn the pump driving gear until it meshes with the crankshaft gear. This will allow the hollow dowels, located in the pressure pump body, to position

in the holes in the bearing cap. Attach the pressure pump to the bearing cap with capscrews and lockwashers and secure with locking wire. The specified backlash between the oil pump driving gear and the crankshaft gear is .006 inch to .014 inch.

(2) Install the oil pump suction tube using a new gasket between the suction tube and the pump.

(3) Place the oil pump discharge tube and oil pressure relief valve, as an assembly, in position on the pump and the cylinder block, using a new gasket at each end of the discharge tube. Attach the discharge tube to the cylinder block and pump with capscrews and lockwashers. Secure the capscrews with locking wire.

52. Piston Cooling Oil Jets

a. General.

(1) Piston cooling oil jets are provided for each cylinder; the jets are positioned with dowel pins in the crankcase along the main oil gallery which supplies the oil to the jets. Continuous oil spray, from the jets, cools the pistons during engine operation.

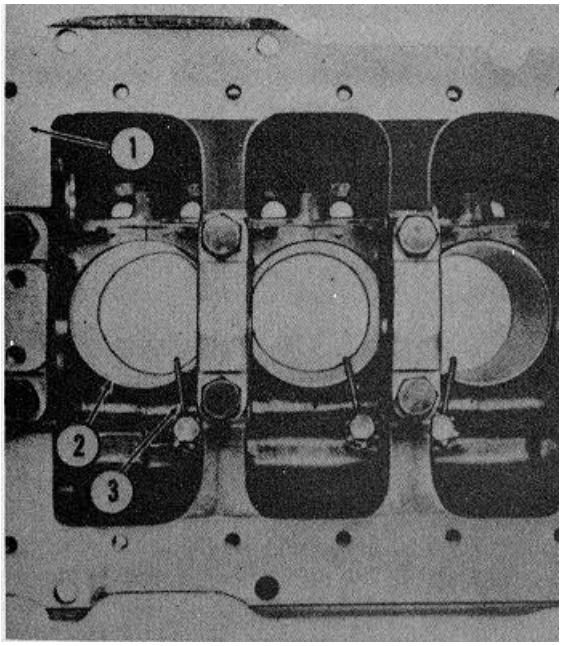
(2) Whenever the engine is being disassembled, the oil jets should be removed, inspected, and cleaned. The oil jets should be removed and ,installed while the crankshaft and pistons are in place in the cylinder block so clearance between the oil jets and these moving parts can be checked.

b. Removal, Cleaning and Inspection.

(1) Remove the oil pan (para 50).

(2) Remove the oil pump (para 51).

(3) Turn the crankshaft to obtain access to an oil jet. Remove the retaining capscrew and lockwasher securing the oil jet to the cylinder block and remove jet. Following this procedure remove all jets noting at which cylinder location each jet was originally installed.



1. Cylinder block
2. Cylinder sleeve
3. Oil jet

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Figure 79. Piston cooling oil jets.

(4) Thoroughly wash all parts in a cleaning solvent. If necessary, use a wire brush to clean any sludge from oil jet nozzles, being careful not to turn or bend nozzles. The size of the oil outlet hole in the nozzle is .109 inch-.1112 inch.

(5) If the silver solder between the jet union and the nozzle is broken, resolder or preferably, replace the oil jet.

***Note*. There are six oil jets, three right hand (for cylinder Nos. 3, 5, and 6) and three left hand (for cylinder Nos. 1, 2, 4). When ordering replacement parts, be certain to specify if the oil jet is right or left hand.**

(6) Check the gage height of the dowel pins; the specified dimension is 1/4 inch. The diameter of the dowel pin is .1218 inch-.1223 inch.

(7) Clean the locations within the cylinder block at which the oil jets are to be reinstalled.

(8) Install each oil jet at its original location in the cylinder block, turning the crankshaft as necessary to gain access to each oil jet location. Secure oil jets with retaining screws and lockwashers. Tighten each retaining screw to a maximum torque of 35 ft. lbs.

***Caution*. The clearances between the oil jet nozzle and the connecting rod, crankshaft check, and balancing pad of the piston are close. Therefore, after each jet assembly has been installed, the crankshaft with pistons installed) should be rotated to see if jet nozzle has proper clearance between it and moving parts. If there is no clearance between the nozzle and the moving parts and the oil jet has been installed correctly, the oil jet must be replaced, otherwise damage might occur to the oil jet and prohibit effective piston cooling. It is not recommended that a nozzle be bent to obtain clearance, of a tapping force applied to it as the nozzle may become crimped or solder ring cracked.**

53. Flywheel and Ring Gear

a. General. The flywheel assembly is bolted to a flange on the rear end of the crankshaft. One bolt hole in the flywheel is offset and the flywheel can be attached to the crankshaft flange in only one position. A starter ring gear is shrunk on the rim of the flywheel.

b. Flywheel Removal.

(1) Remove main generator (para 28).

(2) Remove nuts (fig. 80) and lockwashers attaching flywheel to the crankshaft flange. Remove flywheel.

***Note*. It may be necessary to remove the flywheel timing holes cover and pry flywheel loose with a suitable bar.**

c. Cleaning and Inspection.

(1) Clean the flywheel with an approved solvent.

(2) Check to see if flywheel surface is scored or heat-checked; flywheel should be machined smooth or replaced if either condition exists. It is very important that all burrs and nicks be removed from the flywheel surface that fits against the crankshaft flange. If this surface is not smooth and true, the flywheel may have a slight wobble.

(3) If flywheel surface is scored or heat-checked, it may be machined smooth; replace the flywheel if more than 1/16 inch of stock must be removed.

***Note*. In cases where it is necessary to machine the face of the flywheel, the same amount of material must be machined from the face of the flywheel rim (and also from the counterbore, if applicable) as is machined from the face of the flywheel. This is necessary in order to maintain the flywheel depth.**

d. Flywheel Ring Gear.

(1) Remove ring gear from flywheel by grinding a notch through the ring gear at root of one of the teeth; then expand the ring and drive it from its position. Do not attempt to remove ring gear without-first expanding it.

(2) To install a flywheel ring gear, proceed as follows:

(*a*) The ring gear is shrunk onto the flywheel by uniformly heating the gear to approximately 300°-325°F (dull red heat visible in the dark), then placing in position on the flywheel which is at room temperature.

***Note*. Do not heat the ring gear to a bright red as the heat-treatment of the gear will be destroyed.**

(*b*) After heating, start ring gear on the flywheel so that when the flywheel is installed the chamfered ends of the teeth on the ring gear will face the cylinder block.

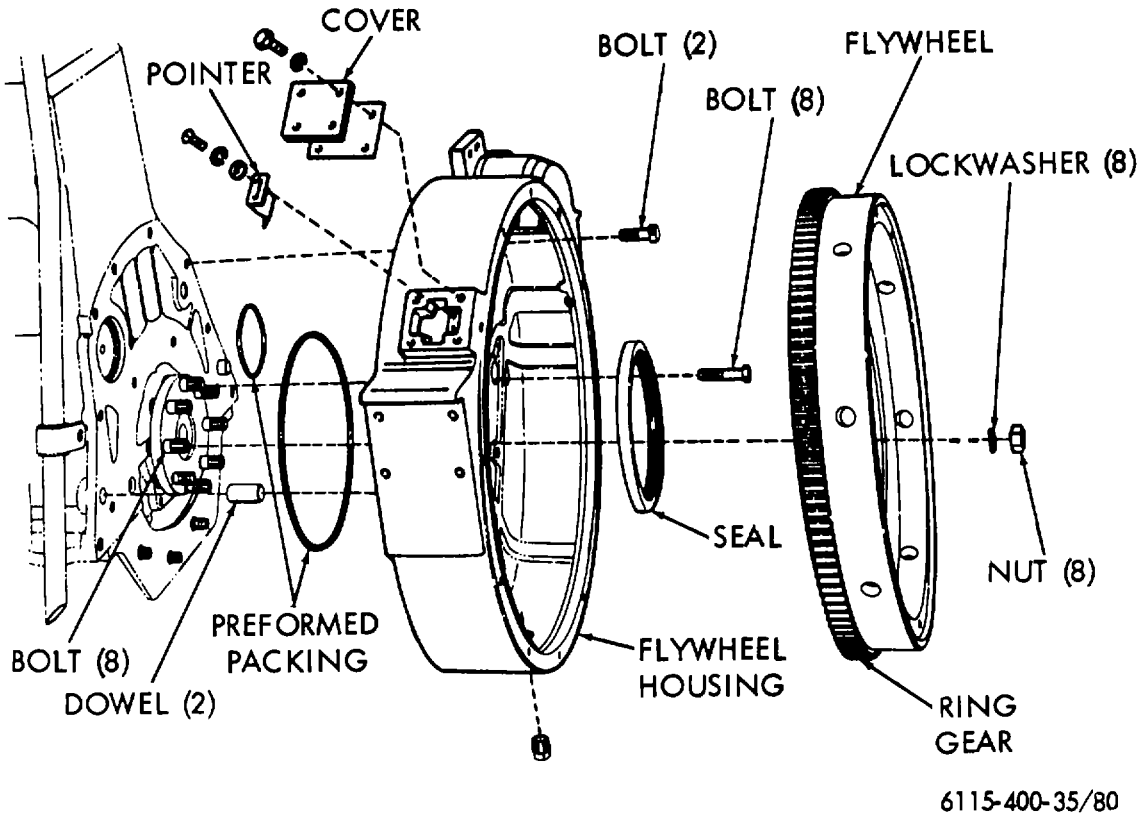


Figure 80. Flywheel and housing.

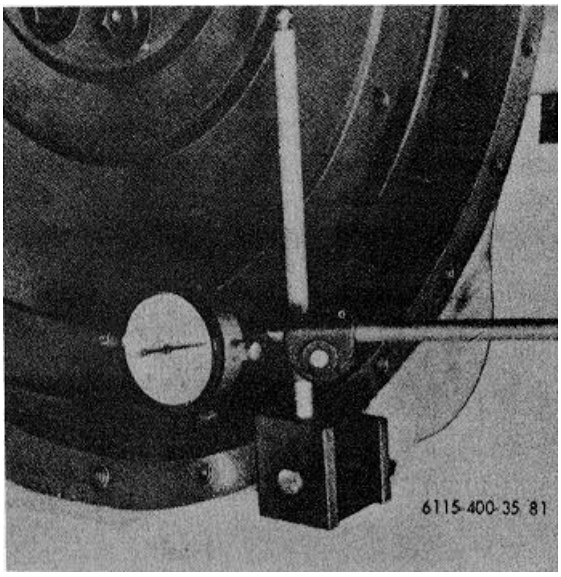


Figure 81. Measuring run-out of flywheel face.

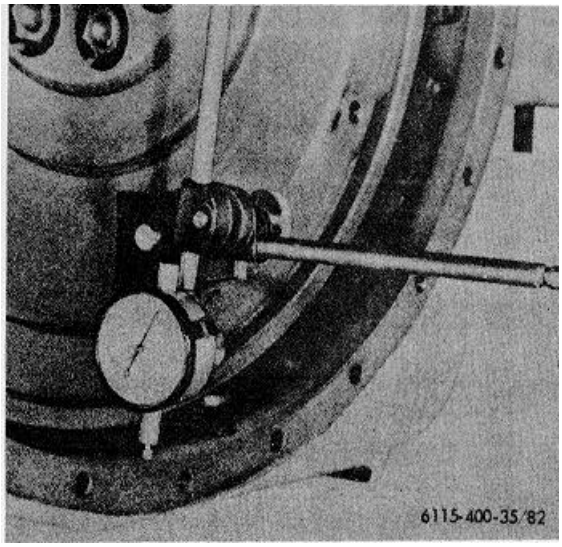


Figure 82. Measuring run-out of flywheel housing bore.

The ends of the teeth engage with the pinion of the starter.

(*c*) Drive ring gear down tight against shoulder on the flywheel. Allow ring gear to cool slowly; do not cool with water.

e. Flywheel Installation.

(1) Install flywheel by reversing the removal procedure.

(2) After flywheel is assembled to the crankshaft, tighten the flywheel nuts to the specified torque of 16 to 170 ft. lbs.

(3) Attach a dial indicator to the flywheel housing and check flywheel face for runout (fig. 81).

Note. Insert a suitable bar into the timing hole and pry flywheel to the rear to eliminate crankshaft end play so dial indicator reading is accurate.

(4) Flywheel face run-out should not exceed .0005 inch maximum total indicator reading per inch of flywheel diameter.

(5) Readjust indicator so that indicator finger rides the bore of the flywheel housing (fig. 82). The bore run-out should not exceed .008 inch total indicator reading.

54. Flywheel Housing

a. Removal.

(1) Remove flywheel from the engine (para 53).

(2) Remove capscrews securing the oil pan to the flywheel housing.

(3) Remove bolts (fig. 80) securing flywheel housing to the cylinder block. Tap housing with a soft-headed hammer to break it loose from the housing dowels; remove the housing.

b. Cleaning and Inspection.

(1) Remove housing-to-block preformed packing and housing-to-camshaft preformed packing.

(2) Remove and discard crankshaft rear oil seal.

(3) Thoroughly clean housing with cleaning solvent.

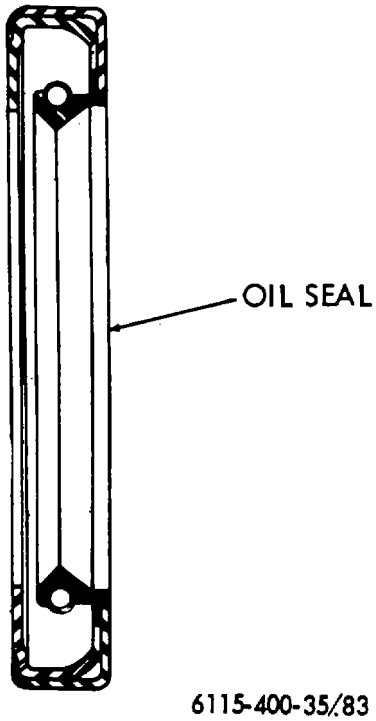


Figure 83. Crankshaft rear oil seal.

(4) Inspect housing for cracks and other damage; repair or replace housing if damaged.

c. Crankshaft Rear Oil Seal Installation.

(1) Clean oil seal bore in the flywheel housing.

(2) The O.D. of the seal has a layer of red-colored sealant which eliminates the use of a sealing compound on the O.D. of the seal prior to pressing it into the flywheel housing.

(3) Position seal squarely with bore in housing and, using a seal installer, carefully drive seal into flywheel housing until it is seated against the seal stop in the bore.

Note. The seal must be installed with sealing lip of seal directed toward the cylinder block.

(4) Make certain the crankshaft flange on which the seal rides is free from nicks or burrs. Polish with crocus cloth if necessary.

(5) Lubricate flange and sealing lip with clean engine oil. Do not use grease, soap, white lead, et.

d. Flywheel Housing Installation.

(1) Clean rear of cylinder block.

(2) Position new flywheel housing-to-block and housing-to-camshaft preformed packings in the grooves of the housing.

(3) Assemble flywheel housing to the rear of the block by reversing the removal procedure. Tighten the attaching housing bolts to a torque of 95-105 ft. lbs. Tighten the capscrews securing the rear of the oil pan to the flywheel housing.

(4) Install the flywheel (para 53).

Note.

Final installation of the flywheel into the seal is blind, therefore extreme care must be exercised to prevent crimping or cutting the sealing lip of seal when installing the flywheel.

55. Camshaft

a. General. The camshaft is supported in the cylinder block by four precision type bronze bearings. Lubrication is supplied to the camshaft bearings from four oil passages drilled horizontally through the cylinder block. An oil passage drilled into the gear end of the camshaft supplies oil to the camshaft gear from the front camshaft bearing.

b. Removal. The camshaft may be removed without removing the engine; however, if the camshaft bearings require replacement, engine removal is necessary.

(1) Remove the timing gear housing cover (refer to para 48).

(2) Remove the push rods and valve lifters (refer to para 44).

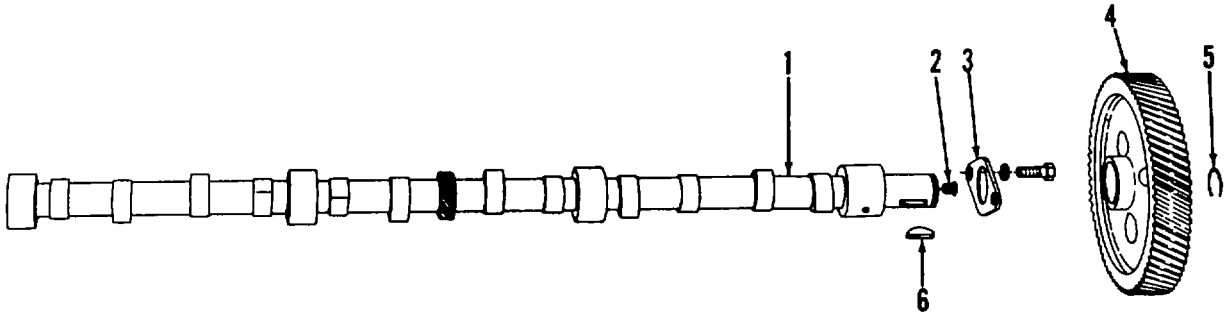
Note.

Before removing the camshaft gear, rotate the crankshaft until the timing marks on the crankshaft gear and the camshaft gear are alined. See figure 85.

(3) Remove capscrews and lockwashers attaching camshaft thrust plate to cylinder block. Using care to prevent the lobes from damaging the bearings, remove camshaft and camshaft gear as an assembly.

c. Disassembly. Remove the gear retaining snap ring from the end of the camshaft and press the shaft from the camshaft gear. Remove the woodruff key and thrust plate.

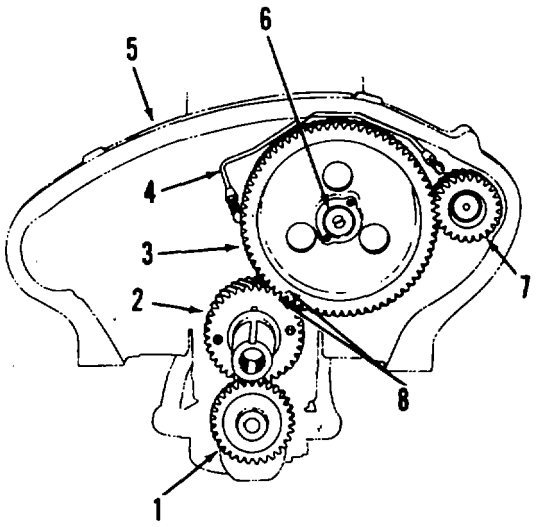
d. Inspection. Inspect camshaft gear for nicked, scored, or broken teeth; inspect camshaft lobes for wear.



1. Camshaft
2. Plug
3. Thrust plate
4. Camshaft gear
5. Snap ring
6. Woodruff key

6115-400-35/84

Figure 84. Camshaft and camshaft gear.



1. Engine oil pump drive gear
2. Crankshaft gear
3. Camshaft gear
4. Accessory drive lubricating oil line
5. Timing gear housing
6. Snap ring
7. Accessory drive gear
8. Timing marks

6115-400-35/85

Figure 85. Gear timing marks.

e. Reassembly.

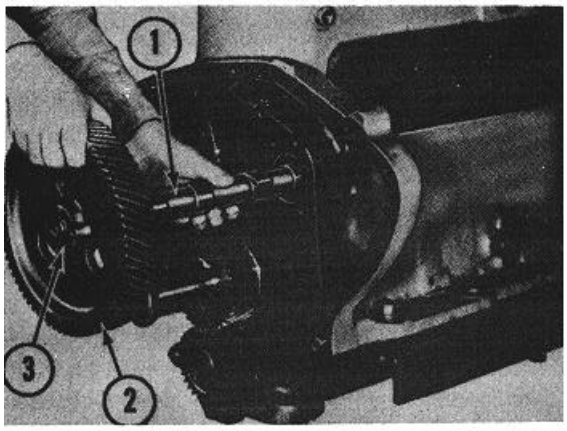
(1) To assemble camshaft gear onto camshaft, first place thrust plate in position on the camshaft. Install the woodruff key. Heat the gear in oil to a temperature of approximately 300°F. Coat camshaft, at gear location, with a mixture of white lead and oil and press camshaft gear onto shaft. Install gear retaining snap ring.

Caution.

Use asbestos gloves when handling the heated camshaft gear.

Note.

The camshaft gear must be installed so that the camshaft protrudes .250 inch beyond the camshaft gear. Use an improvised plug fixture similar to the one illustrated in figure 87 to control the location of the camshaft gear.



1. **Camshaft**
2. **Camshaft gear**
3. **Snap ring**

6115-400-35/86

Figure 86. Removing camshaft.

(2) Measure the clearance between the thrust plate and camshaft journal using a feeler gage. The specified clearance (end play) is .003 inch-.009 inch and should not exceed .015 inch. The specified thickness of a new thrust plate is .329 inch-.331 inch; install a new thrust plate, if necessary.

f. Camshaft Installation. The camshaft may be installed by a direct reversal of the removal procedure.

Note.

Make certain the timing marks on camshaft gear and crankshaft gear are alined when camshaft is installed.

56. Camshaft Bearings

a. Clearances.

(1) The specified clearance between camshaft and camshaft bearings is .003 inch-.007 inch. If clearance is .010 inch or more, new camshaft bearings must be installed. The specified diameter of camshaft bearing journals is 2.494 inch-2.495 inch. The specified inside diameter of camshaft bearings, when installed, is 2.498 inch-2.501 inch.

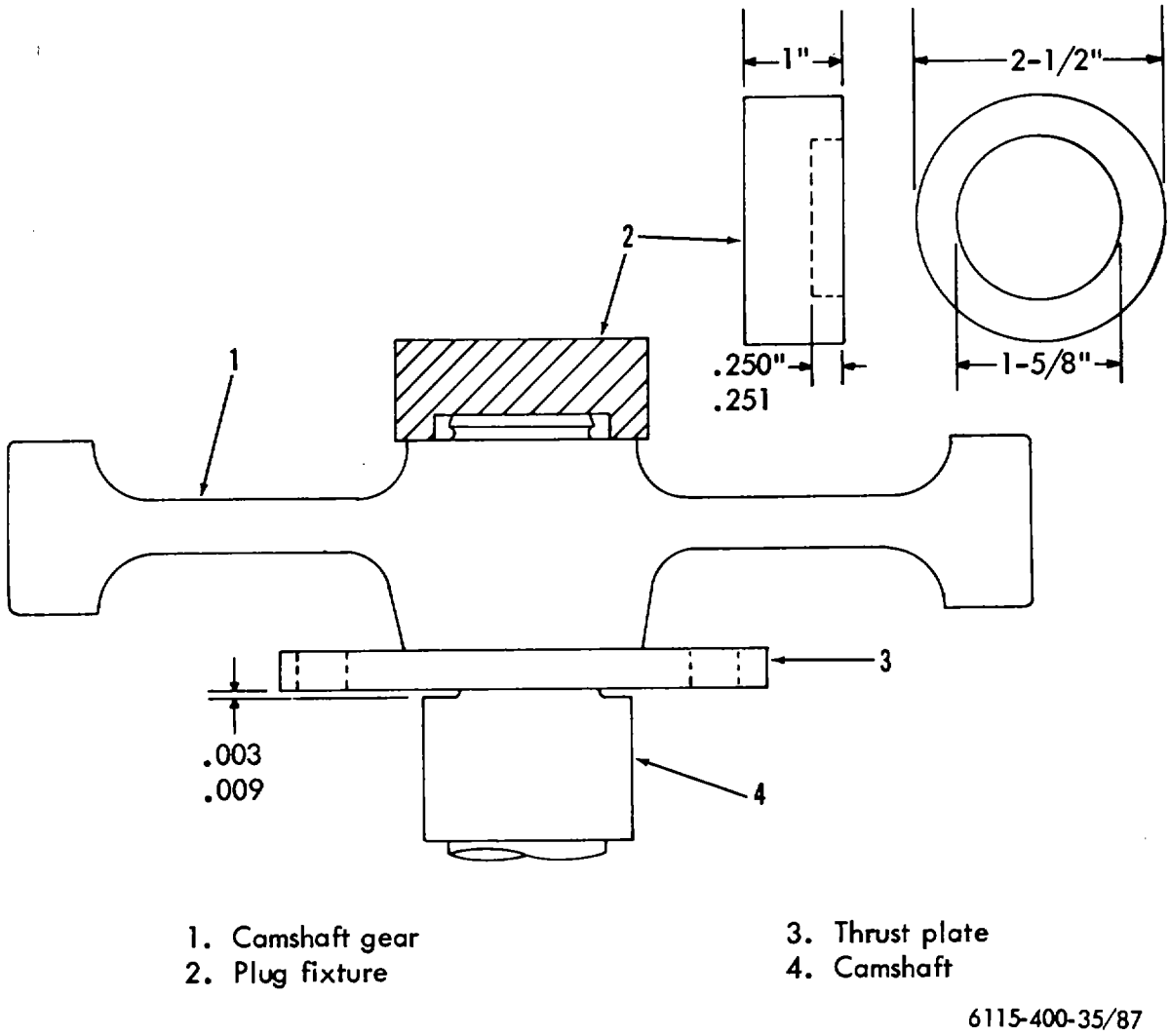


Figure 87. Installation of camshaft gear.

(2) With camshaft removed, measure diameter of camshaft journals and inside diameter of camshaft bearings with micrometers to determine clearance.

Note.

The only factory recommended method for determining camshaft journal-to-bearing clearance is with the proper micrometers; however, as an emergency field expedient only (and when proper micrometers are not available), camshaft journal-to-bearing clearance (with camshaft installed) may be determined by inserting feeler, gages of progressively greater thickness as shown in figure 88, until a gage is found that cannot be inserted (NO GO). The thickness of the next smaller gage that can be inserted (GO) may be considered to be the camshaft journal-to-bearing clearance.

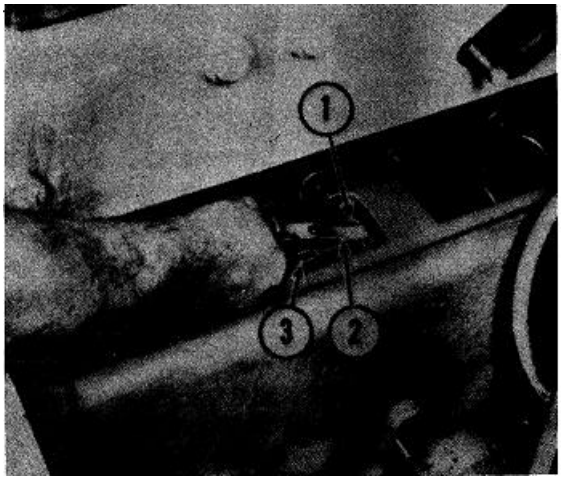
b. Bearing Removal.

(1) Remove camshaft (para 55).

(2) Remove the timing gear housing (para 49).

(3) Remove electric starter. Refer to TM 5-6115-400-12.

(4) Remove flywheel (para 53) and flywheel housing (para 54).



1. **Camshaft bearing**
2. **Feeler gouge**
3. **Camshaft**

6115-400-35/88

Figure 88. Checking camshaft bearing clearance.

(5) It is possible to remove and install camshaft bearings without removing the oil pan; however, to prevent dirt from falling into the oil pan and to facilitate camshaft bearing removal and installation, it is advisable to drain the oil and remove the oil pan (para 50).

(6) Refer to figures 89 and 90 and remove bearings.

c. Bearing Installation.

(1) Assemble the camshaft bearing removing and installing tool with a new front bearing as shown in figure 90.

Note.

Four camshaft bearings are used. Each bearing has an oil groove machined into the outer circumference, with a 1/8 inch and 3/8 inch oil hole located 180° apart. Determine and mark the location of the oil holes in the cylinder block so that when the new bearings are installed, the 3/8 inch hole in the bearing will index with. the oil hole in the cylinder block. The front and rear bearings are 1-7/8 inch long and the intermediate bearings are 1-3/8 inch long. The bearings are of the precision type and do not require reaming after installation.

(2) Tighten the hex nut until the "C" washer contacts the front machined surface of the cylinder block.

Note.

This will push out the old bearing and pull the new bearing into the correct position.

(3) Use a wire to make certain the oil hole in bearing is aligned with the oil hole in the block.

(4) Reassemble the tool as shown in Operation No. 2 and install the intermediate bearing.

(5) Reassemble the tool as shown in Operation No. 3 and install the other intermediate bearings.

(6) Reverse and reassemble the tool as shown in Operation No. 4 and remove and install the rear bearing.

(7) Install the camshaft and the rest of the components by a direct reversal of the removal procedure.

(8) Check the fuel injection pump timing (refer to TM 5-6115-400-12).

57. Pistons and Connecting Rods

a. General.

(1) The pistons are cast aluminum alloy, precision machined, cam ground, balanced, and tin plated. Each piston is fitted with three compression rings and one oil control ring, located above the piston pin. Holes are drilled through the walls of the piston at the oil ring groove to allow excess oil to return to the oil pan. The piston pins are full floating and are held in place in the piston by two retainer rings.

(2) The connecting rods are made of drop-forged, heat-treated steel, rifle-drilled for pressure lubrication of the piston pin and are statically and electronically balanced.

(3) The connecting rod bearings are precision type, replaceable without machining. Each half of the bearing shell is prevented from radial movement by a tang. An oil hole in the center of each shell allows oil from

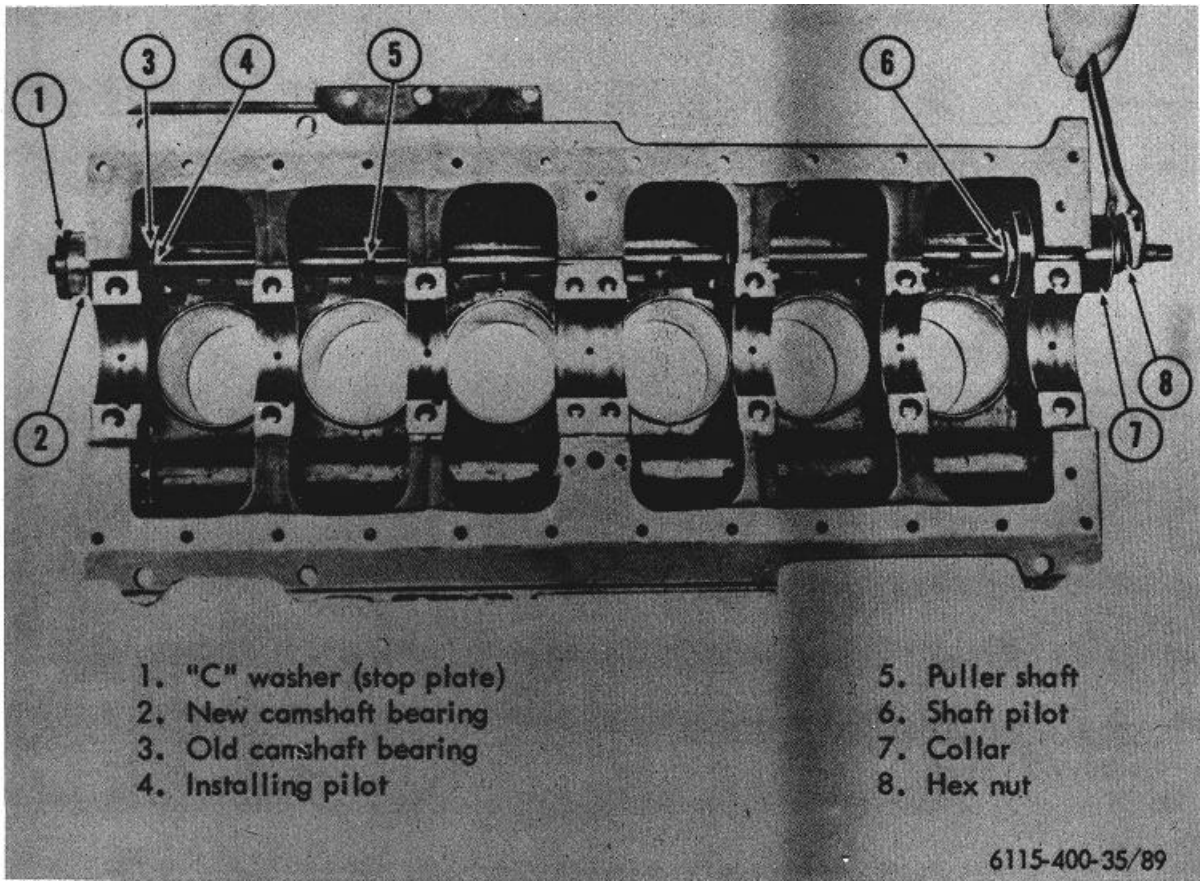


Figure 89. Removing and installing camshaft front bearing.

the crankshaft to flow to the upper end of the connecting rod. The bearing shells are held in place by bearing caps.

(4) The upper end of each connecting rod contains a bushing with an oil hole and a radial groove to allow the oil, pumped through the connecting rod, to lubricate the piston pin.

b. Pistons and Piston Rings.

(1) Removal of piston and rod assembly. Replacement of connecting rod bearings may be accomplished without removing pistons and connecting rods from the engine. If rod bearing removal only is required, follow steps (b) and (d).

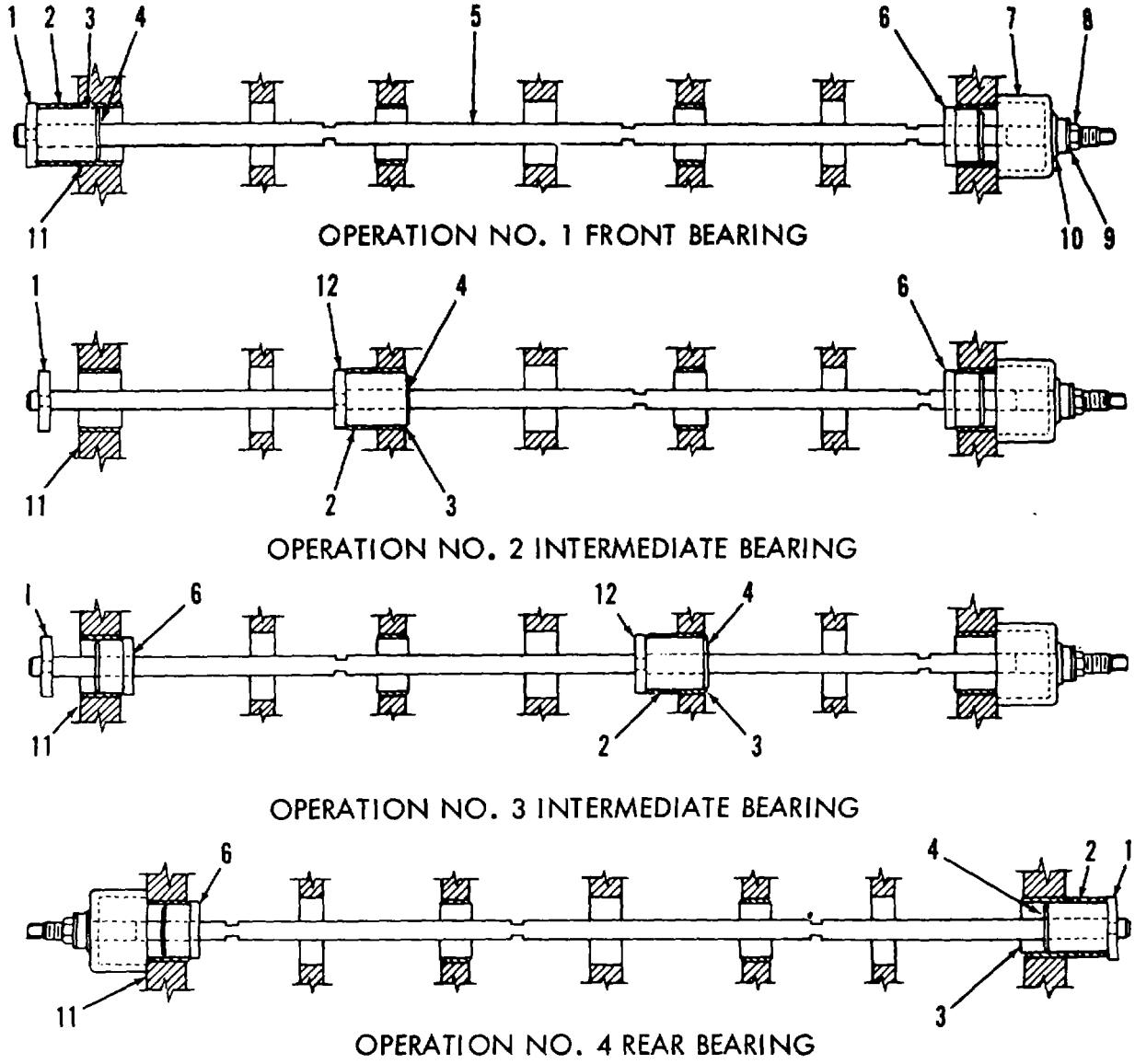
(a) Remove the cylinder heads (refer to para 40).

(b) Drain engine oil and remove oil pan, pump and associated tubing (refer to paras 50 and 51).

(c) Remove the piston ring travel ridge from the cylinder sleeve (refer to para 62).

(d) Remove nuts securing connecting rod bearing caps. Remove bearing caps and free lower end of connecting rods from crankshaft. Remove bearing shells from bearing caps and connecting rods.

(e) Carefully remove each piston and connecting rod assembly by pushing assembly out through top of cylinder sleeve.



1. "C" washer (stop plate)
2. New camshaft bearing
3. Old camshaft bearing
4. Installing pilot
5. Puller shaft
6. Shaft pilot
7. Collar
8. Hex nut
9. Flat washer
10. Thrust washer
11. Front machined surface of cylinder block
12. "C" washer

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Figure 90. Sequence for removing and installing bearing.

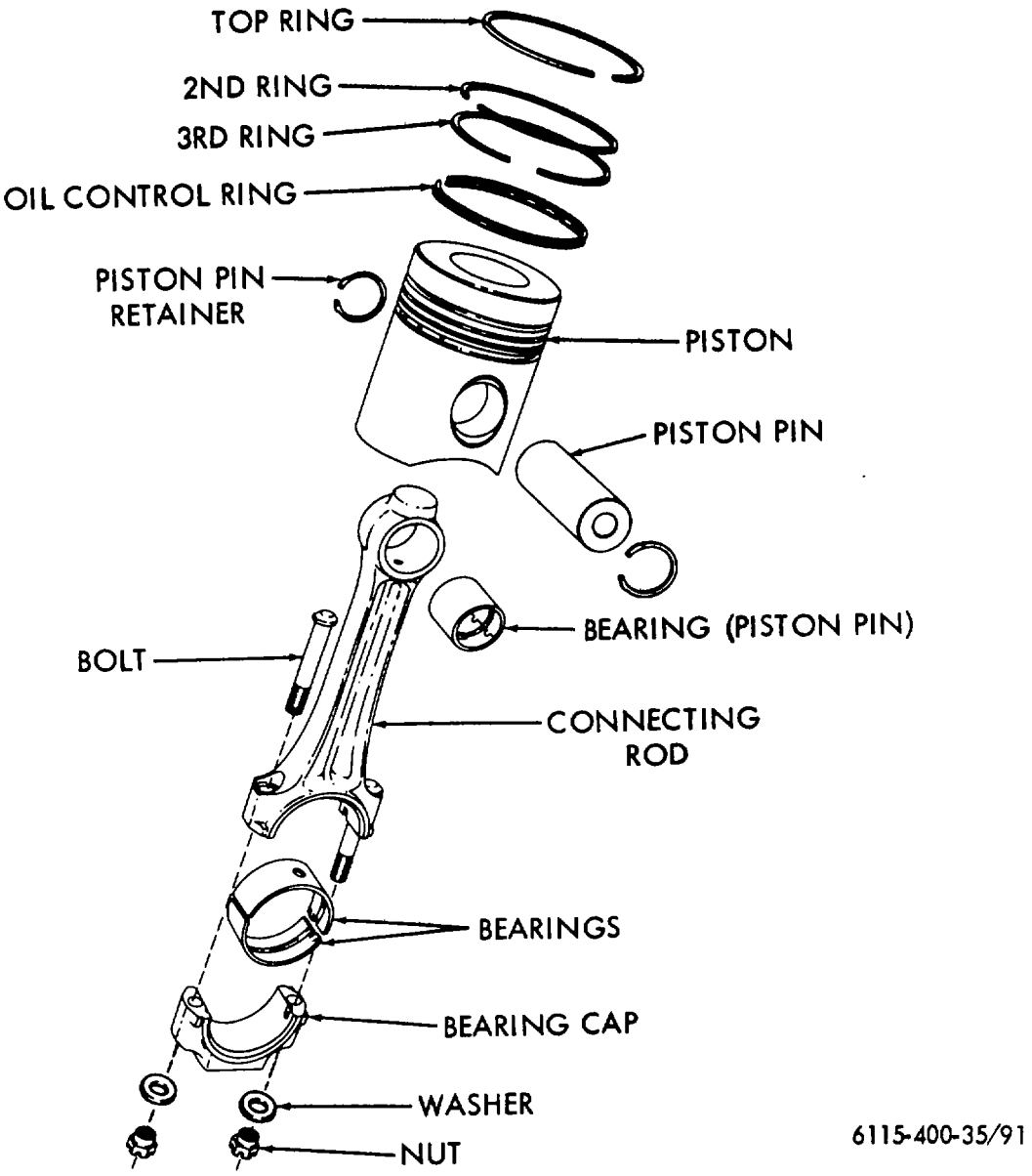


Figure 91. Piston and connecting rod.

(2) Removal of connecting rod and piston rings from piston.

(a) Remove the piston pin retainer rings at each end of the piston pin.

Caution.

Whenever a connecting rod with the piston is secured in a vise, be extremely careful that the bottom of the piston skirt is not nicked. Use lead protective jaws to protect the bottom of the skirt from nicks and also to prevent nicks in the rod which will lead to piston and/or connecting rod failure.

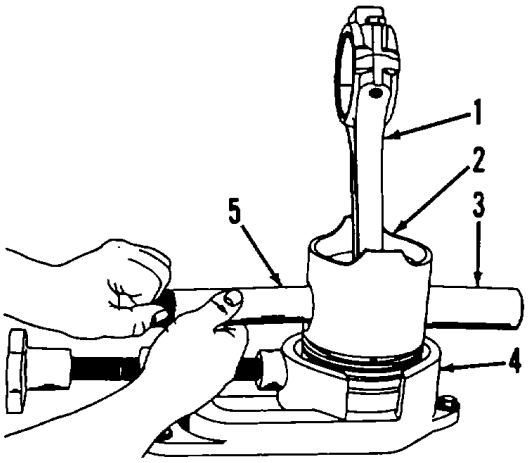
(b) Remove the piston rings using a ring remover and installer tool.

(c) Using a piston pin remover and installer tool drive the piston pin from the piston. The pin should drive out easily since the specified clearance between a new piston and pin is .0001 inch to .0005,inch loose at room temperature.

(3) Piston and piston pin inspection.

(a) The normal pattern of wear on pistons will show maximum wear in the compression ring grooves. Seldom is piston replacement required because of excessive wear in the oil ring grooves or because the piston skirt or piston pin bores are excessively worn.

(b) Piston walls and ring grooves may be cleaned by using a solvent and then blowing off with dry compressed air. After cleaning, the piston skirt, piston rings, and ring grooves should be thoroughly inspected. Be sure oil drain holes in the oil ring grooves are open and clean. If the cleaning solution does not remove all carbon from the bottom of the ring grooves, break the old rings in half and use the butt ends as scrapers. Be careful to remove only carbon or foreign material; do not scrape away any metal from the side or bottom of the ring grooves.



1. Connecting rod
2. Piston
3. Piston pin
4. Piston vise
5. Piston pin driver

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Figure 92. Removing pin from piston.

Caution.

Some types of solvent contain chemicals injurious to aluminum alloy. Do not use this type of cleaning agent.

(c) The piston skirt should be carefully examined for score marks or other indications of improper piston clearance. Inspect the inside of pistons for cracks; scored or cracked pistons should be replaced. Check pistons for wear.

Note.

The skirt diameter of a new piston is 5.243 inch to 5.244 inch (measured at right angles to piston pin and at the bottom of the skirt); the inside diameter of a new cylinder sleeve is 5.251 inch to 5.252 inch, giving a running clearance from .007 inch to .009 inch. Any deviation from these measurements will indicate the amount of wear on the piston and/or the cylinder sleeve.

(d) If the piston rings are removed from the pistons, even after a short period of operation, do not reinstall the same rings; in most cases, used rings will not again seat properly. The O.D. of new piston rings have tool marks and reasonably rough surfaces which allow for a fast wear-in and seating of the rings to the cylinder walls. After a period of operation, the rings wear or lap themselves to fit perfectly with the cylinder walls and the rings "seat".

(e) If the wear in the piston compression ring grooves does not

create side clearance with new piston rings greater than .008 inch; if piston pin bore does not exceed 2.003 inch; and if no cracks or scores are detected in piston pin bosses, on the skirt, or in the combustion chamber area, the pistons may be reused with a reasonable life expectancy of one-half to three-fourths that of new pistons.

(4) Fitting pistons to cylinder sleeves. Measurement of the pistons and the cylinder sleeves, and running clearances between the pistons and the cylinder sleeves, should be taken at room temperature (70°F).

Note.

Pistons must be fitted to their respective cylinder sleeves before the piston rings are installed to provide a running clearance of not less than .007 inch. Insufficient clearance will result in premature failure of pistons and/or cylinder sleeves.

(a) Using an inside micrometer, measure the I.D. of the cylinder sleeve (refer to para 62).

(b) Using an outside micrometer, measure the O.D. of the piston skirt at a right angle to the piston pin and at the bottom of the skirt. For a true reading, the O.D. of the piston skirt can only be measured in the area between the very bottom of the skirt and .560 inch from the bottom.

(c) The difference between the two readings is the running clearance.

(5) Fitting piston rings to pistons.

(a) The gap between ends of piston rings should be measured before rings are installed on pistons. Insufficient end gap will cause scored rings, scored cylinder sleeves, and other damage. Check the ring gap by inserting each ring into the cylinder sleeve in which it is to be used. Use a piston to push ring squarely down in the bore of the cylinder sleeve and far enough to be on the ring travel area. Check ring gap with a feeler gauge. The specified ring end gaps, using standard cylinder sleeves of 5.251 inch-5.252 inch bore are:

top compression ring .021 inch-.039 inch, 2nd and 3rd rings .023 inch-.041 inch and oil control ring (w/spring) .013 inch-.031 inch.

Caution.

The top compression ring and the oil control ring should never be filed to open the gap because the chrome plating might be loosened by the file and later distributed through the engine, causing damage or scoring of the piston and the cylinder sleeve.

(b) Measure ring-to-groove clearance (top of ring to top of groove in piston). The specified ring to groove clearances, using a new piston and new rings, are:

top compression ring .004 inch-.006 inch, 2nd and 3rd rings .003 inch-.005 inch, oil control ring (w/spring) .0015 inch-.0035 inch.

(6) Piston ring Installation. After piston rings have been properly fitted, lubricate piston and rings with Series 3 engine oil. Install rings on piston (with side marked "Top" or "T" toward top of piston), using a piston ring remover and installer tool.

Caution.

When installing rings on pistons, do not spread the rings more than necessary. Whenever a connecting rod with the piston is secured in a vise, be extremely careful that the bottom of the piston skirt is not nicked. Use lead protective jaws to protect the bottom of the skirt from nicks and also to prevent nicks in the rod which will lead to piston and/ or connecting rod failure.

(a) Install the oil control ring by removing the coil spring from the ring and lubricate spring with clean engine oil. Install spring in

piston groove; then install the ring with either side up over the spring with the gap of the ring 1800 from the joint of the spring.

(b) Install the three compression rings.

(7) Assembly of connecting rod to piston.

(a) Before assembling connecting rod to the piston, inspect the connecting rod (refer to para c following).

(b) Install one of the piston pin retainers in one end of the piston pin hole in the piston.

(c) Insert upper end of connecting rod into piston.

Caution.

Pistons have a recess cut into the top of the piston for each valve, the piston MUST be installed with the recesses under the intake valves for each cylinder. See figure 93. Piston numbers 1, 2, 4, and 5 must be installed with the recesses to the rear of the engine. Piston numbers 3 and 6 must be installed with the recesses to the front of the engine.

(d) Lubricate piston pin with clean oil and, with a piston pin remover and installer tool (fig. 92) tap piston pin into piston and connecting rod.

(e) Install the other piston pin retainer at the opposite end of the piston pin.

(8) Piston, connecting rod, and connecting rod bearing installation. Install each piston, with rings and connecting rods, as an assembly. The lower end of each connecting rod, as well as the connecting rod bearing caps, are numbered 1, 2, 3, etc. for identification and must be installed in the corresponding numbered cylinder with the numbered side of rod toward the camshaft side of engine.

Note.

Refer to the caution under step 3 in preceding paragraph (7).

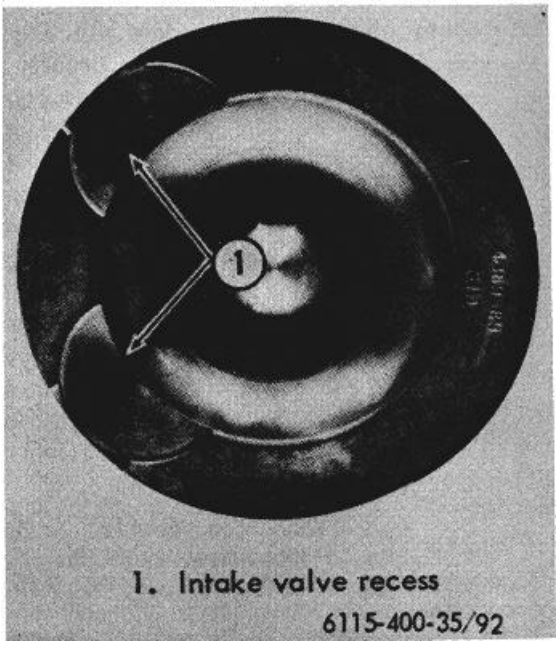


Figure 93. Intake valve recess in top of piston.

(a) Stagger piston ring gaps evenly around piston and apply clean engine oil to pistons and rings. With a piston inserter install the piston and connecting rod in the cylinder sleeve by tapping on top of piston with wooden hammer handle. If any difficulty is encountered, however slight, the piston inserter must be removed and ring set inspected for correct installation in piston grooves. Align lower end of connecting rod with crankshaft before inserting piston into cylinder.

(b) Lubricate and install a bearing shell in position in connecting rod, with tang of bearing shell in the corresponding slot in connecting rod, and position rod on crankshaft journal.

Caution.

Make certain the backs of the bearing shells are free from dirt and grit particles.

(c) Lubricate and install a bearing shell in position in the connecting rod bearing cap, with tang of bearing shell in corresponding slot in bearing cap. Install bearing cap and shell, making certain identification number stamped in the bearing cap is located on the same side as corresponding number stamped in the connecting rod.

(d) Install the connecting rod nuts and tighten to the specified torque.

(e) Check to see that there is sufficient clearance between connecting rods and crankshaft journals. The specified clearance is .004 inch-.009 inch.

c. Connecting Rods and Connecting Rod Bearings.

(1) Inspection.

(a) Clean connecting rod so it is free from oil and other matter. Check connecting rod for cracks by the magnetic particle method. Magnetize the connecting rod and cover it with a fine magnetic powder or solution. Cracks will form a small local magnet which causes the magnetic particles in the powder or solution to gather there, marking the cracks. If any cracks are detected, the connecting rod must be replaced.

(b) Whenever connecting rods are removed from an engine it is good practice to check alinement of the piston pin bushing end with the large bore end. Alinement can be checked with a direct reading alinement gage similar to the one shown in figure 94. Note that with this type alinement gage the rod can be checked with or without the piston assembled to it.

(c) Measure outside diameter of the piston pin to determine wear. The specified diameter of a new piston pin is 2.0015 inches-2.0017 inches. The specified inside diameter of the bushing in the connecting rod is 2.0027 inches-2.0033 inches. These dimensions of pin and bushing provide a clearance of .001 inch-.0018 inch; clearance up to .003 inch is permissible. If clearance is close to or beyond .003 inch, replace the connecting rod bushing.

(d) Blow dry compressed air through the oil passage in connecting rod.

Note.

Be sure that all oil passages are open.

(e) Inspect connecting rod bearing shells for scoring, chipping, corrosion, cracking, or signs of overheating; discard bearing shells if any of these conditions are apparent. The backs of bearing shells should be inspected for bright spots and discarded if any bright spots are found; this condition indicates that bearing shells have been moving in their supports.

(f) Inspect bearing shells for wear. The specified inside diameter of bearing shells is 3.3756 inches-3.771 inches, when installed and bearing cap retaining locking type nuts tightened to the specified torque of 175 to 185 ft. lbs. or when castellated nuts tightened to a torque of 160 to 170 ft. lbs. This provides a running clearance of .0021 inch-.0046 inch; new bearing shells must be installed when this clearance exceeds .009 inch.

(g) Measure rod bearing shells for wear; connecting rod bearings have a specified thickness of .12395 inch-.12445 inch; bearing shells that measure less than .1225 inch at the center should be discarded and new ones installed.

(h) In the event that the crankshaft is worn or damaged and must be ground, bearing shells .010 inch, .020 inch, .030 inch, and .040 inch undersize are available.

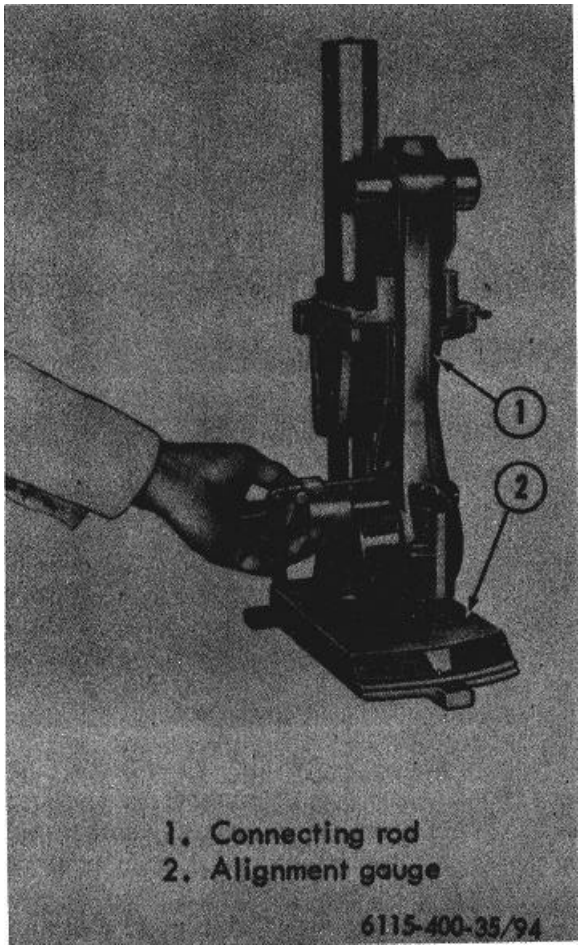


Figure 94. Checking connecting rod alinement.

Note.

Never file or shim the bearing caps to make the bearings fit; install new bearing shells if the fit is unsatisfactory. The crankshaft must turn freely after all the connecting rod nuts have been tightened to the specified torque.

(i) As a general recommendation, it is more practical to replace connecting rod bearings whenever they are removed from the engine after 2,000 to 8,000 hours of service than to reuse them. The cost of new replacement bearings will offset the gamble of reinstalling bearings with undetected fatigue, and also to prevent accelerated fatigue which may develop from a minute repositioning when reinstalling the used bearings.

(2) Connecting rod piston pin bearing replacement. If the connecting rod piston pin bearing (fig. 91) is worn, it must be pressed out and a new bearing pressed into the connecting rod. When new bearings are installed, be sure oil hole in bearing-lines up with rifle-drilled hole in connecting rod. The specified diameter of a new piston pin is 2.0015 inches-2.0017 inches, and inside diameter of the bearing is 2.0027 inches-2.0033 inches; this provides a clearance of .001 inch-.0018 inch between pin and bearing. It will be necessary to ream connecting rod to obtain this clearance. The bore in piston for the piston pin is 2.0018 inches-2.002 inches (cold, providing a pin-to-bore clearance of .0001 inch-.0005 inch).

58. Main Bearing Caps

a. General.

(1) Replacement caps for front, intermediate, and rear bearing locations are machine finished except for the bore which is semi-finished. The replacement center cap is machine finished except for the bore and the thrust faces.

(2) Main bearing caps are not interchangeable, and if replacement becomes necessary, new caps must be machined in place. To maintain correct alinement and size in the main bearing bore in the block, caps must be installed to the specified torque before machining. Replacement of main bearing caps in a machine shop job.

b. Main Bearing Cap Replacement.

(1) When it is necessary to do any machining to the main bearing bore in the block, it is important that the center line of the crankshaft is not altered from its original center line, especially at the timing gear end.

Raising the bore .003 inch-.004 inch at the flywheel end of the engine can be tolerated if the bore is made straight and the front main bore is not repositioned. When installing a replacement cap, make certain the casting or part number on the cap is in the same relative position as the number on the old cap when installed.

(2) After the bearing cap has been machined, the dowel for locating the bearing shell, must be pressed into the cap. Press dowel in far enough so that top of dowel is flush with the bottom of the bearing shell oil groove when shell is positioned in the cap.

(3) If a main bearing burns out with enough heat to cause distortion at one or more of the main bearing bores or saddles, generally the block and bearing caps will pull in at their joint causing an oblong bore. If the flat areas, where the cap contacts the block around the main bearing attaching capscrews, have distorted so they are no longer flat and straight, the area will have to be hand filed and fitted to the replacement bearing cap so that when the new cap is installed it will not be distorted from being pulled down on an out-of-square surface. A thin coat of Prussian Blue can be used on the new cap to detect any out-of-squareness at this point.

59. Main Bearings

a. General.

(1) The main bearings are of the precision type and are replaceable without machining. The front and rear main bearings are 1.995 inch-2.005 inch long; the four intermediate main bearings are 1.495 inch-1.505 inch long; and the center main bearings are 2.746 inch-2.756 inch long. The center main bearing includes four thrust flanges and four dowel pins which prevent the flanges from moving radially. All the main bearings have an inside diameter of 8.9981 inches-3.9998 inches when installed and with bearing caps properly torqued.

(2) The bearing shells are prevented from radial movement by a dowel pin in the bearing cap which locates the lower half of the bearing shell and in turn prevents the upper bearing shell from radial movement. The halves of the bearing shells are identical, therefore, they may be installed in either the upper or lower positions.

b. Removal.

(1) Remove the crankshaft (refer to para 60).

(2) Remove the main bearing upper shells from their seats in the cylinder block.

(3) Remove the main bearing lower shells from their seats in the main bearing caps.

Note.

Identify bearing shells as to their original location in the cylinder block and main bearing caps in the event inspection proves they can be reused.

c. Inspection.

(1) Any bearing shells that are scored, chipped, pitted, or worn beyond the specified limits given below must be replaced. Inspect backs of the shells for bright spots. Bright spots on backs of the shells indicate shells have shifted in their supports and are unfit for further use.

Note.

The specified clearance between main bearing shells and the crankshaft journals is .0021 inch - .0048 inch. New bearing shells must be installed when this clearance exceeds .009 inch.

(2) With crankshaft removed, measure inside diameter of the bearing at a point 900 from the parting line, with bearing cap installed and tightened to the specified torque. Bearing shells when in place are .002 inch larger in diameter at the parting line

than they are 90° from the parting line, and do not form a true circle. The two halves of the shells have a crush fit in their bore in the block and must be tight when the cap is secured in place. Do not measure inside diameter at the parting line. The specified inside diameter of new main bearings is 3.9981 inches-3.9998 inches and any reading above 3.9998 inches indicates the amount of bearing wear. Measure diameter of the crankshaft journal at the corresponding bearing location and subtract this dimension from inside diameter measurement of the bearing (as determined above); the difference between these two measurements is the crankshaft-to-bearing clearance.

(3) Another method for determining amount of wear on bearing shells is by measuring each shell with a micrometer at a point 90° from the parting line. New shells are .1876 inch-.1881 inch thick. Bearing shells less than .186 inch thick are worn beyond the allowable limits and must be replaced.

(4) The most accurate method of determining main bearing clearance is by using micrometers as described in the preceding paragraphs. However, if the proper size micrometers are not available or the crankshaft is installed in the engine, bearing clearance may be measured by using a plastic strip manufactured for this purpose. The plastic strip must be used in accordance with the manufacturer's instructions.

(5) Main bearings are available in standard thickness (.1876 inch-.1881 inch) and .010 inch, .020 inch, .030 inch, and .040 inch undersize.

d. Main Bearing Installation.

(1) Install a main bearing shell in each of the bearing seats in the cylinder block.

Caution:

Make certain the backs of the bearing shells are free from dirt and grit particles.

(2) Lubricate all crankshaft main bearing journals, install crankshaft and main bearing caps, and check crankshaft end play. Refer to paragraph 60.

e. Main Bearing Replacement with Engine Installed. It is unwise to replace main bearings without removing the engine and taking it into a clean shop where disassembly and inspection can be effected properly; however, when removal of the engine is impractical or in emergency cases, the following procedure may be used.

(1) Main bearing removal with engine installed.

(a) Remove fuel injection nozzle holders from engine to relieve compression and allow free turning of the crankshaft.

(b) Drain oil from oil pan and remove the oil pan, oil pump, and associated tubing. Refer to paragraph 50.

(c) Remove only one main bearing cap, install new bearing, reinstall bearing cap, and tighten cap retaining capscrews to the specified torque before removing next bearing cap.

(d) The lower bearing shell can be removed from the bearing cap after cap is removed. Remove upper bearing shell as follows. Insert a ¼ inch X 1 inch capscrew, with the head ground down to a thickness of approximately 3/32 inch, into the crankshaft main bearing oil hole, or a cotter pin with the head flattened, as shown in figure 95, then rotate crankshaft in the direction that will turn head of the bolt against an end of the bearing shell. Continue rotating crankshaft until bearing shell has been pushed out. The upper half of the rear main bearing shell may be rolled out of place by driving on the edge of bearing shell

with a small curved rod as shown in figure 95, while rotating the crankshaft.

(e) Inspect the crankshaft journals for scoring, chipping, cracking, or signs of overheating. If crankshaft has been overheated (usually indicated by discolored or blue bearing journal surfaces) or is scored or excessively worn, reconditioning or replacement will be required. Examine the bearing journals for cracks if overheating has occurred.

(f) Inspect each main bearing shell as described in paragraph c above.

(2) Main bearing installation with engine installed.

(a) Install all main bearings, except the center main, as follows: Lubricate a bearing shell with clean oil and roll it around the crankshaft journal and into position in the cylinder block.

Note.

The halves of the main bearing shells are identical, therefore they may be installed in either the upper or lower positions.

(b) Install a bearing shell in position on the dowel pin in the bearing cap. Lubricate the bearing shell and place the bearing cap in position on the cylinder block. Install the cap retaining capscrews and washers; tighten the capscrews evenly to the specified torque. Refer to paragraph 60.

Note.

The main bearing caps are numbered 1, 2, 3, etc. indicating their respective positions.

(c) Lubricate and install the upper half of center main bearing shell. Install the upper halves of the thrust flanges (flanges without dowel pin holes) with oil grooved side of flanges toward cheeks of crankshaft. Install a bearing shell in position on the dowel pin in the center main bearing cap. Install the lower halves of the thrust flanges on the dowel pins in the center main bearing cap, with the oil grooved side of flanges to the outside of bearing cap. Lubricate and place bearing cap in position on cylinder block with the number facing the camshaft side. Install cap retaining capscrews and washers.

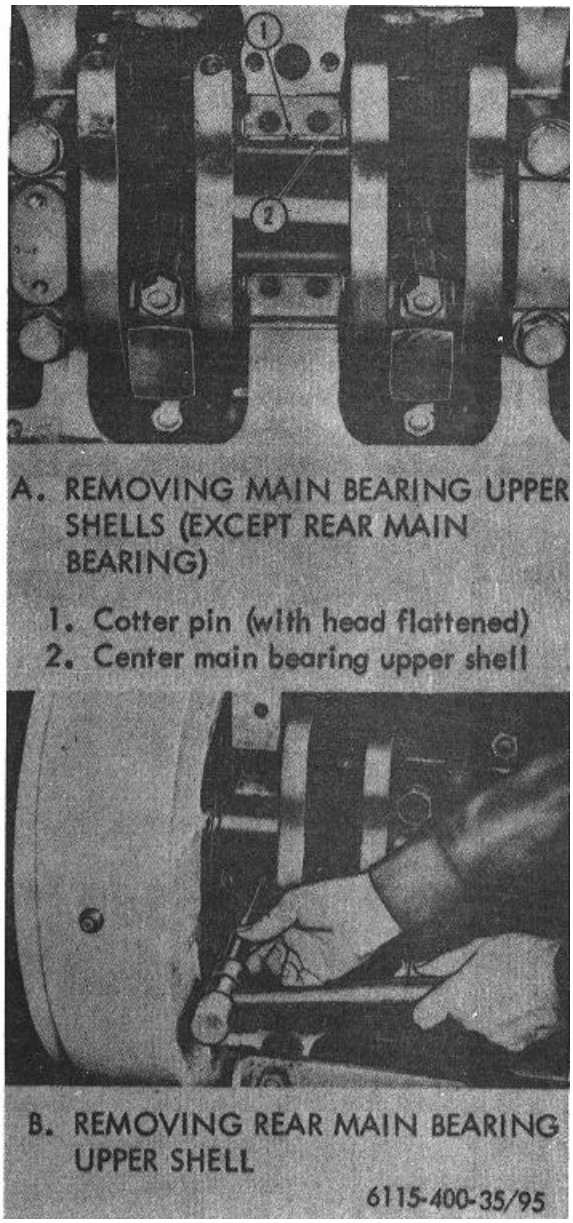


Figure 95. Removing main bearing upper shells.

(d) After all bearing shells have been installed, retighten main bearing capscrews using a torque indicating wrench. Tighten the capscrews evenly to the specified torque (refer to para 60).

Caution.

Do not overtighten main bearing capscrews. If these capscrews are overtorqued, bearing caps will be distorted, causing bearing to be drawn tight against the crankshaft journals and premature failure will result. The crankshaft should turn freely after all capscrews are tightened to the specified torque.

(e) Check crankshaft end play (refer to para 60).

60. Crankshaft and Crankshaft Gear

a. General.

(1) The seven bearing, counterbalanced crankshaft is a steel drop forging, carefully heat-tested to assure strength. The crankshaft is balanced dynamically. End thrust of the crankshaft is taken up by thrust flanges at the center main bearing. The specified end play of the crankshaft is .007 inch-.015 inch and must not exceed .023 inch. Thrust flanges are available in standard size and .005 inch, .010 inch, and .015 inch oversize.

(2) The crankshaft gear is keyed and pressed onto the front end of the crankshaft with a .0005 inch-.0025 inch interference fit.

b. Crankshaft Removal.

(1) Remove flywheel and flywheel housing. Refer to paragraphs 53 and 54.

(2) Remove the timing gear housing cover. Refer to paragraph 48.

(3) Remove oil pan, pump, and associated tubing. Refer to paragraph 51.

(4) Remove connecting rod bearing caps and shells. Refer to paragraph 57.

(5) Remove main bearing caps and lower main bearing shells.

(6) Remove the crankshaft.

(7) Remove upper main bearing shells from the cylinder block.

Note.

Identify the bearing shells as to their location in the connecting rods and in the block and main bearing caps in the event inspection proves they can be used again.

c. Cleaning and Inspection.

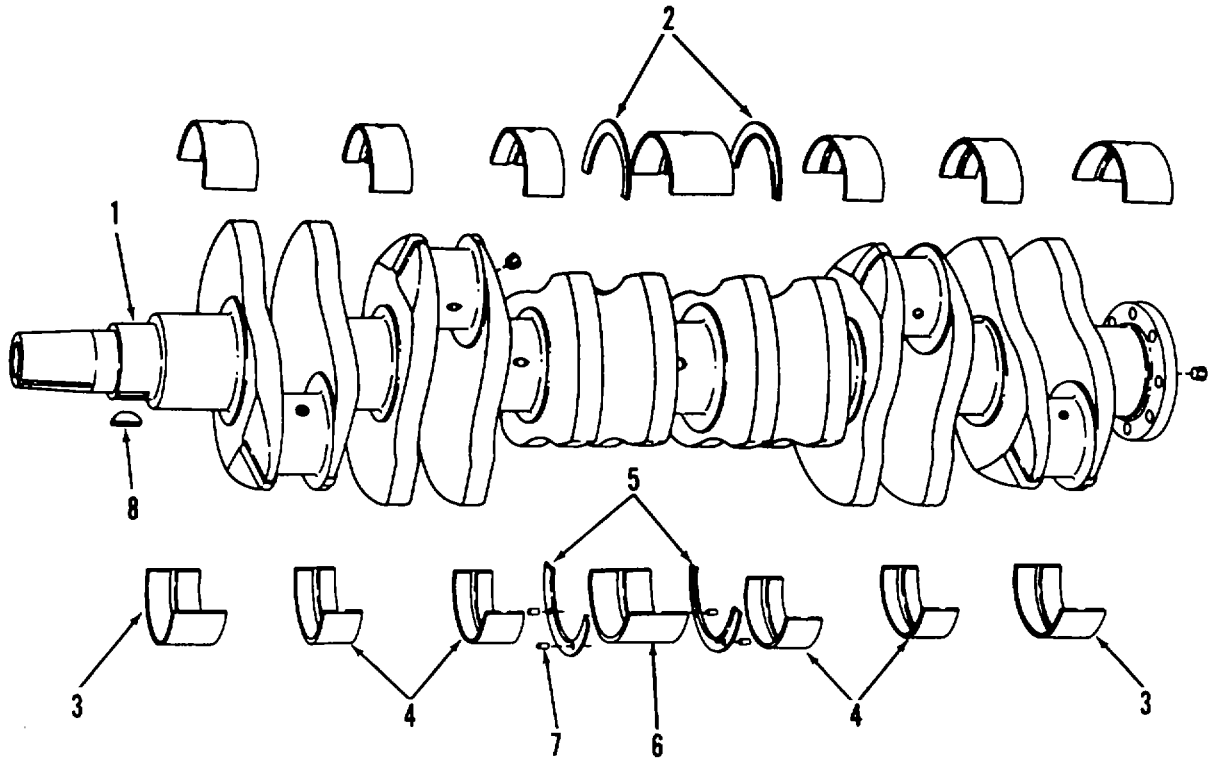
(1) Clean crankshaft thoroughly and inspect the journals for scoring, chipping, cracking, or signs of overheating. If crankshaft has been overheated (usually indicated by discolored or blue bearing journal surfaces), or is scored or excessively torn, reconditioning or replacement will be required. Examine bearing journals for cracks if over-heating has occurred.

(2) Measure the crankshaft main bearing and connecting rod journals at several places on their diameter to check for roundness. The specified diameter of main bearing journals is 3.995 inches-3.996 inches; connecting rod journals 3.3725 inches-3.3735 inches. The only recommended method of reconditioning the crankshaft is regrinding, as required to accommodate undersize bearings. Chrome plating or metallizing the bearing journals is not recommended.

Caution.

When regrinding a crankshaft in the field it is important that the original journal fillet radii be maintained and not decreased. Decreasing these fillet radii will weaken the crankshaft to the extent that breakage can be expected.

(3) All main and connecting rod bearing journal surfaces of the crankshaft are hardened to a minimum depth of approximately .060 inch. Main bearing shells .010 inch, .020 inch, .080 inch, and .040 inch undersize are available.



1. Crankshaft
2. Upper thrust flanges
3. Front and rear main bearings
4. Intermediate main bearings
5. Lower thrust bearing
6. Center main bearing
7. Dowel pin
8. Woodruff key

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Figure 96. Crankshaft and main bearings.

If crankshaft is ground, the diameter of main bearing journals should be reduced in steps of .010 inch, .020 inch, .030 inch, or .040 inch below 3.995 inches-3.996 inches to fit the undersize main bearing shells. If out-of-round or taper of journals exceeds .002 inch, crankshaft must be reground to a standard undersize or replaced.

(4) Remove the hex-socket pipe plugs from crankshaft and blow out all oil passages in crankshaft with compressed air. Reinstall plugs, tighten them securely until they are 1/16 inch below crankshaft surface. Peen area around plugs to prevent them from loosening.

d. Crankshaft Installation.

(1) Install the upper halves of main bearing shells in position in bearing seats of the cylinder block.

Caution.

Make certain the backs of bearing shells are free from dirt and grit particles.

(2) Lubricate all crankshaft main bearing journals and lower crankshaft into position in the cylinder block with flywheel flange end of crankshaft toward the rear.

Caution.

Make certain that timing mark on crankshaft gear is alined with timing marks on camshaft gear, when crankshaft is installed. See figure 85.

(3) Place the lower halves of the main bearing shells in position on the dowel pin in the main bearing caps.

Caution.

Make certain the backs of the bearing shells are free from dirt and grit particles.

(4) The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions. Before installing center main bearing cap, insert upper thrust flanges (flanges without dowel pin holes) with oil grooves of thrust flanges located next to cheeks of the crankshaft. Position lower thrust flanges on dowel pins, with the oil grooves in the thrust flanges to the outside of the bearing cap.

(5) Install main bearing caps with numbers facing camshaft side of the engine and corresponding to number stamped on lower edge of cylinder block as shown in figure 97. Install the main bearing cap attaching capscrews and hardened washers.

(6) Using a torque indicating wrench, tighten the 7/8 inch capscrews with hardened washers to a torque of 370 to 380 ft. lbs. Tighten the center main bearing 5/8 inch capscrews with hardened washers to a torque of 160 to 170 ft. lbs.

Caution.

Do not overtighten main bearing capscrews. If these capscrews are overtightened, bearing caps may be distorted, causing bearings to be drawn tight against the crankshaft and premature failure will result. The crankshaft should turn freely after all capscrews are

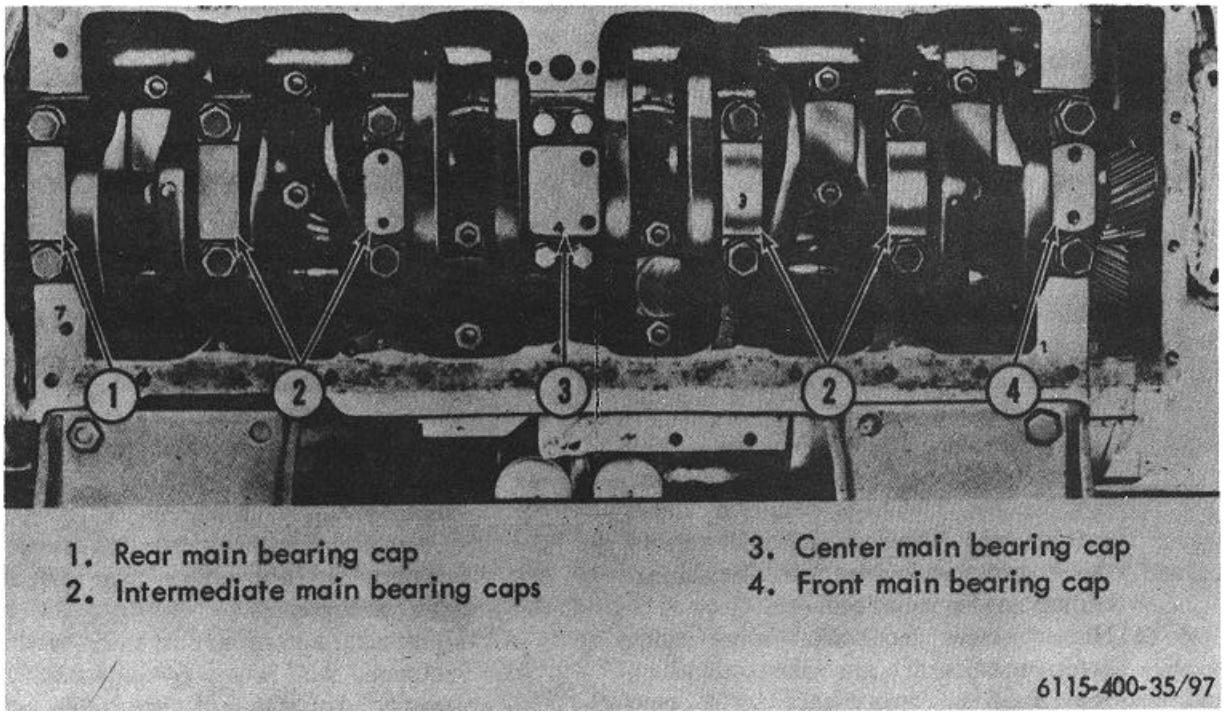


Figure 97. Main bearing caps locations.

properly torqued. Never file or shim a bearing cap to make the bearing shell fit; install new bearing shells if fit on the crankshaft is unsatisfactory.

(7) Check end play on the crankshaft using a dial indicator. The specified end play is .007 inch-.015 inch and must not exceed .023 inch. The end play is controlled by thrust flanges at the center main bearing (fig. 98). If end play is not within the specified range, replace thrust flanges. Thrust flanges are available in standard thickness (.151 inch-.153 inch) and .005 inch, .010 inch, and .015 inch oversize.

(8) Install connecting rod bearing caps and shells and check side clearance between connecting rods and crankshaft journals.

(9) Install oil pan, pump, and associated tubing.

(10) Install the timing gear housing cover.

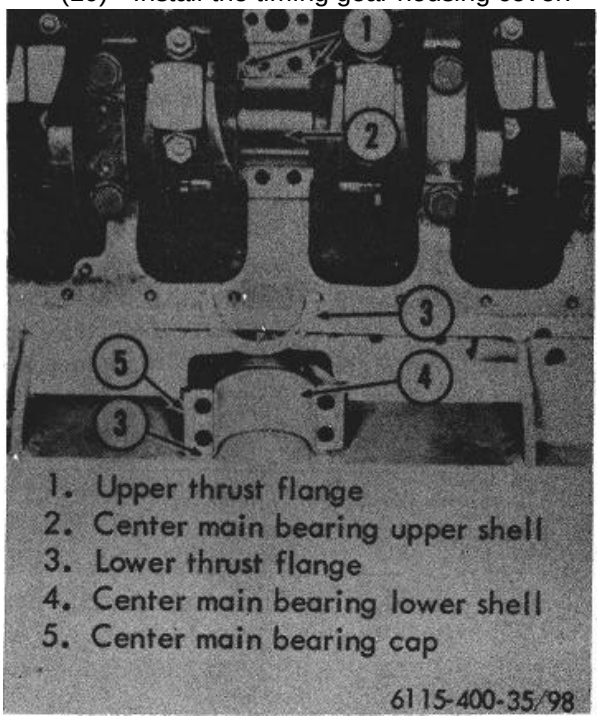


Figure 98. Center main bearing cap details.

(11) Install flywheel and flywheel housing.

e. Crankshaft Gear Removal and Installation.

(1) The crankshaft gear may be removed from the crankshaft with a gear puller. The gear may be removed either with the crankshaft installed in the engine or after the crankshaft has been removed.

(2) To install crankshaft gear on crankshaft, install woodruff key in crankshaft. Heat gear in oil to a temperature of approximately 300°F. Coat crankshaft, at gear location, with a mixture of white lead and oil; drive or press gear onto crankshaft.

Caution.

Use asbestos gloves when handling the heated gear. If crankshaft is installed In engine, make certain that timing mark on crankshaft is alined with timing mark on camshaft gear when crankshaft gear is installed. See figure 85.

61. Cylinder Block

a. General.

(1) The cylinder block is a one-piece casting made of alloy cast iron. The cylinder block is cored to receive removable wet-type cylinder sleeves. The cylinder sleeves are surrounded by water jackets which extend the full length of the cylinder walls. Oil passages direct the oil from the main oil gallery to the camshaft and main bearings and through the rifle-drilled connecting rods to the piston pins. A horizontal oil passage through the center of the cylinder block extends from the main oil gallery to a vertical passage (on the left side of the block) leading to a small cavity from where two openings extend to the rocker arm assemblies.

(2) The cylinder block, when ordered for service, is furnished with camshaft bearings, main bearing caps and capscrews; the necessary plugs and various small parts.

b. Cleaning and Inspection.

(1) Whenever the engine is being overhauled, the block should be thoroughly inspected for any conditions that would render it unfit for further use. Such inspection must be made after all the parts have been removed and it has been thoroughly cleaned with live steam, or a suitable solvent, and dried with compressed air.

(2) All the oil passages in the cylinder block must be cleaned before assembling the engine. Effective cleaning of these passages can be accomplished only with the use of high steam pressure with a solvent used in the water to dissolve the sludge and foreign material that has collected. Remove the oil pressure regulating valve and the various plugs of the oil galleries to clean the passages. After cleaning, flush the passages with clean water (under pressure) to remove all traces of the solvent.

(3) To clean the water jacket of the cylinder block, apply high pressure steam and water to the block and turn the block in various positions while this is being done so that the loose scale will be washed out.

Caution.

Note

the location of the plugs removed for cleaning of the passages in the cylinder block and be sure the regulating valve and all the plugs are reinstalled in their proper places after the block has been cleaned and dried. The plugs must be installed so that they do not interfere with attached parts.

62. Cylinder Sleeves

a. General. The removable wet-type cylinder sleeves are made of alloyed cast iron. Three packing rings, fitted into grooves in the lower outside circumference of the sleeve prevent water leakage into the oil pan. The sleeve is retained at the top by a flange which fits into a machined recess in the cylinder block. The cylinder head gaskets are compressed between this flange and the cylinder heads, holding the sleeve in place and serving as a coolant and pressure seal at the upper end of the sleeve.

b. Inspection and Removal.

The cylinder sleeves may be removed and replaced while the engine is installed in the unit by removing the cylinder head, oil pan, oil pump and associated tubing, and the piston and connecting rod assemblies.

Note.

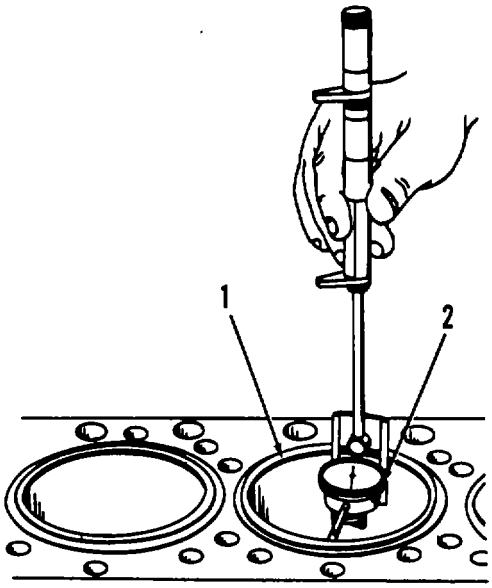
Removal of the cylinder sleeves while the engine is installed is only recommended in emergencies or when it is impractical to remove the engine from the unit.

(1) Check cylinder sleeves for roundness by means of a gage similar to the one shown in figure 99. Using an inside micrometer, measure cylinder sleeve for taper and wear. The specified inside diameter of a cylinder sleeve is 5.251 inches-5.252 inches.

(2) When measuring cylinder sleeves with an inside micrometer, first measure in a position parallel to crankshaft then at right angles to crankshaft. These measurements should be taken at several locations within the area of piston ring travel. The normal pattern of wear in cylinder sleeves will show maximum wear at the top three-fourths of ring travel.

(3) If maximum sleeve wear at top of ring does not exceed .003 inch out-of-round, .009 inch total wear, and if no deterioration of the flange has occurred to decrease the specified protrusion (standout), the sleeves may be reinstalled with a life expectancy of approximately one-half to three-fourths of new sleeves. The sleeves must be free of cracks, scores, and other physical defects.

(4) If the cylinder sleeves are to be reused, it is important that the ridge above the ring travel is removed with a hone or a ridge removing tool similar to the one shown in figure 100 and that the glaze in ring travel area is broken.



1. Cylinder sleeve
2. Cylinder diameter checking gauge

6115-400-35/99

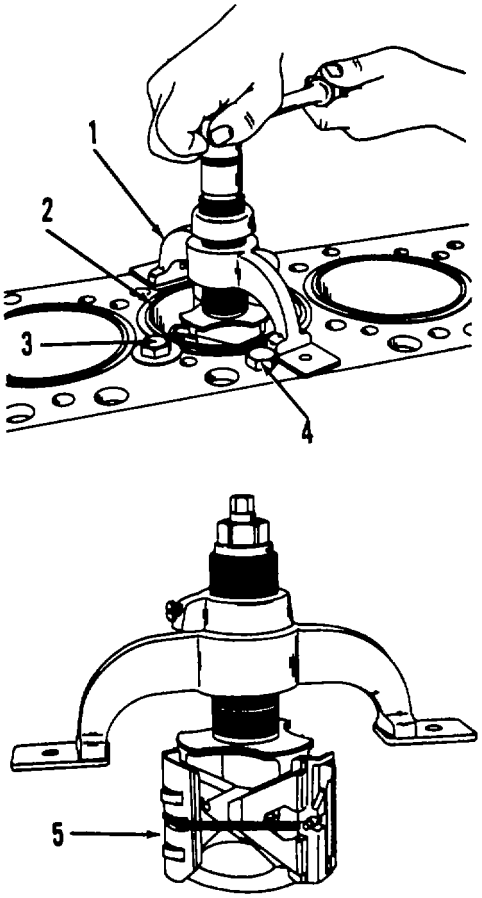
Figure 99. Checking cylinder sleeve for roundness.

(5) Remove cylinder sleeves using removal tool as shown in figure 101 and 102.

(6) Remove all dirt, carbon, and oil from cylinder sleeves and from the machined recess and bore in cylinder block. Replace sleeves if scored or cracked.

c. Installation.

(1) Thoroughly clean cylinder sleeve and the bore in cylinder block. Make certain bottom surface of flange on cylinder sleeve and the counterbore in cylinder block are clean and free from nicks or burrs. Before installing packing rings on sleeve, insert sleeve into bore of cylinder block to make sure sleeve can be pushed down into place and turned in the bore by hand pressure. If the sleeve cannot be inserted and turned in the above manner, more cleaning is necessary.



1. Ridge reamer tool
2. Cylinder sleeve
3. Capscrew and washer
4. Capscrew
5. Ridge reamer tool

6115-400-35/100

Figure 100. Removing ring travel ridge.

(2) Check the out-of-square relationship of the cylinder sleeve counterbore to the center line of the cylinder using a special sleeve tool with an attached dial indicator as shown in Figure 108. Rotate the sleeve with the contact point of the dial indicator, contacting

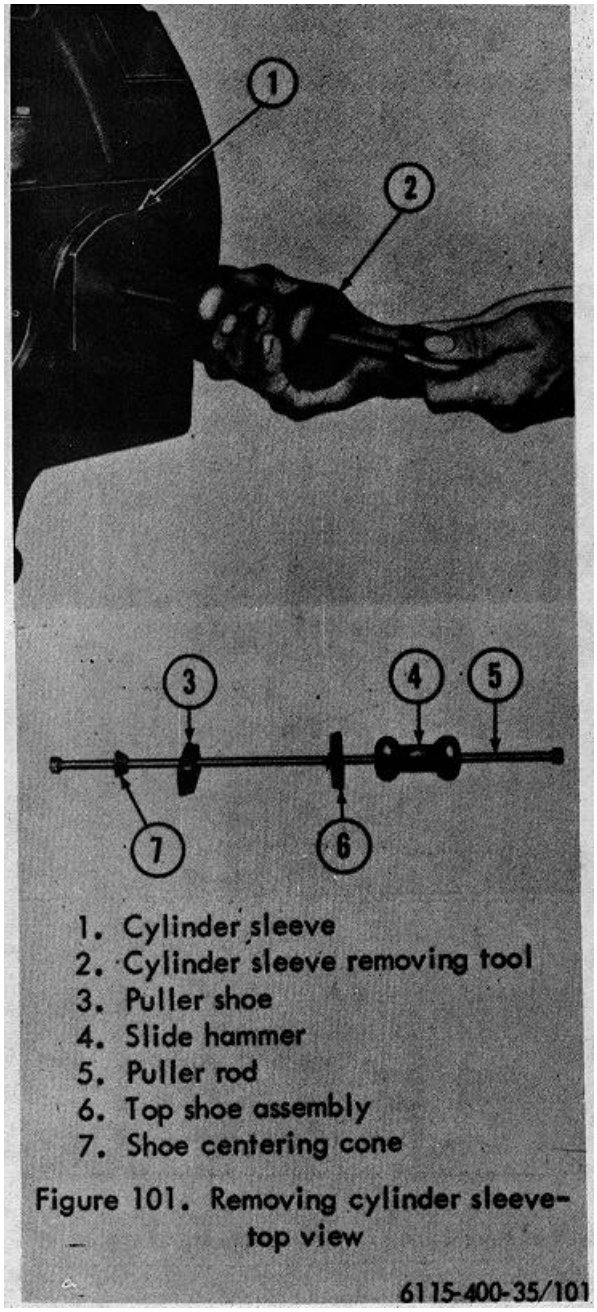
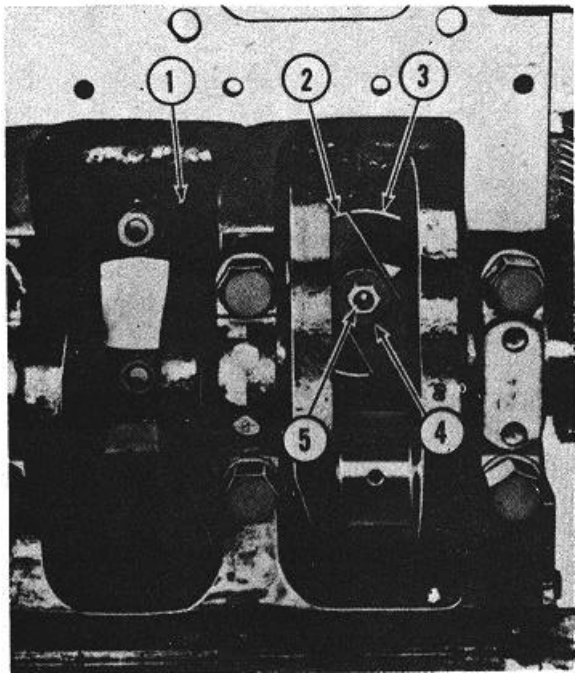


Figure 101. Removing cylinder sleeve-top view.

the bottom of the counterbore as shown in figure 103. Total indicator reading should not exceed .002 inch. If the total dial indicator reading exceeds the specified limit, reworking the counterbore is necessary



1. Crankshaft
2. Cylinder sleeve puller shoe
3. Cylinder sleeve
4. Shoe centering cone
5. Puller rod

6115-400-35/102

Figure 108. Removing cylinder sleeve-bottom view.

(refer to following para *d*). The special sleeve tool, shown in figure 103, is made from a new cylinder sleeve. The sleeve is machined as follows to assure proper relationship between the lower surface of the sleeve flange and the sleeve center line.

(a) Place the flange end of a new sleeve in the chuck of a lathe.

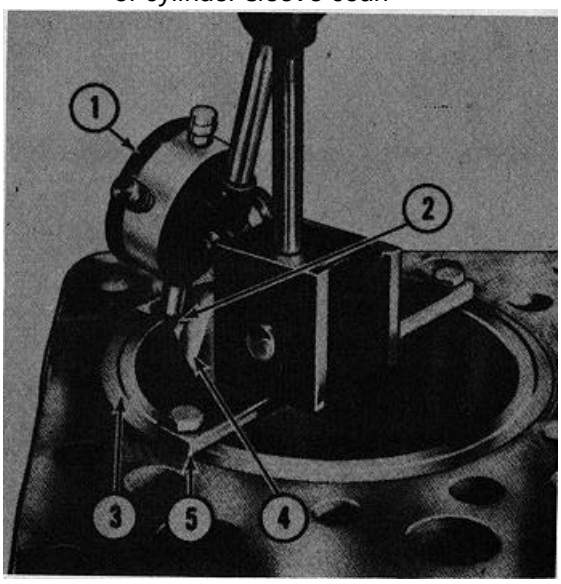
(b) True the center line of the sleeve as closely as possible to the lathe center by using dial indicators at each end of the sleeve.

(c) If necessary, machine the bottom surface of the sleeve flange to make it as true as possible to a 900 angle with the sleeve center line.

(d) Refer to figure 103 and cut a V-section out of the sleeve to allow the dial indicator to contact the sleeve counterbore in the cylinder block. Drill and tap two holes in the sleeve and attach a strap or bar as shown.

(3) The protrusion (standout) of the cylinder sleeve flange above the top flat surface of the cylinder block is very important. The specified standout is .002 inch-.005 inch. Measure cylinder sleeve standout as follows:

(a) Using a depth micrometer, measure depth of cylinder sleeve counterbore in the cylinder block (measure at two or more locations). The specified depth is .460 inch-.462 inch.



1. Dial indicator
2. Indicator contact point
3. Cylinder sleeve tool
4. V-section (cut from sleeve)
5. Mounting bar

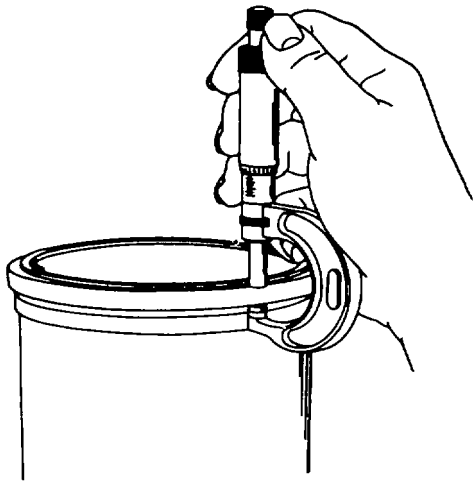
6115-400-35/103

Figure 103. Measuring out-of-8quare relationship of cylinder sleeve counterbore.

(b) Using an outside micrometer, as shown in figure 104, measure width of cylinder sleeve flange (measure at two or more locations). The specified width is .463 inch-.465 inch.

(c) Subtract counterbore depth from width of cylinder sleeve flange.

The result is the cylinder ,sleeve standout. If the standout is not within the specified .002 inch.005 inch, install a cylinder sleeve shim of the proper thickness in the sleeve counterbore to bring the standout within the specified limits. Cylinder sleeve shims are available in .005 inch, .008 inch, .010 inch, .015 inch and .020 inch thickness. If shimming will not correct the cylinder sleeve standout, reworking of the counterbore will be necessary (refer to cylinder sleeve reseating, para d).



6115-400-35/104

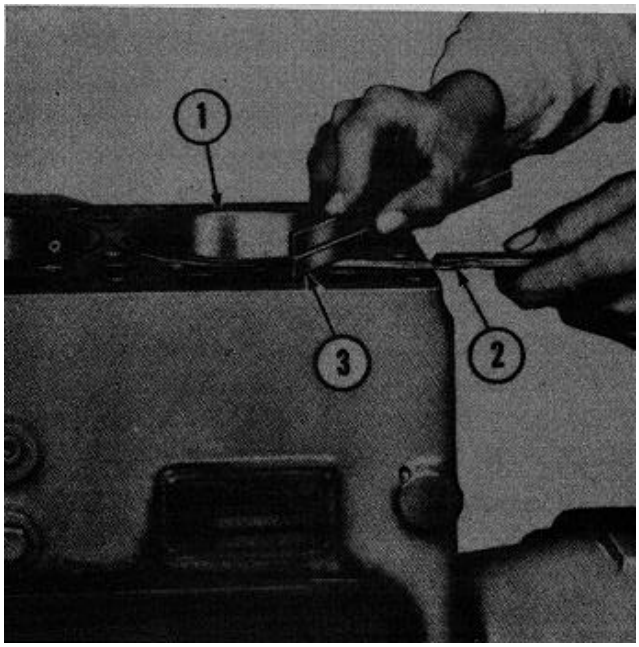
Figure 104. Measuring width of cylinder sleeve flange.

(d) To double check the cylinder sleeve standout, insert sleeve in cylinder block, firmly seating sleeve flange in the counterbore. Hold a straight edge across top of sleeve flange, and using a feeler gage as shown in figure 105, measure sleeve standout. Make certain straight edge is on cylinder sleeve flange and not on firewall, refer to figure 106.

Caution

Do not attempt to measure cylinder sleeve standout in this manner with a shim installed in counterbore, rough edges or burrs on shim may give a false reading.

(4) Two types of packing rings are used on each cylinder sleeve, silicone rubber, and Buna N rubber. They are identified by their color. Silicone packing rings are red; Buna N rings are black.



1. Cylinder sleeve
2. Feeler gouge
3. Straight edge

6115-400-35/105

Figure 105. Measuring cylinder sleeve flange height (standout) block.

Caution.

Silicone rubber packing rings are very tender, having less than half the tensile strength of the black Buna N packing rings. Use extreme care in handling and installing them in order not to cut or shear them. Silicone rings swell and expand after short contact with petroleum products and certain types of permanent anti-freeze. This causes them to drop out of their cylinder sleeve grooves and their installation in the cylinder block becomes impossible. Do not apply lubricant to a silicone ring prior to installation of the cylinder sleeve.

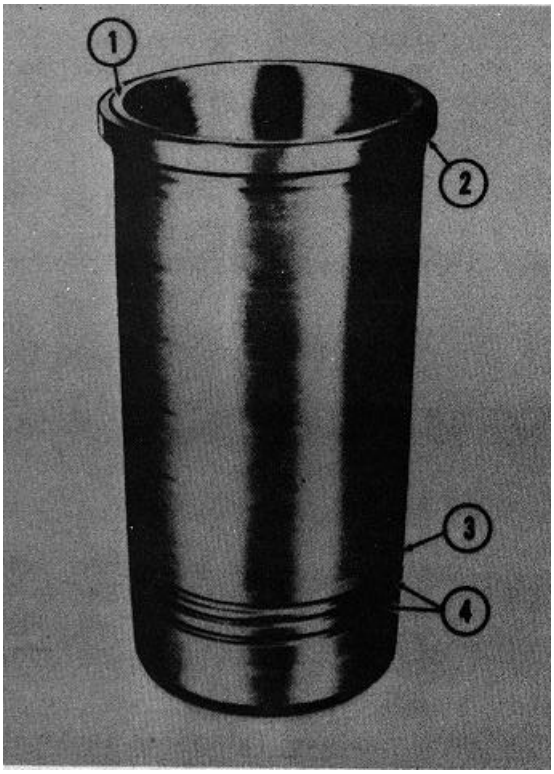
(5) Thoroughly clean the packing ring grooves, in the cylinder sleeve. Stand sleeve on a clean work bench with packing ring end up. Refer to figure 106 and install the black Buna N packing ring in the groove indicated. Install a red silicone packing ring in each of the other grooves. The silicone rings must be installed dry without lubrication of any kind.

(6) Brush a light coat of engine lubricating oil in lower sleeve bore in cylinder block and install cylinder sleeve. Be extremely careful so packing rings are not cut on sharp edges of bore in block when install ring.

Caution

New cylinder sleeve packing rings must be used at each installation of a new or used sleeve. Do not use any other lubricant except light engine oil; doing so prevents proper installation and operation.

(7) The cylinder sleeve is relieved in four places on the upper pilot diameter directly under the top flange. These relieved sections are to provide additional clearance between the sleeve and the cylinder head cap screw bosses in the block, and eliminate any possibility of distortion to the sleeve when cylinder head capscrews are tightened to their specified torque.



1. Fire wall
2. Flange
3. Top groove for Buna N (black) ring
4. Lower grooves for silicone (red) rings

6115-400-35/106

Figure 106. Cylinder sleeve.

Caution

The letters "PRS," representing PUSH ROD SIDE, are stamped on the top flange. This marking must be positioned on push rod side of engine when sleeve is installed in block. This will position the relieved sections opposite the cylinder head capscrew bosses in the block.

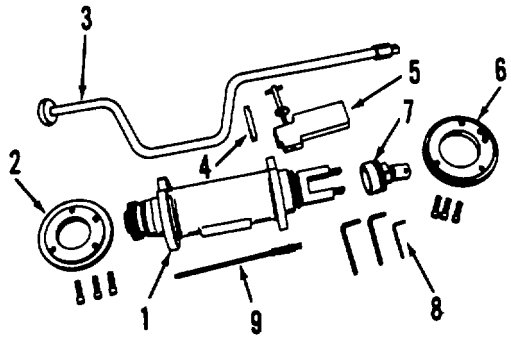
d. Cylinder Sleeve Reseating.

(1) General.

(a) Cylinder sleeve reseating may become necessary if the cylinder sleeves have been allowed to move due to incorrectly torqued cylinder head capscrews, deteriorated head gaskets, or from block counterbore or sleeve flanges eroding from long use. It is important that the cylinder sleeve standout from the top surface of the cylinder block be held between .002 inch-.005 inch. Variation of, more than .003 inch between adjacent sleeves must not be allowed. Failure to retain specified cylinder sleeve standout will invite premature cylinder head gasket failure.

(b) A cylinder sleeve reseating tool is available; the tool, is discussed in detail below.

(c) Listed in the steps below are the assembly, installation, and operating instructions for the Counterbore Tool (fig. 107).



1. Tool housing
2. Lower adapter plate
3. Speed handle
4. Carboloy tool bit
5. Tool holder
6. Upper adapter plate
7. Locking nut
8. Allen wrenches
9. Spring loaded extension

6115-400-35/107

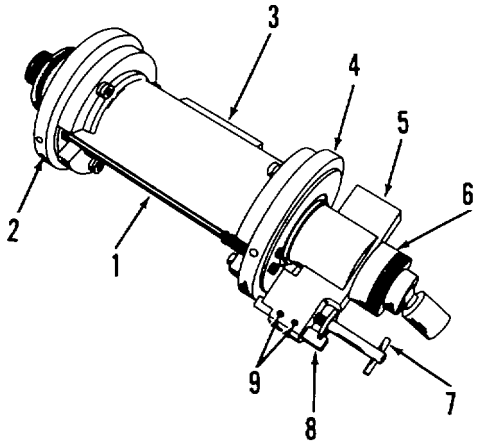
Figure 107. Cylinder sleeve reseating tool

(2) Assembly of Tool.

(a) Install the lower adapter plate with its adjusting screw facing up and positioned in the cutout section of the tool bearing housing (fig. 108).

(b) Install the upper adapter plate to the tool housing so its adjusting screw is facing up and its access hole for installation of the extension for operating the lower adapter plate adjusting set screw is positioned in line with the lower adjusting screw and in the cutout section of the tool bearing housing.

(c) Assemble the spring loaded extension between the upper and lower adapter plates (fig. 108).



1. Spring loaded extension
2. Lower adapter plate
3. Tool housing
4. Upper adapter plate
5. Tool holder
6. Locking nut
7. Tool bit T handle
8. Tool bit
9. Setscrews

6115-400-35/108

Figure 108. Cylinder sleeve reseating tool assembled.

(d) The tool bearings must be adjusted so no end play exists in the spindle shaft. A small preload is desired. To adjust the bearings to control shaft end play, loosen the set screw in the bottom knurled nut and tighten the nut by hand to remove shaft end play. Retighten set screw when desired adjustment is obtained.

(e) Install the tool holder and tool bit (fig. 108).

(2) Preparation of Cylinder Block for Checking and Reseating Counterbore.

(a) Thoroughly clean the top deck of the cylinder block.

(b) Thoroughly clean upper and lower sleeve bores in cylinder block; remove all scale, rust, and carbon so upper and lower adapter plates and their adjusting pins contact original bore diameters.

Caution

Failure to thoroughly clean bores can allow tool to misalign and cut untrue seats.

(c) Measure the present depths of the sleeve counterbores with a depth micrometer at the front and rear of each counterbore, and record. The specified original depth of the counterbore for cylinder sleeve is .460 inch to .462 inch.

Note

Cylinder block top decks, especially on older engines, are not necessarily square with the sleeve bores.

(3) Installation of Tool in Block.

(a) Loosen the two small set screws (fig. 108) which secure the tool bit in the tool holder and retract the tool bit into the tool holder by turning the tool bit "T" handle counterclockwise as far as possible by hand. This will raise the tool bit to a safe position so its cutting edge cannot be damaged while installing tool assembly in cylinder block sleeve bores.

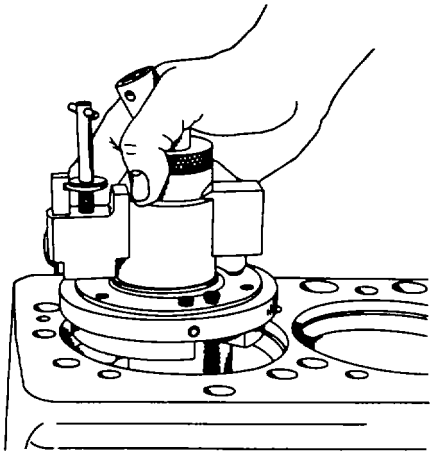
(b) Retract the centralizing pins in the lower and upper adapter plates.

(c) Insert the tool assembly into the cylinder block so the upper adapter plate is between 1/32 inch and 1/16 inch below the counterbore sleeve seat in the block (figs. 109 and 111).

(d) Secure the upper and lower adapter plates in the sleeve bores by tightening the set screws (fig. 110).

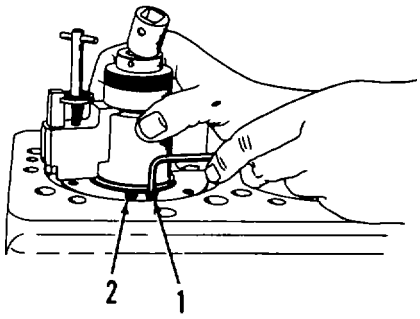
(4) Adjusting and Operating Tool.

(a) To adjust the tool for cutting the correct diameter in the counterbore, loosen the knurled nut securing the tool holder. Move the tool holder so the tool bit can be extended into the counterbore about half way. Slide the tool holder until the tool bit just contacts the inside diameter of the counterbore. Tighten the knurled locknut securing the tool holder by hand only. Carefully and slowly turn the tool to be sure the tool bit does not tightly contact the counterbore I.D. at any point in a complete revolution. The specified original counterbore I.D. is 6.229 inches to 6.234 inches. Readjust tool holder, if necessary, so tool can be revolved easily without excessive contact with counterbore I.D.



6115-400-35/109

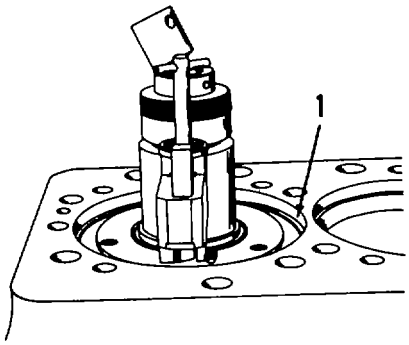
Figure 109. Positioning cylinder sleeve reseating tool.



1. Setscrew for securing lower adapter plate
2. Setscrew for securing upper adapter plate

6115-400-35/110

Figure 110. Securing cylinder sleeve reseating tool in block.



1. Counterbore sleeve seat

6115-400-35/111

Figure 111. Cylinder sleeve reseating tool installed.

(b) Lower tool bit until it just contacts the counterbore seat to be cut. Tighten the two small set screws securing the tool bit (figure 108).

Caution

Never turn tool counterclockwise; this will damage tool bit cutting edge.

(c) Do not attempt to cut deeper than .001 inch at a time. Each graduation on tool bit adjusting handle moves the bit approximately .002 inch on the tool. Loosen and retighten the two set screws securing the tool bit each time the tool bit is readjusted for depth.

Note

The cylinder sleeve reseating tool Carboloy tool bit may be replaced with a standard tool bit for rough machining only. For the finish cuts, use the Carboloy tool bit. A regular cylinder boring bar can also be used to rough cut the cast iron to the enlarged bore but the sleeve reseating tool with the Carboloy tool bit must be used for the finish cut.

(d) Determine approximate depth to be cut by checking counterbore depth and sleeve flange thickness with micrometers before starting any cuts. Refer to sub-paragraph (3) of paragraph c.

(e) Insert speed handle and rotate slowly clockwise until tool bit stops cutting.

(f) Check depth of recut seat with depth micrometer and calculate desired depth by checking sleeve flange thickness with outside micrometer and selecting desired shims to obtain the specified sleeve protrusion or projection. Cut seat at rate of approximately .001 inch per cut until calculated desired depth is reached.

Caution

When machining new seats, take micrometer readings frequently to prevent the possibility of machining a counterbore too deep.

(g) Thoroughly clean cylinder block of all machining chips before attempting to install cylinder sleeves. Install shims as required under sleeve flanges to obtain the specified sleeve protrusion.

Note

Do not attempt to measure cylinder sleeve standout with a straight edge and a feeler gage when a shim is installed in the counterbore because a rough edge or burrs on the shim may give a false reading.

CHAPTER 4
MAIN GENERATOR AND AUXILIARY EQUIPMENT REPAIR INSTRUCTIONS

Section I. MAIN GENERATOR

64. General

The Electric Machinery Model 651853 alternating current generator is a fully enclosed, fan-cooled, revolving field, 3-phase alternator. The generator rotor is driven directly by the engine flywheel through a flexible coupling.

When driven at its rated speed of 1,800 rpm, the generator will produce 200 KW (kilowatt) at 60 cycles with a power factor of 0.8 and it will deliver 694 amperes at 120/208 volts or 347 amperes at 240/416 volts. When driven at 1,500 rpm, the generator will produce 167 KW at 50 cycles with a power factor of 0.8 and it will deliver 580 amperes at 120/208 volts or 290 amperes at 240/416 volts.

65. Brush Tension Adjustment

Adjust the brush springs to obtain a brush tension between 15 ounces minimum to 24 ounces maximum. See figure 112.

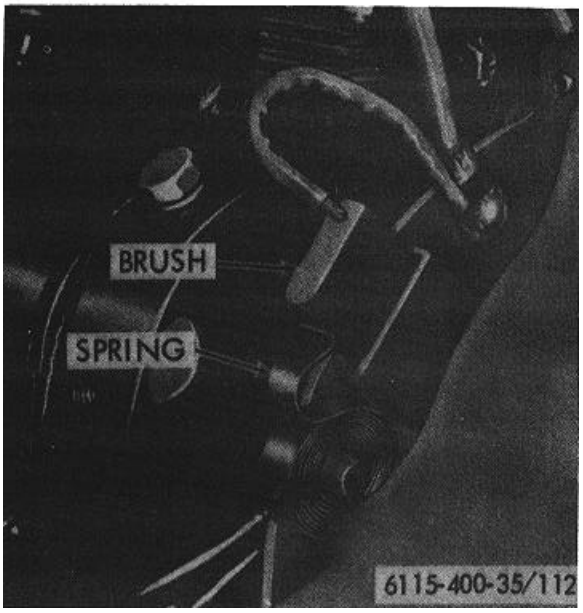


Figure 112. Brush tension adjustment.

66. Drying Out Generator Windings

a. If the generator set has been subjected to extreme dampness, a preliminary period of operation may be required to thoroughly dry all generator windings. Use a megger to determine if drying out is necessary. Refer to Table 3 to determine the insulation limits of the stator rotor.

Table 3. Insulation Limits

Minimum values when insulation resistance is taken at various ambient temperatures:

Stator		Rotor	
Ambient	*Megohms	Ambient	*Megohms
15°C	39	15°C	58
20°C	32	20°C	47
25°C	27	25°C	39
30°C	22	30°C	32
35°C	18	35°C	27

*The megged values should equal or exceed the figures given for the temperatures at the time of test.

Note

Before measuring the resistance of the generator stator and rotor, disconnect all controls. Do not use a megger to check the rectifiers and other components installed in the voltage regulator and excitation unit.

b. To dry out the generator windings, first disconnect the static exciter leads from the generator brushes and connect an external source of field excitation direct current to the brushes. Short circuit the stator terminals and insert a current transformer and ammeter, capable of reading full-load generator current, in one of the shorting leads. Operate the generator at rated speed (1,800 rpm) and apply sufficient field excitation to develop rated full load stator current. Operate under these conditions for sufficient time to insure thorough drying of the windings as determined by periodic measurements of rotor and stator insulation resistance.

67. Winding Resistance Measurements

a. General. The leads of the winding to be measured must be clean. The terminal lugs should be cleaned with emery cloth to make sure that all foreign matter, paint, varnish or oxide coating is removed and only bright bare metal remains exposed for contact with the Kelvin or Wheatstone Bridge leads. The bridge leads shall be secured firmly to assure positive contact with the terminal lugs. Care must be taken to compensate for lead resistance to the test instrument, if such resistance is of a significant value compared to the resistance being measured.

b. Low Resistance Measurement. To measure resistance of less than one Ohm the Kelvin Bridge method shall be used. In using the double bridge on inductive circuits, the galvanometer may swing violently when the key is depressed. This is due to the inductive transient and may be ignored. The final steady position of the galvnometer is the significant indication in all cases.

c. Medium Resistance Measurement. To measure resistance of one Ohm or greater, the Wheatstone Bridge method shall be used. In using the Wheatstone Bridge, ratios should be selected so that the bridge resistance corresponds as closely as possible to the resistance being measured. So that the galvanometer will not be subjected to an inductive voltage surge, use the instrument shunt key to complete the current circuit before the galvanometer circuit is closed.

d. Test.

(1) Stator Winding. To measure stator winding resistance of less than one Ohm, connect the Kelvin Bridge across the phase leads as follows:

(a) Connect to T1 and T2 at the reconnection panel and read.

(b) Record data and disconnect.

(c) Repeat the above on T2 and T3, T3 and T1.

Note

The D.C. resistance of the current position of the CVT Transformer Primary is also included in this measurement but is negligible and can be disregarded.

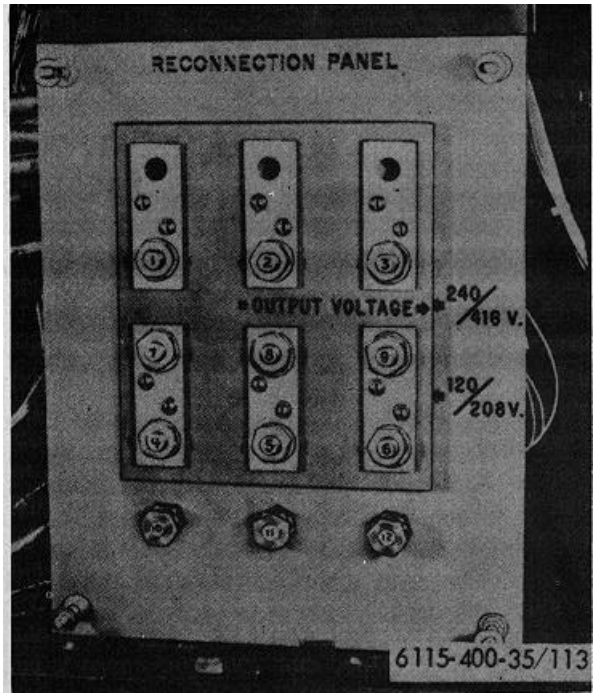


Figure 113. Reconnection panel

(2) Field Winding. To measure field winding resistance of more than one Ohm, manually lift brushes in brusholder until they do not make contact with the slip ring and connect a Wheatstone Bridge to the two slip rings. Measure D. C. Resistance. Record data and disconnect leads.

68. Insulation Resistance Measurements

a. General. The generator winding insulation shall be thoroughly dried by operating the unit at full load until the insulation resistance becomes stabilized before testing. Windings are considered dry when the generator has been operated on full-load for approximately 2 hours under normal ambient conditions. Disconnect the circuit under test from all other circuits. Disconnect Amphenol connector to the Voltage regulator (Refer to fig. 114) then disconnect Y_1, Y_2 and Y_3 connection to the rectifier (fig. 115). Securely ground all other circuits not under test. Dis-

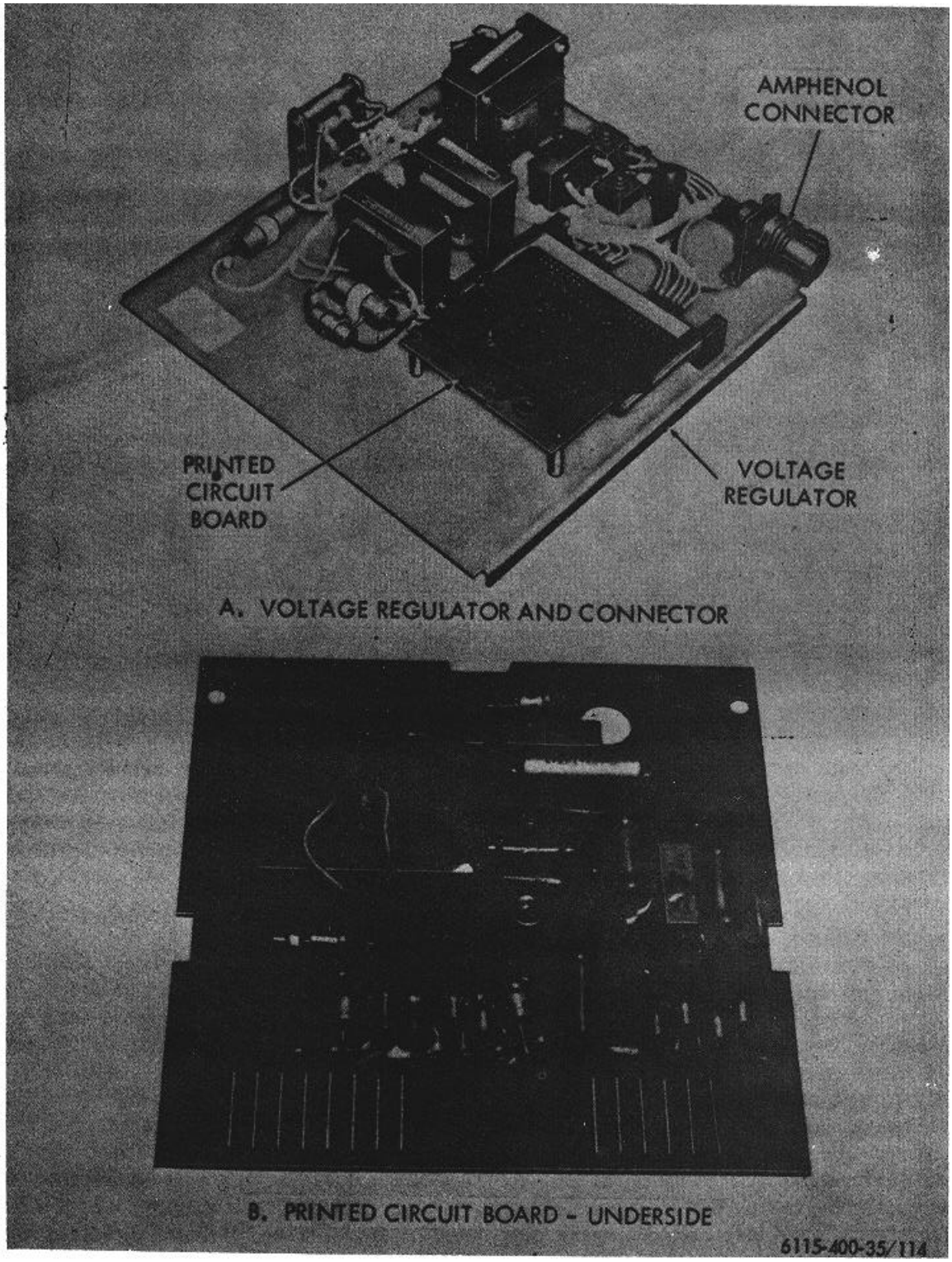


Figure 114. Voltage regulator.

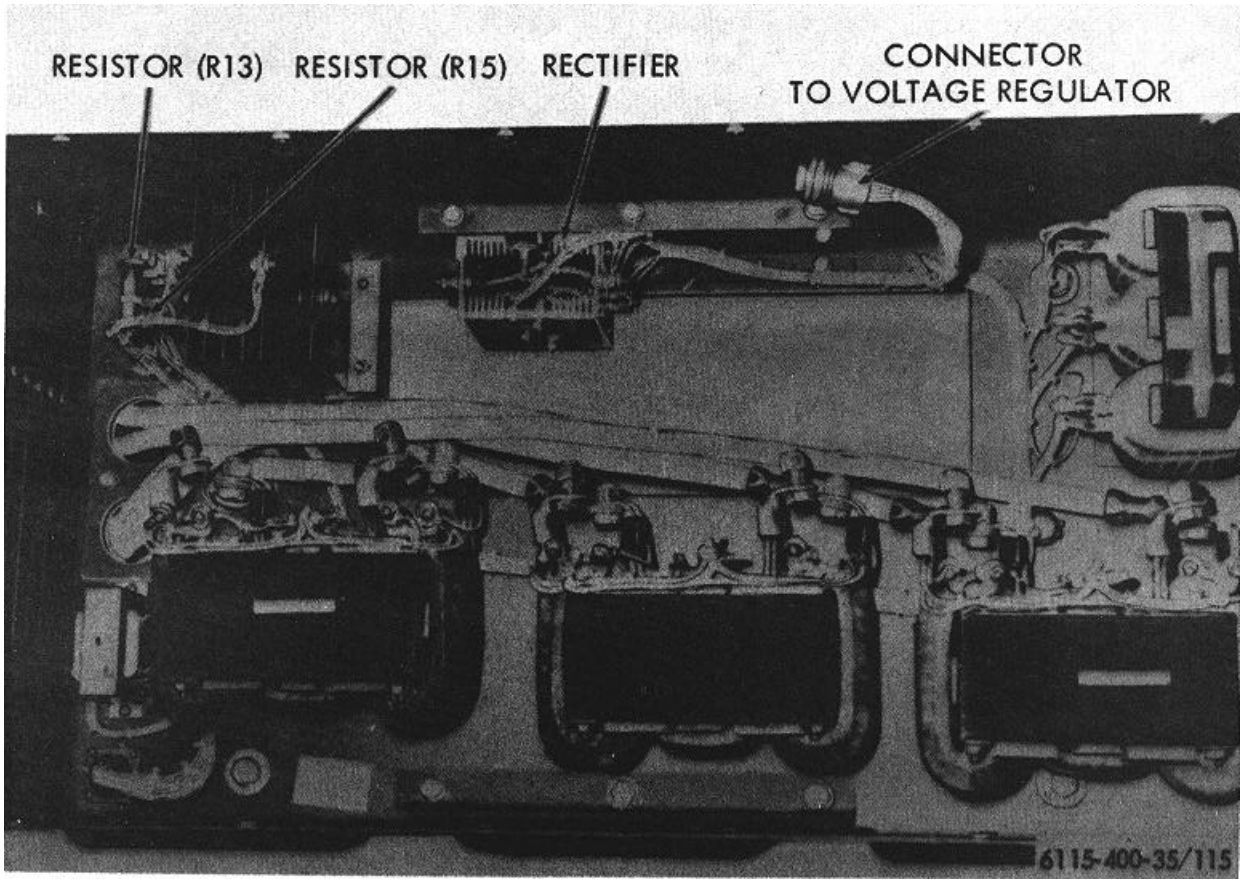


Figure 115. Excitor and rectifier.

connect all radio suppression capacitors from the circuit to be tested. When testing a stator element, connect one lead from the test apparatus to the generator frame (ground). When testing elements that rotate, connect the test apparatus ground lead to the shaft.

Warning

Observe Safety Regulations. The voltage used in this test are dangerous to human life. Constant with the leads on the windings under test may cause severe, and possible fatal shock. Arrange the high voltage leads so that they are not in a position to be accidentally touched. Keep clear of all energized parts. Always reduce the test voltage to zero and ground the winding under test before making any mechanical or electrical adjustments on the equipment. When grounding out windings which have been tested, always connect the connecting wire to ground first, and then to the winding. Never perform this test without at least one other person assisting. Generator frame shall be securely grounded. Record the ambient temperature and relative humidity. Record the winding temperature if the winding is at other than ambient temperature.

b. Test.

(1) Stator Leads Insulation. Measure insulation resistance while the windings are at ambient temperature. Connect stator leads (T1, T2 and T3, T4, T5, T6, T7, T8, T9, T10, T11, and T12) together and test as a unit. Connect one side of megger to the multiple connection and the other side of megger to generator frame (ground). Measure the insulation resistance after one minute of operation. Refer to Table 3 to determine the limits of insulation. Disconnect neutral ground.

(2) Rotor Insulation. Lift the brushes from slip ring until they do not make contact. Connect one side of megger to slip ring terminal and other side of megger to shaft (ground). Measure the insulation resistance after one minute of operation. Refer to Table 3 to determine the insulation limits.

69. Bearing Lubrication

The bearings are sealed. Add one ounce of Molykote grease to bearing bracket housing when necessary.

70. Generator Disassembly and Reassembly

Refer to figure 116 to disassemble and reassemble the main generator.

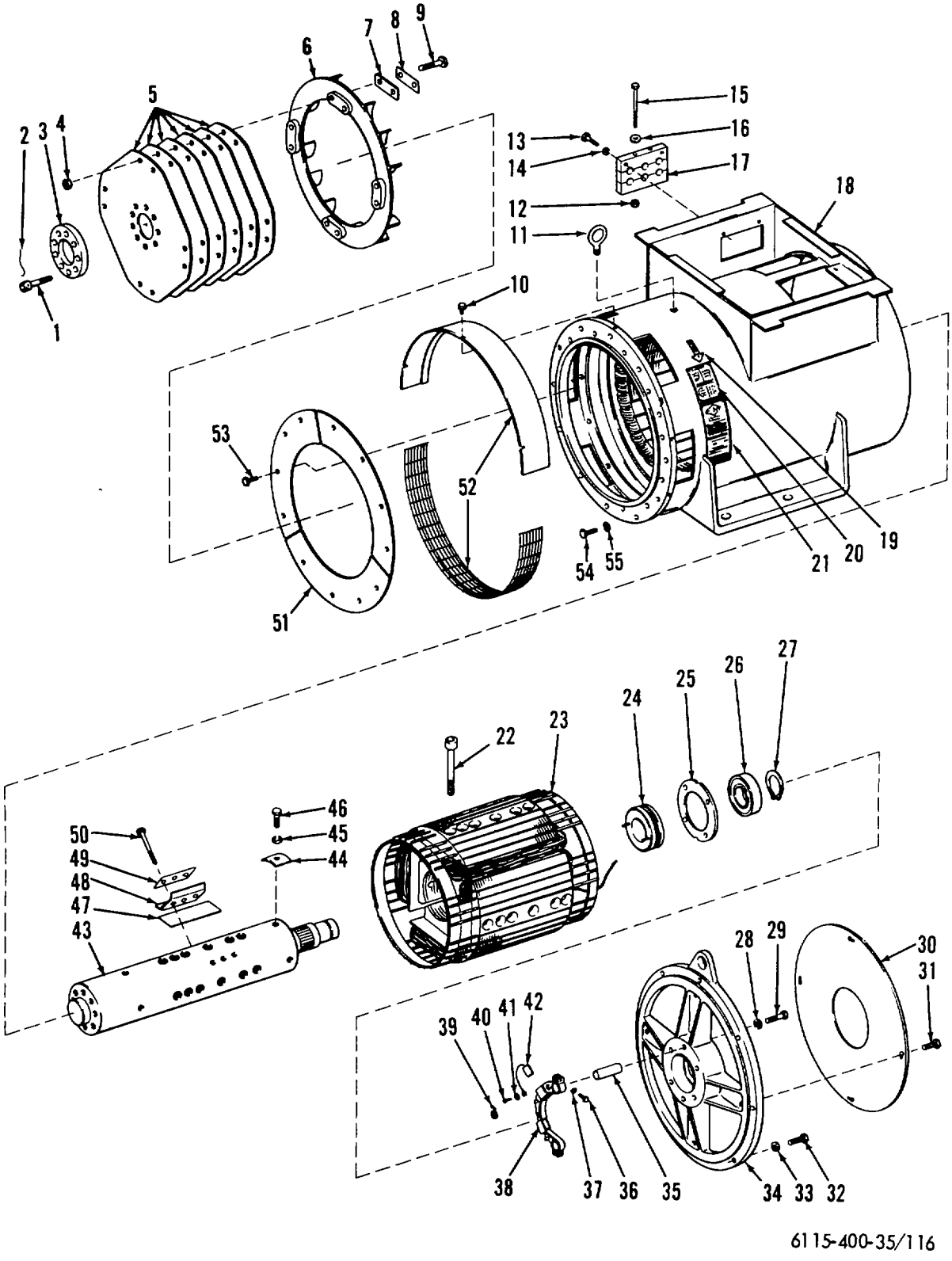


Figure 116. Main generator-exploded view.

1	Bolt	16	Washer	31	Screw
2	Lockwire	17	Block	32	Screw
3	Ring	18	Stator assembly	33	Lockwasher
4	Nut	19	Instruction plate	34	Bearing bracket
5	Disk	20	Instruction plate	35	Stud
6	Blower	21	Identification plate	36	Screw
7	Plate	22	Bolt	37	Lockwasher
8	Locking plate	23	Cage	38	Brush holder
9	Screw	24	Collector ring	39	Spring
10	Screw	25	Washer	40	Screw
11	Eye bolt	26	Bearing	41	Lockwasher
12	Nut	27	Retaining ring	42	Brush
13	Screw	28	Lockwasher	43	Shaft
14	Lockwasher	29	Bolt	44	Balance weight
15	Bolt	30	Cover		

Figure 116-Continued.

Section II. STATIC EXCITER AND VOLTAGE REGULATOR

71. General

The voltage regulator and excitation unit provide excitation current and voltage regulation for the synchronous generator. A simplified block diagram of both the excitation unit and voltage regulator is provided in figure 118. A simplified schematic diagram of the voltage regulator power amplifier is provided in figure 124.

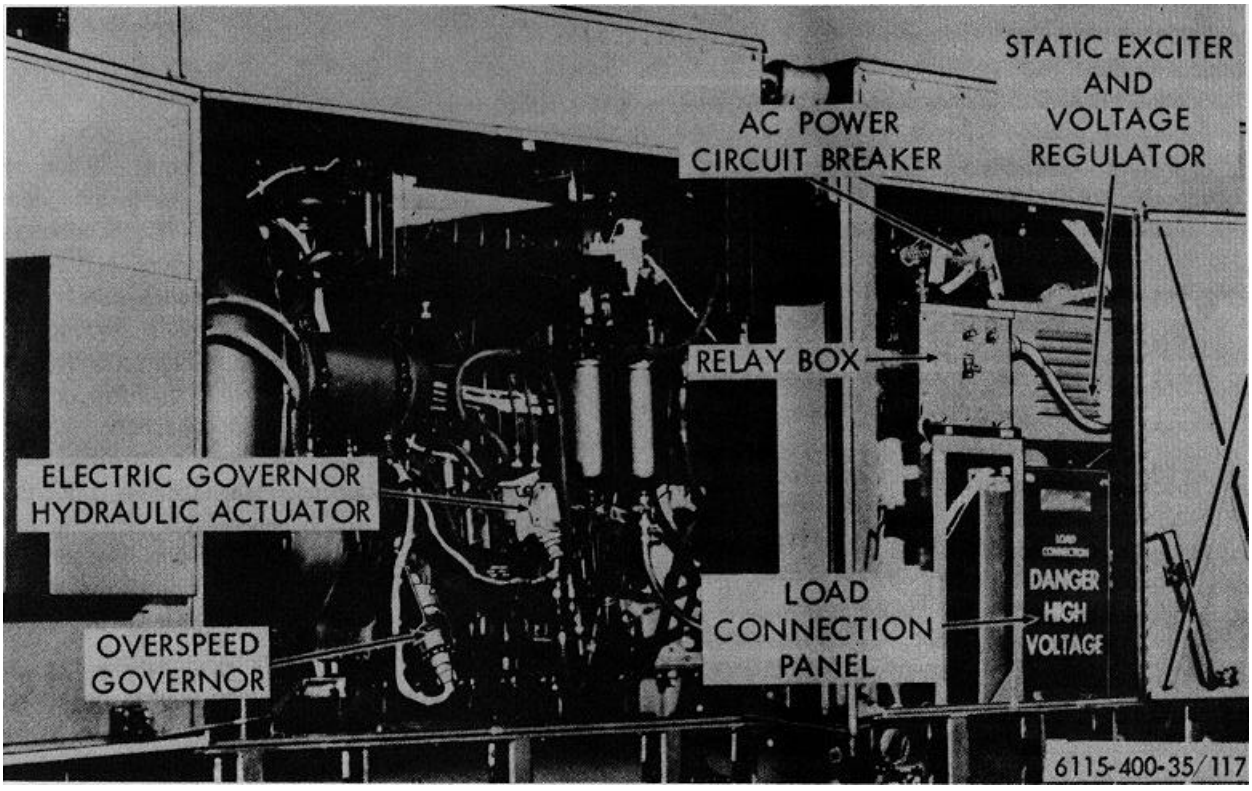


Figure 117. Major electrical equipment.

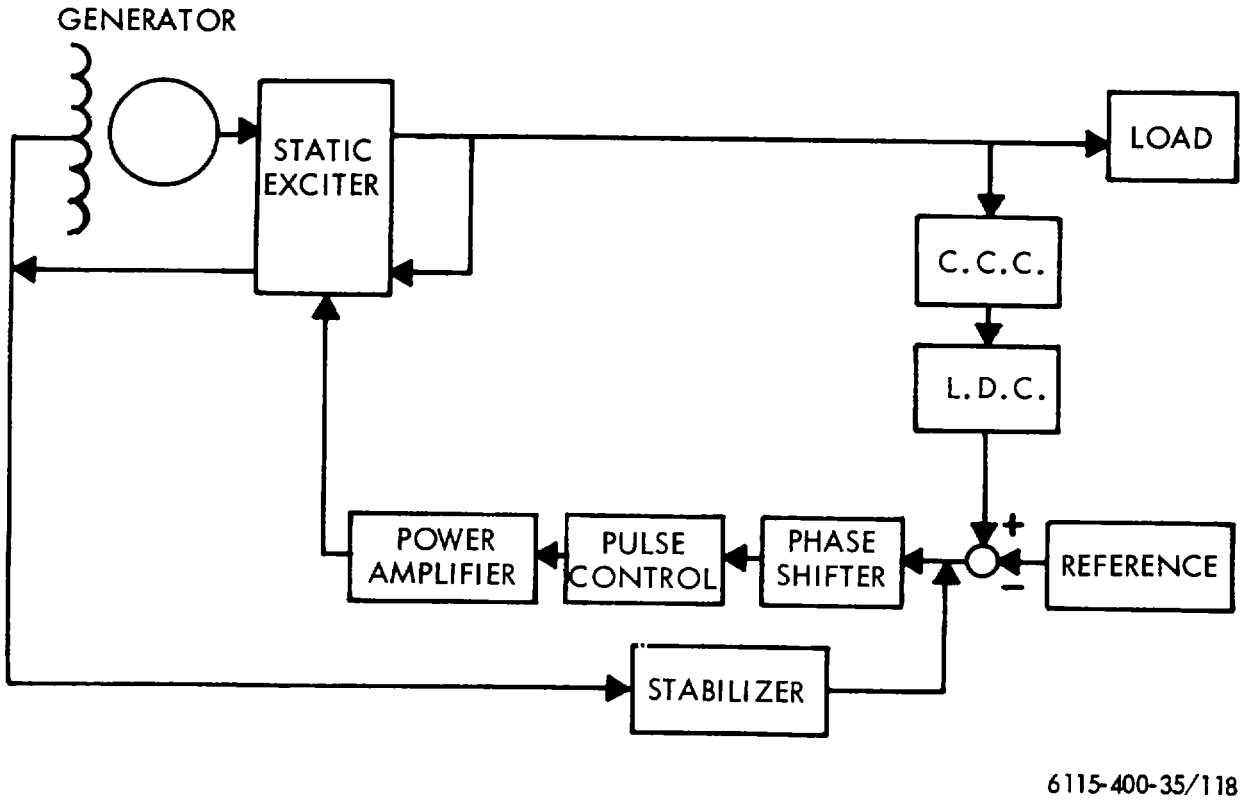


Figure 118. Voltage regulator and excitation unit-block diagram

A complete connection diagram of the excitation unit and voltage regulator is provided in the wiring and schematic diagram, figure 1.

72. Static Exciter

a. General.

(1) The exciter assembly (fig. 119) is a static type and is mounted above the main generator.

(2) The static exciter consists basically of three d.c. controlled, single-phase, current voltage transformers, (CVT), a linear three-phase reactor (X_L) and a three-phase, full-wave rectifier. Figure 120 is a simplified schematic diagram illustrating one third of the static exciter.

(3) The static exciter has two modes of operation: One when the generator is operating under no-load conditions, and the other with the generator operating under load. With the generator operating without load, winding P (I) and P (I') of the current voltage transformer (CVT; see fig. 120) are not used since these windings are connected in series with any external load. Temporarily assuming the control winding S (C) is not used, the current voltage transformer becomes a simple stepdown coupling transformer having a rector (X_L) connected in the primary circuit P (V) and the secondary winding S (V) supplying rectified current to the generator field.

(4) Operating under the above condition, the generator would build up from zero voltage to above rated voltage, reaching a ceiling voltage in a manner similar to the operation of a direct current shunt-wound generator.

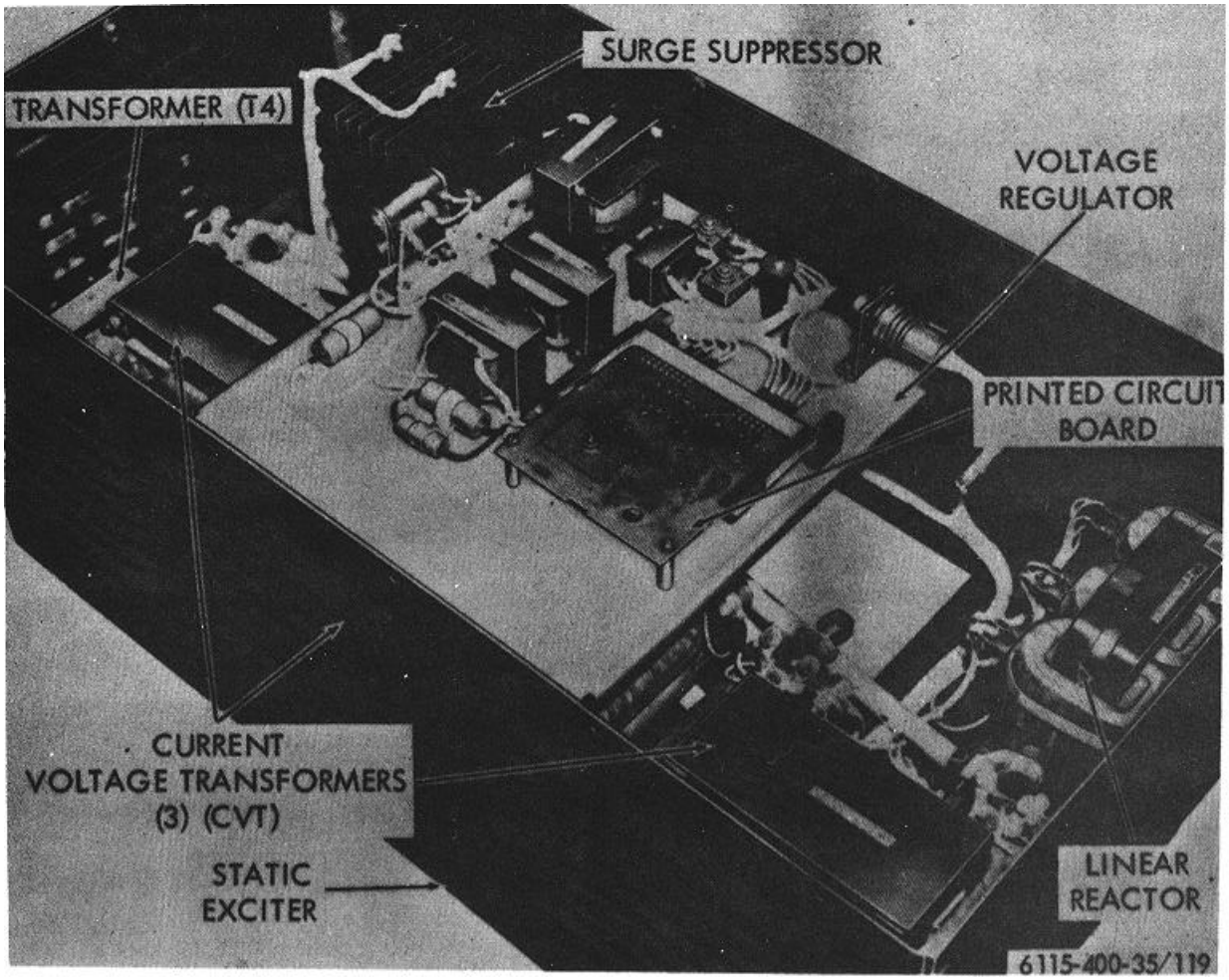


Figure 119. Static exciter and voltage regulator.

However, since it is desired to stabilize the generator output at rated voltage, a direct current is applied to the control winding S (C) of the current voltage transformer (CVT), thus increasing the magnetizing current in the primary winding P (V). This additional magnetizing current increases the voltage drop across the reactor (X_L) producing a result equivalent to a shift in the shunt field resistance line of a direct current generator to limit generator output to rated voltage.

(5) With the generator under load, all the windings of the current voltage transformer (CVT) are used. The load current flowing through the P (I) and P (I) windings provide additional flux components in the CVT. The vector addition of the flux due to the P (V) current and the P (I)-P (I) currents for a given level of control current is S (C), determine the voltage that appears across S (V). With a zero power factor load, this vector addition is approximately arithmetic, resulting in a large S (V) voltage. For unit power factor loads, the vector additions are approximately at right angles, resulting in only a slight increase

in S (V) voltage. The boosting of S (V) voltage under conditions of a zero power factor load is desired since a considerable increase in generator field current is then required. The control winding S (C) serves the same function under load conditions as explained for no-load conditions.

(6) Since the synchronous generator is self-excited and retains only a small amount of field residual magnetism for voltage build-up, an external 24volt direct current supply source is required to flash the generator field. Application of this field flash voltage is controlled by the overspeed governor. The field flash voltage is applied when the engine reaches 600 revolutions per minute.

b. Removal. Part of the housing must be removed in order to remove the exciter (fig. 3). Refer to figures 117 and 118 to remove the exciter.

Warning

When malfunction of the selenium rectifier surge suppressor occurs, thoroughly ventilate the suppressor area to prevent inhalation of poisonous fumes. Do not handle the damaged rectifier. Selenium oxide may be absorbed through the skin, especially when the rectifier is hot. Failure to observe this warning can result in serious damage or death.

c. Bench Testing.

(1) Connect a simulated load to the exciter without the voltage regulator in place.

(2) Check load voltage and current regulation between unity and zero power factor lagging.

(3) With the voltage regulator connected to the exciter, check the load voltage and current regulation between unity and zero power factor lagging.

d. Disassembly. Refer to figure 121 to disassemble the exciter.

e. Cleaning. Clean all parts with a clean dry cloth and compressed air.

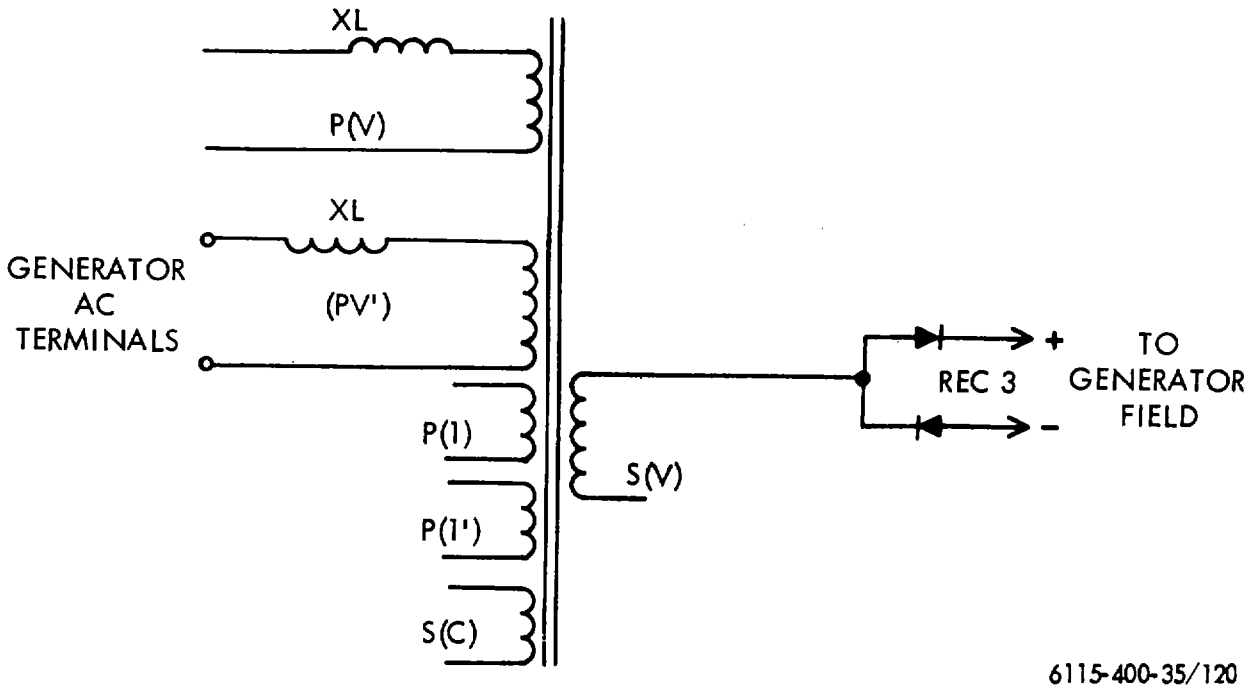


Figure 120. Simplified schematic diagram of static exciter.

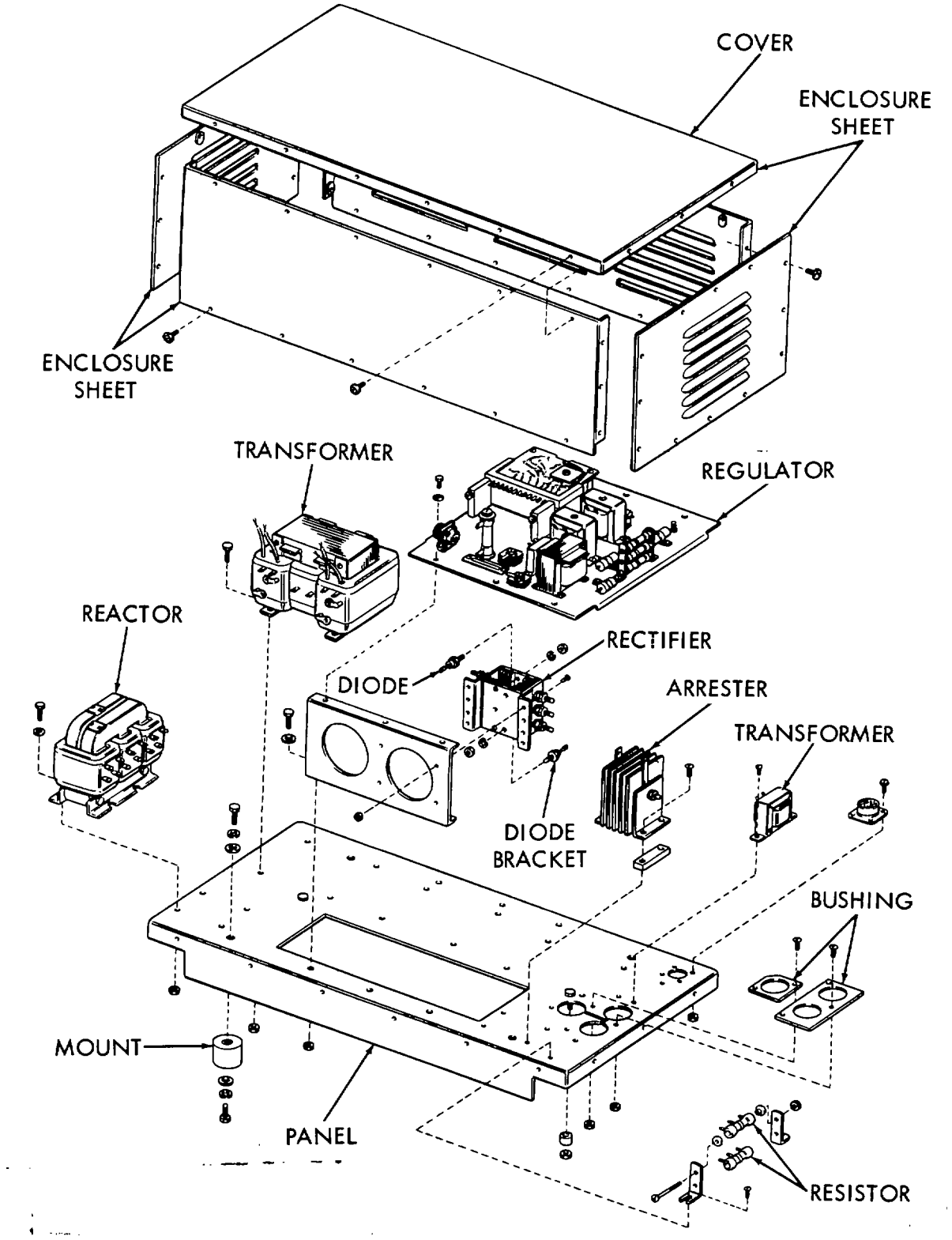


Figure 121. Static exciter-exploded view.

f. Inspection and Repair.

(1) Inspect the rectifier and the transformers for damaged insulation, terminals, and windings, and for discoloration due to overheating.

(2) Inspect all threaded parts for worn and damaged threads. Repair or replace as required.

(3) Replace damaged or defective parts.

g. Testing.

(1) Current voltage transformers. Refer to figures 121 and 122 and test the current voltage transformers.

(2) Rectifier. Using a multimeter, test between the positive and negative terminals. It should read high in one direction and low in the other.

The actual magnitudes vary considerably. Replace the rectifier if it does not conform to this test.

(3) Reactor. Using a multimeter, test the reactor for continuity. Use a megohmmeter to test between one lead and the reactor core for insulation resistance. If less than 0.5 ohm is indicated, replace the reactor.

(4) Field flash resistor. Test the field flash resistor with a multimeter. If less resistance than 10 ohms ± 10 percent is indicated, replace the resistor.

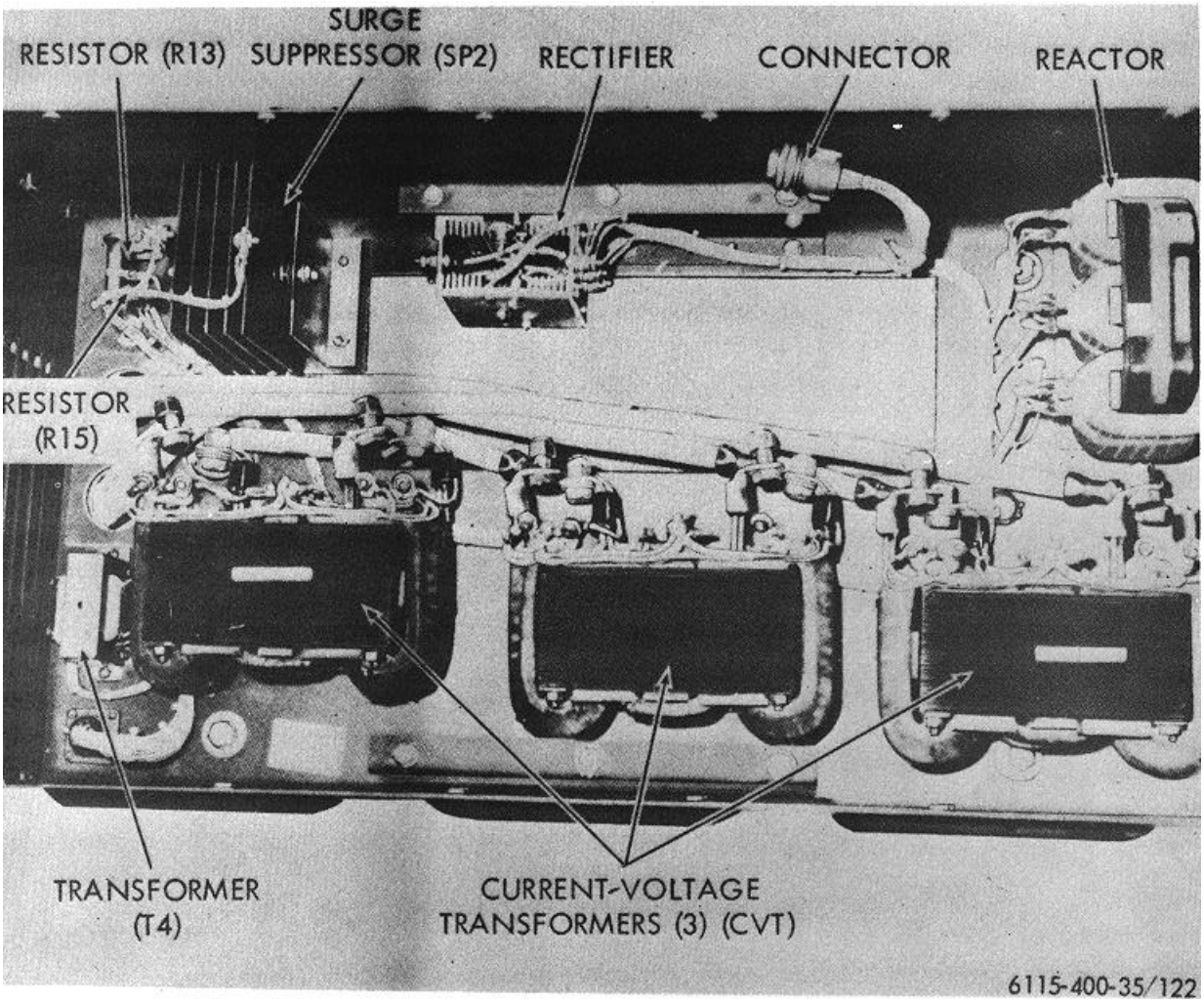


Figure 122. Exciter with voltage regulator removed

(5) Discharge resistors. Test discharge resistor with a multimeter.

h. Refer to figure 121 and reassemble the exciter.

i. Installation. Refer to figures 117 and 121 to install the exciter and install the housing components that were removed (fig. 3).

73. Voltage Regulator

a. *General.*

(1) The voltage regulator assembly is mounted in the exciter box. A simplified block diagram of both the excitation unit and voltage regulator is provided in figure 118. A simplified schematic diagram of the voltage regulator power amplifier is provided in figure 124. A complete connection diagram of the excitation unit and voltage regulator is provided in the schematic wiring diagram (fig. 1).

(2) The voltage regulator compares a portion of the generator output voltage with a reference voltage The difference in voltages constitutes an error signal that is amplified and used to establish the level of control current applied to the S (C) winding of the static exciter current voltage transformer (CVT). This control current maintains generator terminal voltage within regulation

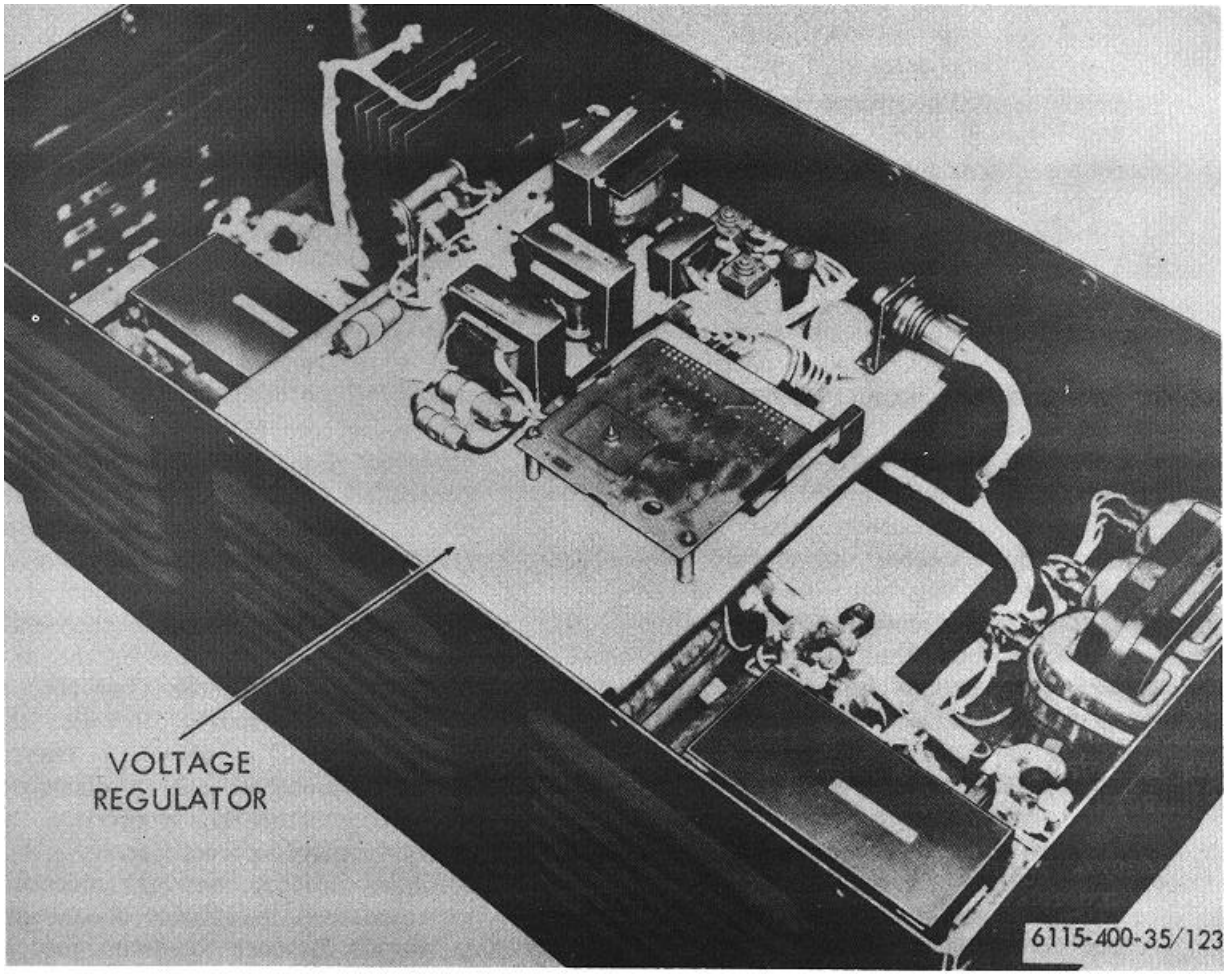


Figure 123. Voltage regulator installed in exciter box.

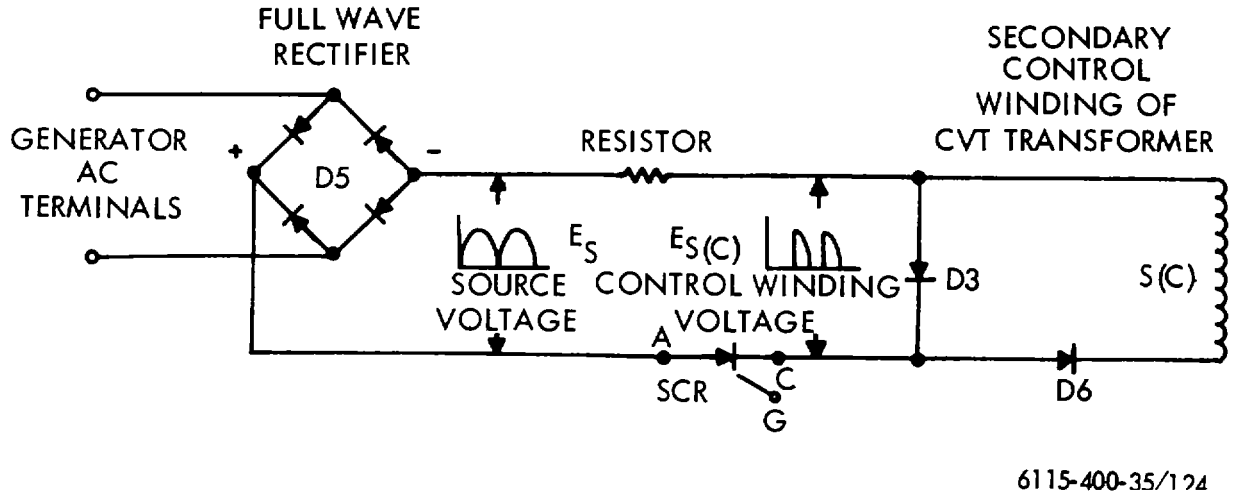


Figure 124. Simplified schematic diagram of voltage regulator.

limits for the various load conditions to be encountered. The basic elements of the voltage regulator are illustrated in block diagram form in figure 118 and explained in the following paragraphs, refer to figure 1 for a detailed schematic diagram.

(3) The control current supplied the S (C) winding of the CVT (fig. 120) is developed by the full-wave rectifier D5 which received a portion of the generator output. The amount of control current supplied is determined by the silicon controlled rectifier SCR (power amplifier of fig.124). Isolation transformer T3 at this point isolates the circuit that contains silicon controlled rectifier SCR from the main lines, preventing feed-back and eliminating radio interference. The silicon controlled rectifier possesses characteristics that enable it to absorb all the source voltage E. between points A and C (see fig. 124) until such time as a voltage pulse is applied between points G and C. At the instant the voltage pulse is applied, the SCR can no longer absorb voltage, the voltage across A and C drops to zero, and the source voltage E, ap 158 pears across the S (C) winding of the CVT. The SCR regains the ability to absorb voltage when the source voltage drops to zero at the end of each cycle of pulsating dc (1/120 second based on a 60 cps ac input to D2). Thus; by applying a voltage pulse between points G and C each cycle, and shifting the pulse in time with respect to the cycle, full control of the control current applied to the S (C) winding is established.

(4) The pulse control circuit which supplies the voltage pulse to the silicon controlled rectifier (SCR) consists of a unijunction semi-conductor (Q2) and resistors R6 and R7. The action of this circuit is such that when the voltage level between the emitter and Number 1 base of the unijunction semiconductor (see fig. 1) reaches approximately 10 volts, the Q2 triggers. This allows the energy stored in capacitor C2 to discharge through resistor R7, triggering the silicon controlled rectifier.

(5) A phase shifting network consisting of transistor Q1, resistor R4 and capacitor C2, is used to determine at what point of a given cycle the unijunction semiconductor will fire.

Functionally, transistor Q1 acts as a variable resistance in series with capacitor C2, thus forming an RC circuit with a variable time constant. If the transistor is set for a high resistance, the capacitor charges at a relatively slow rate and does not reach the voltage level required to fire the unijunction until late in the cycle. Consequently, the SCR fires]ate in the cycle and the control current supplied the S (C) winding is small. If the transistor has a low resistance, capacitor C2 charges rapidly and reaches the required voltage level early in the cycle. This causes the SCR to fire early in the cycle, supplying a relatively high value of control current to the S (C) winding.

(6) The silicon controlled rectifier (SCR), unijunction semi-conductor Q2 and transistor Q1 are all synchronized and power supplied by the 120 pulses per second rectified output of D5. Zener diode Z2 limits the voltage across the Q1 and the Q2 to a maximum of 18 volts even though the output of D2 has a maximum peak of nearly 200 volts.

The voltage difference is absorbed by resistor R5.

(7) Control of the transistor Q1 (ie its relative resistance) is established by the error signal resulting from the difference in voltage between the zener reference Z1 and the portion of the generator output voltage seen across resistor R12. This generator voltage is supplied by transformer T1, rectified by full-wave rectifier D1 and filtered by reactor L1, capacitor C1 and resistors R6 and R12.

(8) Voltage regulator adjustments are made by means of a 250 ohm rheostat VOLTAGE ADJUST mounted on the control panel. The upper range of the voltage control can be extended by decreasing adjustable resistor R1.

(9) The remaining circuit elements used in the voltage regulator serve the following functions:

(a) Transformer T2, capacitor C3 and resistors R10 and R11 form a network which helps stabilize the generator voltage.

(b) Rectifier D6 is used to assist in the correct operation of the silicon controlled rectifier (SCR).

(c) Surge protector SP1 is used to limit transient voltages.

(d) The cross current compensation (CCC) system consists of the current transformer CCCT (fig. 125) and KVAR rheostat. The current transformers are mounted to the left of the reconnection panel assembly and the rheostat is mounted on the relay box.

(e) Cross current compensation is required to minimize circulating current between generators operating in parallel. This is accomplished by using the current transformer CC-CT to detect the zero power factor load of each genera

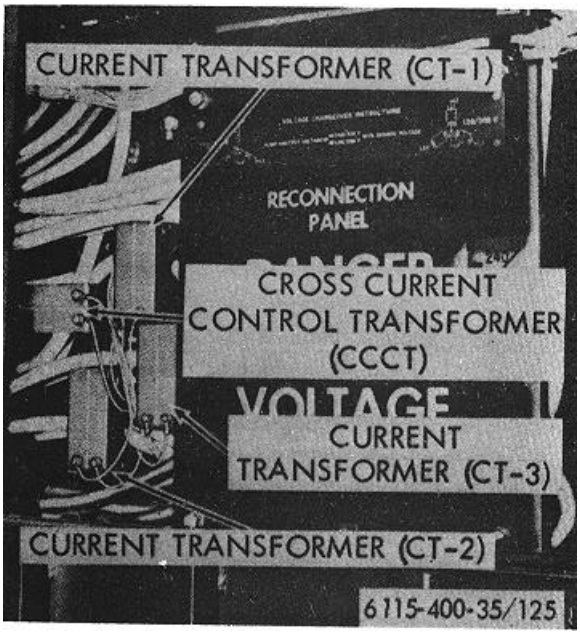


Figure 125. CCCT, CT1, and CT3 transformer

tor. The output of the transformer provides a signal that is applied to transformer T1, thus affecting the controls to transistor Q1 and adjusting the generator excitation in the right direction to minimize cross current circulation.

b. Removal. Refer to figures 121 and 123 to remove the voltage regulator.

c. Bench testing.

(1) Test all transistors and capacitors using suitable transistors and capacitor test equipment.

(2) Test all resistors using an ohmmeter.

The three thru-bolt mounted resistors should measure within 10 percent of their rated values. All resistors soldered to the panel boards should measure within 10 percent of their rated values.

(3) Test chokes and transformers for continuity using an ohmmeter. Test the chokes and transformers for grounds by testing between one lead of each winding and the core with a multimeter. Test each transformer for shorted windings by testing between one lead of the secondary winding and one lead of the primary winding.

(4) Test the diodes for shorts or opens using an ohmmeter. When testing the diodes, connect the leads of the ohmmeter in such a way as to isolate the diodes from other diodes and surrounding circuitry. A normal diode will indicate very low resistance in one direction and extremely high in the other. If the diode is shorted, very low resistance will ;be indicated in both directions. An open diode will read infinite in both directions.

d. Disassembly. Disassemble the voltage regulator assembly as shown in figure 126.

e. Cleaning. Clean all parts with a clean cloth dampened with an approval cleaning solvent and dry thoroughly.

f. Inspection and Repair.

(1) Inspect the resistors and transistors for damaged terminals, defective insulation, and other visible damage.

(2) Inspect the capacitors for broken leads or cracked cases.

(3) Inspect the transformers and chokes for cracks, breaks, broken terminals, and evidence of overheating.

(4) Inspect the chassis for cracks, breaks, and other damage. Inspect threaded parts for defective threads.

(5) Repair or replace defective parts as necessary.

g. Testing.

(1) Check for voltage regulation.

(2) Check for Steady-State variations.

(3) Check for Transient Performance.

h. Reassembly. Refer to figure 126 to reassemble the voltage regulator.

i. Installation. Refer to figure 123 to install the voltage regulator.

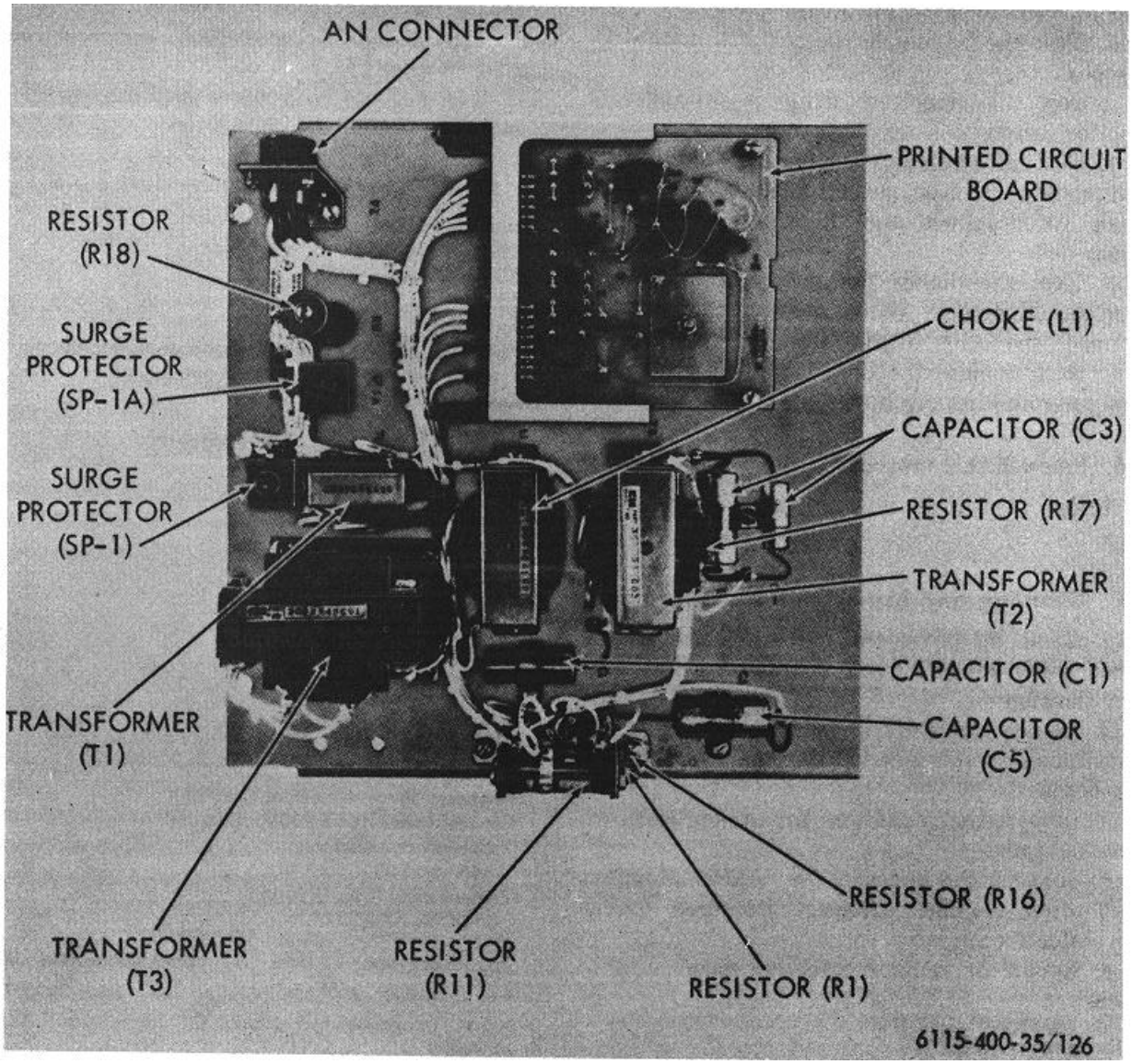


Figure 126. Voltage regulator.

Section III. RELAY BOX

74. General

The relay box (refer to TM 56115-40012) contains all relays, control devices, resistors, capacitors and diodes not contained in the Control Cubicle or required to be located elsewhere in the generator set.

75. Testing Relay Box Installed in Generator Set

a. Refer to figure 128 and disconnect all plugs and wiring harness terminating in the relay box.

b. Test wiring harness (control panel to relay box) for short circuits and continuity.

c. Refer to figure 1 and 127, then test wiring harness terminating in the jacks.

d. Test the wiring harnesses within the relay box.

e. Test all capacitors using a suitable capacitor tester.

f. Test all resistors using an ohmmeter. All resistors whose measurements are beyond their rated values and tolerances should be discarded.

g. Test the diodes for shorts or opens using an ohmmeter. When testing the diodes, connect the leads of the ohmmeter in such a way as to isolate the diode from other diodes and surrounding circuitry.

76. Relay Box Removal

Refer to figure 129 to remove the relay box.

77. Cleaning and Inspection

a. Clean all parts with a clean cloth dampened with an approved cleaning solvent and dry thoroughly.

b. Inspect resistors and diodes for damaged terminals, defective insulation, and other visible damage.

c. Inspect the capacitors for broken leads or cracked cases.

d. Inspect the chassis for cracks, breaks, and other damage. Inspect threaded parts for defective threads.

e. Repair or replace defective parts as necessary.

78. Bench Testing

a. Refer to Table 4, specifications for (K2) over voltage relay, and use the test procedure below to checkout the relay.

(1) Connect a light and suitable power supply in series with terminals 3 and 4 and in like manner with 4 and 5.

(2) Connect a variable voltage supply (60-400 cps) to terminals 1 and 2.

(3) Set voltage to 120V.

(4) Slowly increase voltage to 156V or until a trip is indicated by the lights. Do not increase beyond 165V.

(5) Check remaining relay contacts by 162 removing connections to lights and reconnect as follows:

(a) 3 and 4 remove and reconnect to 6 and 7.

(b) 4 and 5 remove and reconnect to 7 and 8.

Table 4. Specification for Over Voltage Relay

Nominal Voltage
  120V, 60-400 CPS
Pull-In Voltage
  157V
Time Delay
  Must sustain over voltage for minimum of 180 milliseconds and trip within one second.
Relay Contacts
  Rating
    10 amperes resitine at 26.6 VDC
Contact Arrangement
  2 PDT
Connections
  120V Line
    Terminals 1 and 2
N. C. Contacts
  3 and 4
N. 0. Contacts
  4 and 6
N. C. Contacts
  6 and 7
N. 0. Contacts
  7 and 8
Contacts shown in normal position
Contacts transfer at 166V (Fault)
Temperature Limits
  -65° to 85°C
Temperature Trip Affects
  +85°C-+1 Volt

b. Refer to Table 5) specifications for (K11) under voltage relay, and use the test procedure below to checkout the under voltage relay.

(1) Connect a light and suitable power supply in series with contact 3 and 4 in like manner also with contacts 4 and 5.

(2) Connect a variable A.C. power source (60 or 400 cps 0-120V) to terminals 1 and 2.

(3) Adjust input voltage (1 and 2) to 120V.

(a) Light to 3 and 4 should go out.

(b) Light to 4 and 5 should go on.

(4) Reduce voltage slowly to 102V or until lights indicate relay drop-out.

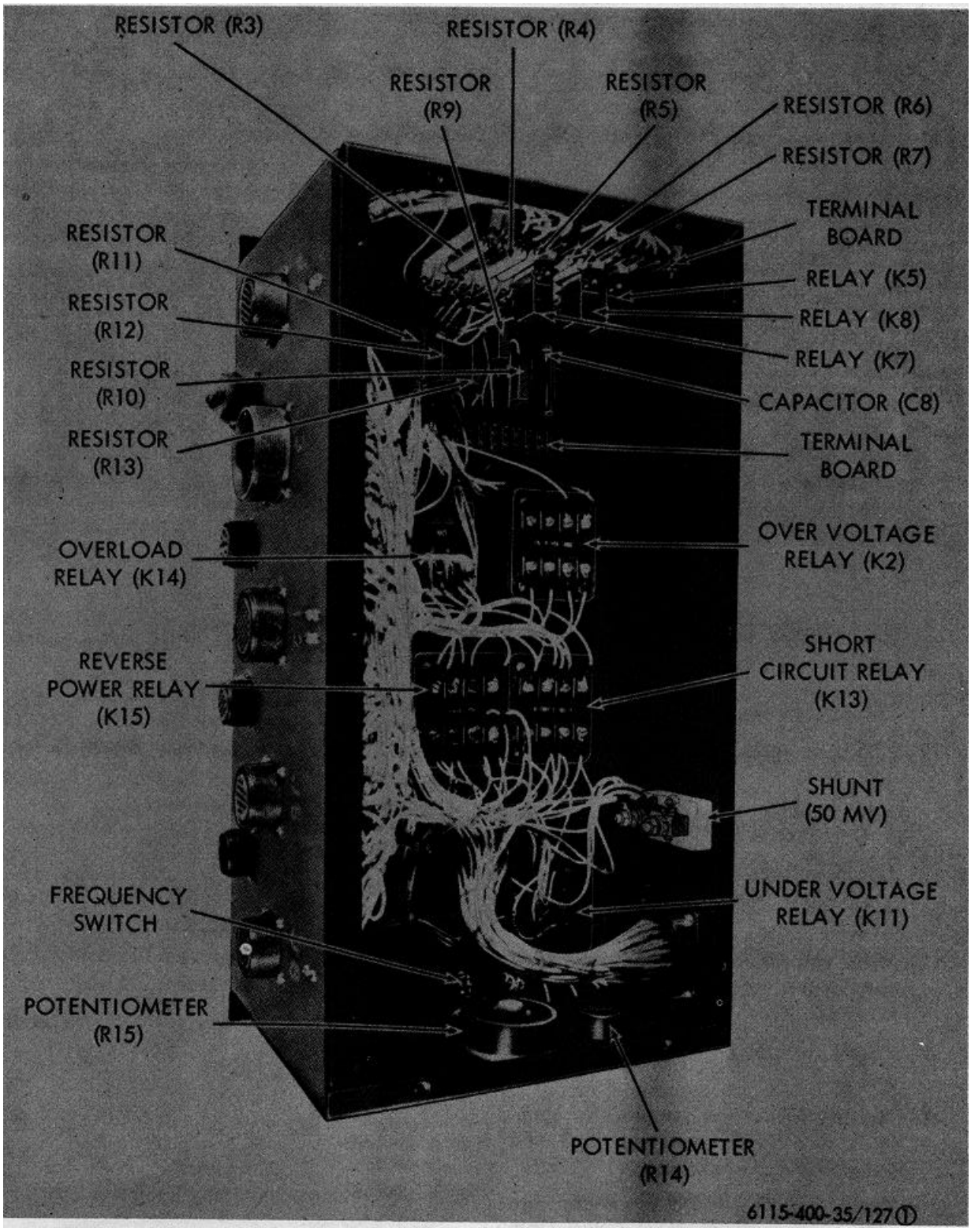


Figure 127 (1). Relay box.

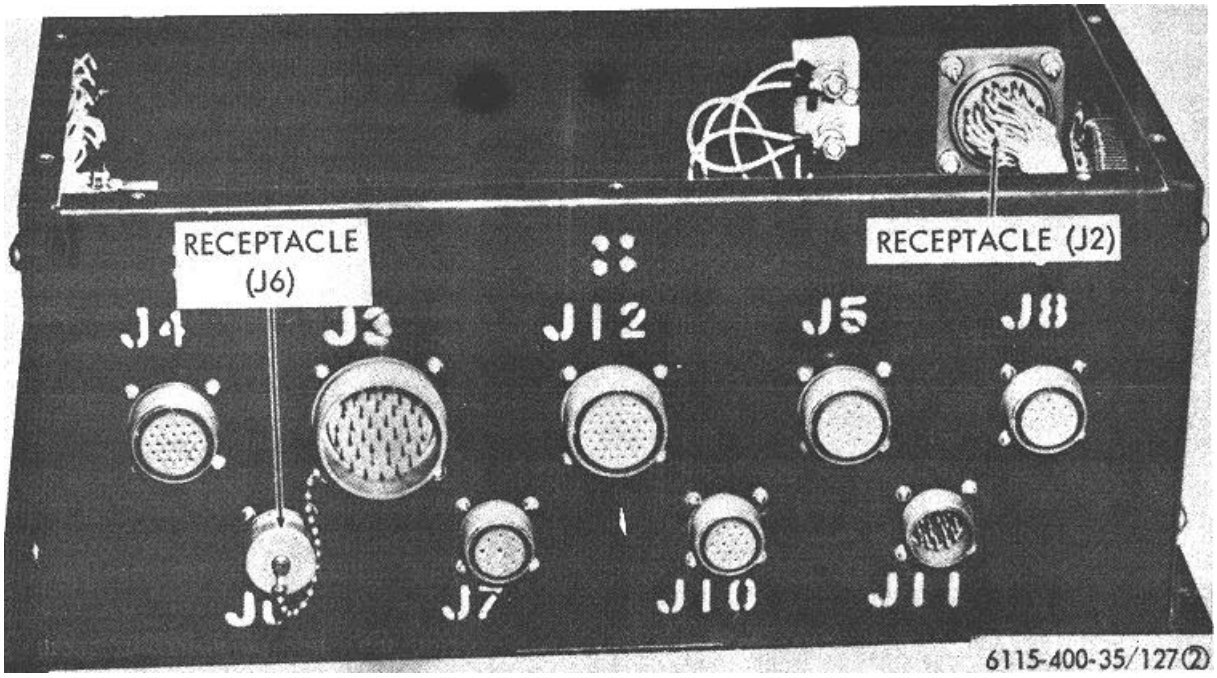


Figure 127 (2) -Continued.

Figure 1-8. Wiring diagram-interconnecting wining harness.

(Located at back of manual.)

(5) Increase voltage slowly to 110 V or until
   (a) Relay pulls-in.
   (b) Tolerance is + 3V.

(6) Lower voltage quickly to 60V.
   (a) Drop out should be instantaneous + 5V.

(7) Drop voltage to 102V quickly. Dropout should occur in 6 seconds + 2 seconds.

(8) Check remaining relay contact 6, 7, and 8.

(9) Remove test light connections from 3, 4, and 5 and connect to 6, 7 and 8 in respective manner.

(10) Raise and lower voltage about trip point and check contacts for closing and opening.

Table 6. Specifications for Under Voltage Relay

Nominal Voltage
  120V, 60-400 CPS
  Drop-Out Voltage
    102V 3V
  Pull-In Voltage
    110V 3V
  Time Delay
    6 seconds 2 seconds at drop-out
    Instantaneous 60V 5V
Relay Contact
  Rating
    54, 24V Resistive
Connections
  120V Line
    Terminals 1 and 2
N. C. Contacts
  3 and 4
N. O. Contacts
  4 and 5
N. C. Contacts
  6 and 7
N. O. Contacts
  7 and 8

Table 5. Specification for Under Voltage Relay Continued.

Contacts shown in fault (drop-out) at 120V and below
Contacts transfer (pull-in) at 110 Volts or more
Temperature Limits
-66°C to +86°C
Temperature Trip Affects
-65°C - ± 1%
85/C - ± 1°Xc

c. Refer to table 6 (specifications for (K15) short circuit relay) and use the test procedure below to checkout the relay.

(1) Connect a light series with a suitable power source to terminals 5 and 6 and in like manner to terminals 7 and 8. Relay trip will be indicated by the two lights. The one to 5 and 6 will go out and the one to 7 and 8 will turn on.

(2) Connect a source of variable AC voltage between terminals l and 4, 810wly advance voltage. Relay shall trip when voltage equals or exceed 20V. Repeat the test with the input connected to - and 4 and then again between 3 and 4.

d. Refer to the specifications in table 7 and test the reverse popover relay.

e. Test the governor paralleling control relay Kit, field flashing relay K5, parallel voltage control relay K7, and fuel level relay K8 then compare the results from each relay test with the specifications given in table 8.

f. Test (K3) Crank limit relay and (K9) circuit breaker control relay; then check the results with the specifications found in Table 9.

79. Disassembly and Reassembly

Refer to figure 129 to disassemble and reassemble the relay box.

80. Relay Box Installation

Refer to figure 129 to install the relay box.

Table 6. Specifications for Short Circuit Relay

Phase
3 Phase short circuit detection circuit that senses a short circuit in any 1 phase or all 3 phases.
Input connection
Arranged in "Y"

Table 6. Specification for Short Circuit Relay- Continued

Input requirements
Frequency - 60-400 CPS
Note. Relay shall trip when voltage on any phase to neutral equals or exceeds 20V and will stay tripped if voltage remains.
External Power Required
No additional power required.
Contacts
One N. O.
Transfer on short circuit
Contact Rating
10A, 28 VDC
Connections
Input voltage
Terminal 1, 2, 3, (3 phases)
Neutral
Contacts
5 and 6 N. O.
7 and 8 N. O.
Temperature Range
55°C to +70°C
Temperature Limits
-65°C to 86°C
Temperature Trip Affects
-66°F - - 2*o
+85°C - + 8%

Table 7. Specifications for Reverse Power Relay

D. C. Input Voltage
0-10 Volts
A. C. Voltage Superimposed On D. C. Input Voltage
Up to 20V
Reverse Trip Voltage
2 Volts
Reverse Polarity (Corresponds to Approximately 20-% Reverse Power)
Contacts
External Power Reqd-2
24 VDC, One N. C., One N. O.
(Transfer on reverse power)
Connections
Contact Rating
10A., 28 VDC Temperature range
-55°C to 70°C
Norm Input Voltage
Term. 1 Neg.
Term. 2 Pos.
External Power
Term. 3 Pos. 24V
Term. 4 Neg. 24V
Contacts
Term. 6 and 6 N. O.
Term. 7 and 8 N. C.
Temperature Limits
-65°C to 85°C
Temperature Trip Affects
-66°C - + 1.4V
+86 ° C - - .6V

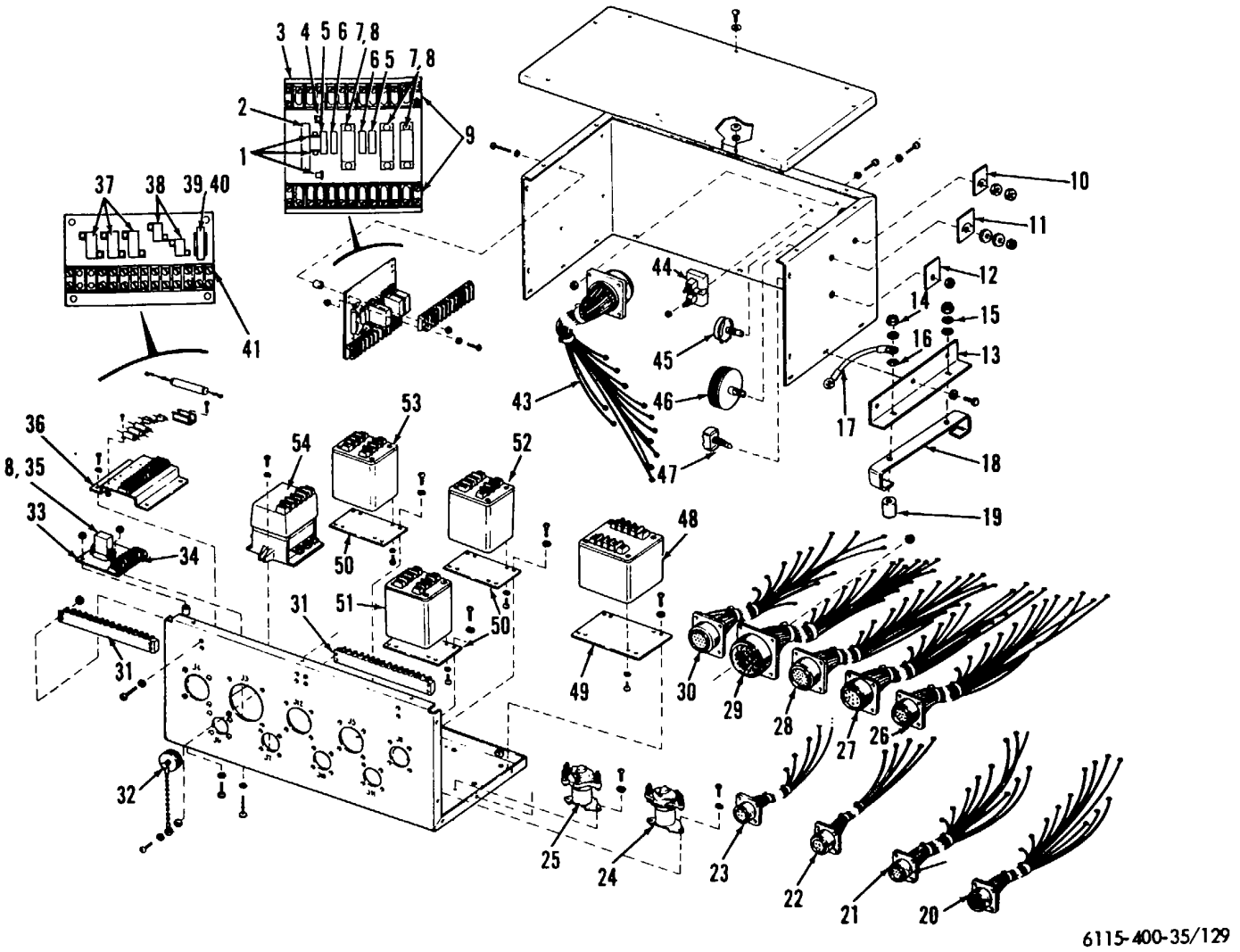


Figure 129. Relay brat-exploded vies,.

1 Diode
2 Resistor
3 Circuit board
4 Diode
5 Resistor
6 Resistor
7 Relay
8 Socket
9 Terminal board
10 Name plate
11 Name plate
12 Name plate
13 Bracket
14 Nut
16 Washer
16 Lockwasher
17 Cable
18 Stop
19 Mount
20 Plug assembly
21 Plug assembly
23 Plug assembly
24 Relay
26 Relay
26 Plug assembly
27 Plug assembly
28 Plug assembly
29 Plug assembly
30 Plug assembly
31 Terminal board
32 Cover
33 Circuit board
34 Terminal board
36 Relay
36 Bracket
37 Resistor
38 Resistor
39 Capacitor
40 Mount
41 Terminal board
42 Connector
43 Harness
44 Shunt

Figure 129-Continued.

Table 8. Specification for Governor Paralleling Relay, Field Flashing Relay, Parallel Voltage Control Relay, Fuel Level Relay, Lock-On Relay and Remove Sensing Relay.

Special Requirements: Relay must operate 100 consecutive times without failure with the two normally open contacts connected in series and interrupting 26 amperes to a load having a DC resistance of 1.0 ohms and having and inductance of 8-10 Millihenries.

Contact Ratings
Current, resistive load at
26.5VDC ..... 10 Amperes
Maximum Contact drop at
rated current ..... 100 Millivolts
Minimum operations with
rated current at 125°C 100,000
Temperature Range, Operating
and Storage ..... -65°C to +125°C
Operating Characteristics
Maximum pull-in voltage at
rated ambient temperatures ..... 18 volts DC
Minimum holding voltage at
rated ambient temperatures ..... 10 volt DC
Minimum drop-out voltage at
rated ambient temperatures ..... 1 volt DC
Maximum pull-in time at
26.5 VDC, and -65°C to +125°C 16 milliseconds
Maximum drop-out time at
26.6 VDC, and -66°C to
+126°C ..... 15 milliseconds
Electrical Data
Coil resistance at 25°C 300 ohms + 10%
Dielectric strength at sea level between all mutually insulated terminals and between all terminals and case ..... 1,000 volts A C
Minimum insulation resistance at 600 VDC 1,000 megohms

Table 8-Continued

Contact Arrangement
Double pole, Double throw
Case
Hermetically sealed
Terminals
Plug-in type
Weight
2 ounces maximum
Shock
intensity ..... 60 G
Vibration
10 to 2,000 CPS ..... 20 G

Table 8. Specifications for Crank limit Relay - (K8) and Circuit Breaker Control (k9)

Maximum Operating
Voltage .....29 Volts.....DC
.....18 Volts .....DC
Drop-Out Voltage .....7 Volts +0.-5.5.....DC
Rated Load
Resistive .....60 Amps.....DC
Inductive.....50 Amps.....DC
Motor .....60 Amps.....D C
Lamp .....26 Amps.....DC
Minimum .....6 Amps. .....DC
Coil current .....0.35 Amp.
Minimum Operating
Period .....3 Hours
Minimum Operating
Cycles 50,000
Maximum Weight.....0.6 Pounds
Rated Duty .....Continuous
Nominal Coil Voltage .....28 Volts.....DC

81. Paralleling Controls

Two potentiometers (EVER adjustment and KW adjustment) are mounted on the relay box. Refer to paragraph 93 for adjustments.

Section IV. CONTROL PANEL

82. General

a. The engine control panel and the generator control panel (see fig. 130) located on the rear of the generator set, contain the controls and instruments necessary for operation of the engine and generator. These control panels are grounded to protect the operator from electrical shock in case a short circuit occurs. The control panel is a hinged section that provides access to the interior of a generator control box. The control panel (control cubicle) is removable as a single unit; fasteners used to secure the cubicle to set structure have captive nests. The circuits of the cubicle are designed such that the set can be started, operated and monitored when the control cubicle is located at any distance up to 500 feet Freon the rest of the set with conductors in connect ing cables being AWG 16. All wires enter the cubicle through a single connector (J1, fig. 128).

b. Removal and Installation. Refer to figure 130 to remove and install the control panel and components mounted in cubicle.

c. Testing. Disconnect PI from J1 (fig. 128) and test wiring harness from control panel to relay box for continuity and possible short circuits.

d. Assembly and disassembly. Refer to figure 130 to disassemble and reassemble the control pane] and its components.

83. Frequency Meter and Transducer

a. General. The frequency meter consists of a converter and an indicator. The indicator has a 250 degree scale calibrated in cycles over the range of 48 to 62 cycles, inclusive, and scale divisions of 0.1 cycle. The needle rests on the deft hand edge of the scale when the instrument is de-energized. Alternating current voltage applied to the converter is transformed to a direct-current voltage which is proportional to the frequency of the alternating-current voltage and which is registered on the "D" Arsonval indicator. The converter is made of static components and is mounted within the control cubicle. The converter is connected across generator winding T9-T12, including any series exciter windings associated therewith.

b. Repair. Whenever a defect is found in either the frequency meter or the transducer; both must be replaced as a matched set.

84. Kilowatt Meter and Transducer

a. General.

(1) The kilowattmeter measures and indicates the power output to an accuracy of 3 percent of full scale value at 77°F from set no load to rated load current under the following conditions:

(a) Balanced load at any power factor from unity to 0.80, lagging.

(b) Unbalanced load, where the three phase voltages, currents, and power factors differ.

(c) With the output of any one phase equal to zero.

(2) The potential coils of the kilowattmeter are connected to the generator coils (and associate exciter series windings) with lowest potential above neutral when the generator is in the 240/416-volt connection.

b. Repair. Either the kilowattmeter or the transducer can be replaced, if defective, without replacing the other.

85. Relay Testing

Relay K1 (fig. 130) and relay K6 if 8USpected of being defective, should be tested and the results compared with the specifications found in Table 8.

86. Diodes

a. General. CR1 and CR2 (fig. 130 and fig. 1) are junction silicon rectifiers operating in connection with relays K6 and K1.

b. Testing. Refer to paragraph 73 (4).

87. AC Power Circuit Breaker

a. General.

(1) The ac power circuit breaker (fig. 131) is a circuit interrupter (C1) rated at 694 amperes at 240 volts and 347 amperes at 480 volts.

(2) The circuit breaker is mounted above the relay box and is connected between the voltage reconnection panel and the load connection terminals.

(3) The circuit breaker is electrically operated from the set 24 volt do system, by circuit breaker switch S3 (fig. 130) on the control panel. The AC power circuit breaker is a three pole, three phase device constructed so that the three sets of main contacts clone and open simultaneously through action of a common mechanism. It is not possible for any of these main contacts to remain closed while others are open. Suitable auxiliary contacts are included to prevent interconnection of governor and voltage regulator circuits of machines being operated in parallel, until the circuit interrupter

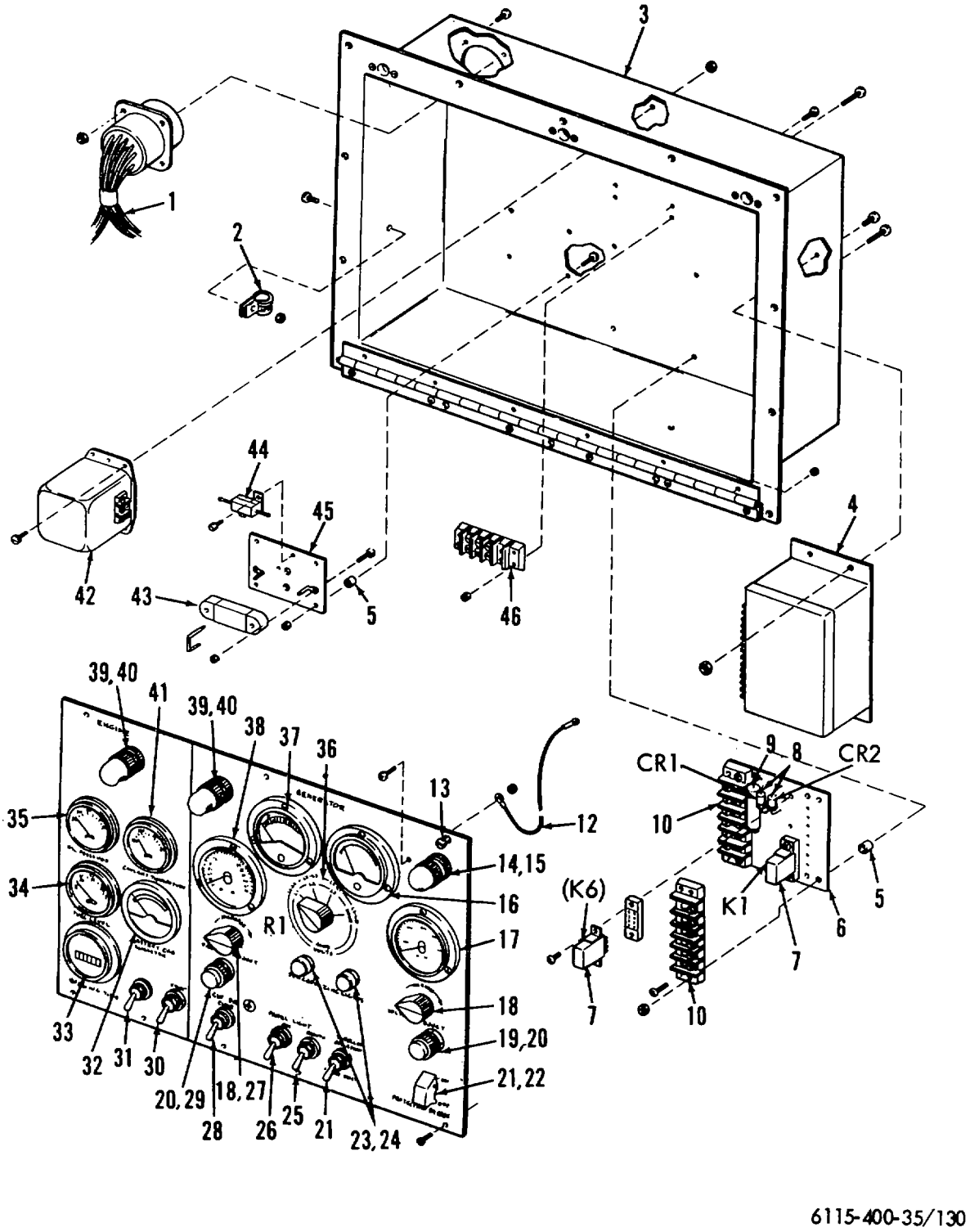


Figure 130. Control pane! and cubicle contents.

1 Wiring harness
2 Clamp
S Control box
4 Converter
6 Spacer
6 Circuit board
7 Relay
8 Diode
9 Resistor
10 Terminal board
11 Socket
12 Cord
13 Fastener
14 Lampholder
16 Lamp
16 Ammeter
17 Voltmeter
18 Knob
19 Light assembly
20 Lamp
21 Switch
22 Guard
23 Lampholder
24 Lamp
26 Switch
26 Switch
27 Rheostat
28 Switch
29 Light assembly
30 Switch
31 Switch
32 Ammeter
33 Meter
34 Gage
36 Gage
36 Switch
37 Wattmeter
38 Meter
39 Lampholder
40 Lamp
41 Gage
42 Transducer
43 Flasher
44 Resistor
46 Mounting board
46 Terminal board

Figure 130-Continued.

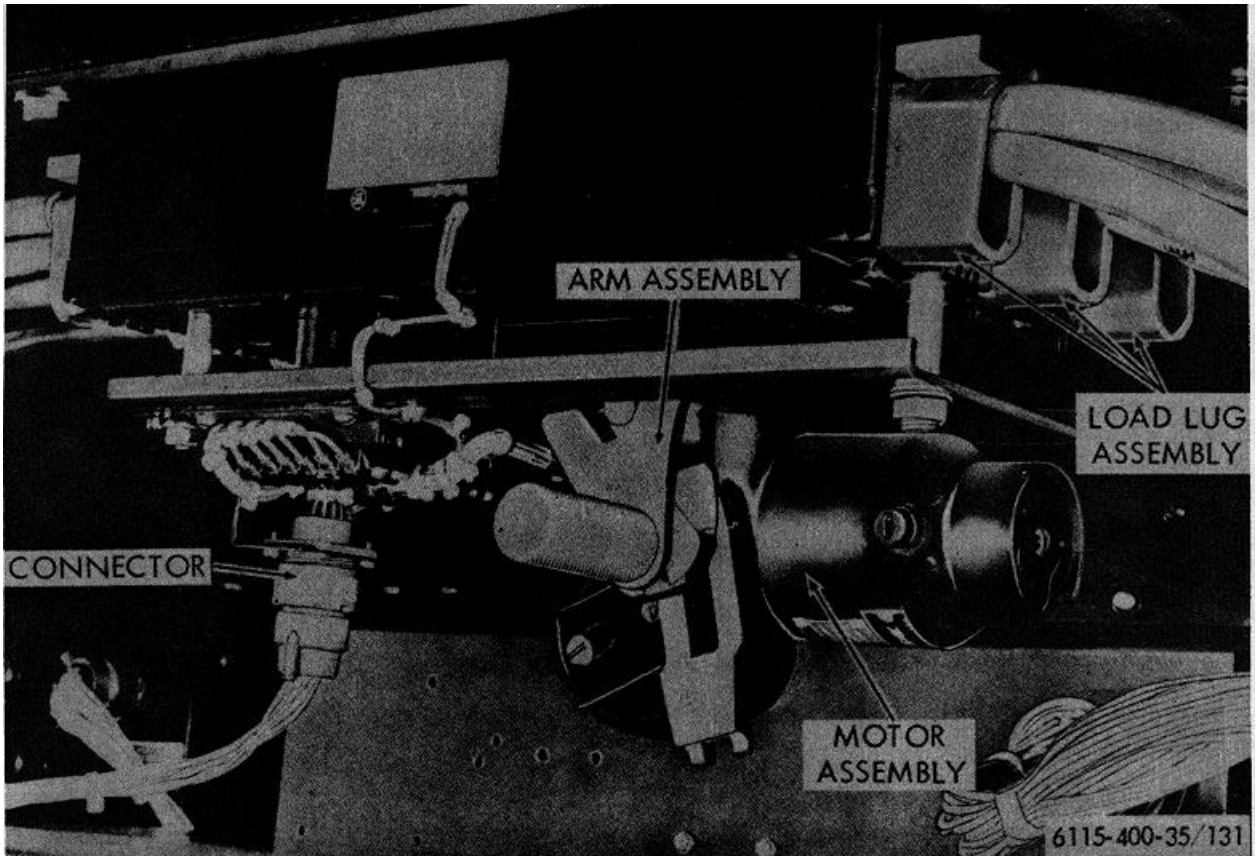


Figure 131. AC power circuit breaker.

is closed. Other auxiliary contacts are provided to perform control functions as required. The circuit interrupter is so connected that it will open automatically when either the circuit interrupter actuator switch or the master switch (on the control cubicle) is place] on the "OFF" position; this is accomplished independently from the underfrequency or any other protective device. Interrupting capacity of the main contacts are not less than 10 times rated current for the contacts.

b. Removal and Installation. Refer to Figure 131 to remove and install the AC power circuit breaker.

c. Testing.

(1) Refer to figure 128 and disconnect all cables and wiring harnesses from the circuit breaker.

(2) Test the ink connections, contacts, terminals and motor assembly for continuity, low insulation resistance and short circuits.

(3) Check the circuit breaker for manual operation.

d. Inspection and Repair.

(1) Inspect the circuit breaker for damaged terminals, defective insulation and other visible damage.

(2) Inspect the motor mechanism assembly for evidence of overheating.

(3) Inspect the assembly for cracks, breaks and other damage.

(4) Inspect threaded parts for defective threads.

(5) Replace defective parts as necessary.

Section V. ELECTRIC GOVERNOR

88. General

a. The electric governor is a speed (frequency) regulating device for the engine of the generator set. It offers fast response and minimum speed (frequency deviations) with load fluctuations. It features electrical frequency sensing, electrical load sensing, has static components, and no electronic tubes. The governor is effective on load sharing and paralleling of two or mare engine generator sets on an isochronous basis.

b. The electric governor consists primarily of an electric control unit, a load measurement unit, and an electro-hydraulic throttle actuator.

Note. The electric governor features static magnetic components with inherent reliability. No routine replacement of static electrical components should be necessary.

89. Electric Control Unit

a. General. The electric control unit (fig. 132) contains a transistor inverter, magnetic amplifier circuit; a frequency sensing and frequency reference circuit, a throttle position feedback circuit, and a paralleling circuit.

(1) Figures 1 and 128 illustrate the connections of the control unit to other components.

(2) The transistor inverter inverts 24 VDC to approximately 1000 cps AC through the use of a transistor oscillator circuit. The 24 volt 1,000 cps output from the inverter is applied to the magnetic amplifier power winding.

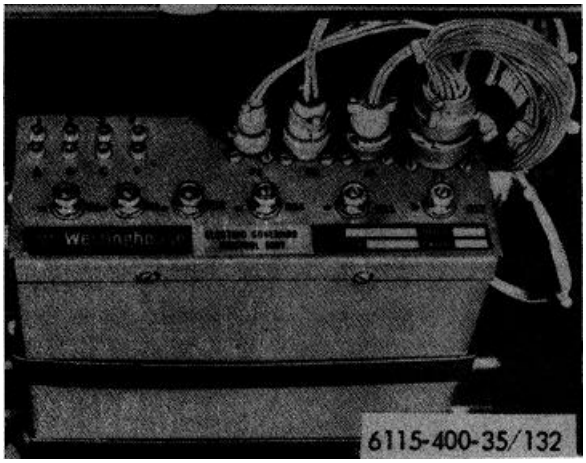


Figure132 Electric governor control unit.

(3) The magnetic amplifier, operating at 1,000 cps, has 4 control windings and an output or power winding. Its purpose is to mix or totalize the control error signals and amplify the result for use by the servo actuator. The control windings include frequency error winding, negative feedback winding, load sharing winding, and bias winding. The level of these DC control windings affects the output of the power winding which is the input to the electro-hydraulic actuator.

b. Removal. Refer to figure 132 to remove the electric control unit.

90. Load Measurement Unit

a. The load measurement unit, consisting of a three phase transformer, diode rectifiers and a load resistor, measures the total load on the generator set regardless of power factor or phase. The DC output of this unit is connected to the feedback and paralleling circuits of the LEH control unit.

b. Figure 1 and 128 show the connection of the load measurement unit to other components.

c. Removal and installation. Refer to figure 133 to remove and install the load measurement unit.

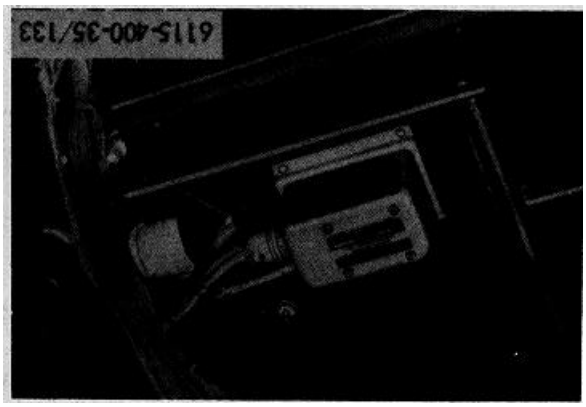


Figure 133. Load measurement unit.

d. Testing.

(1) Test the load resistor using an ohmmeter.

(2) Test the transformer for continuity using an ohmmeter.

(3) Test the transformer for grounds by testing between one lead of each winding and the core with a multimeter.

(4) Test the transformer for shorted windings by testing between one lead of the secondary winding and one lead of the primary winding.

(6) Refer to paragraph 73c (4) to test the diodes.

e. Inspection and Repair.

(1) Inspect the resistor for damaged terminals, defective insulation and other visible damage.

(2) Inspect the transformer for cracks, breaks, broken terminals and evidence of overheating.

(a) A defective load measurement unit should be replaced.

91. Electro-Hydraulic Actuator

a. General.

(1) The actuator (fig. 134) receives its intelligence from the magamp output in the electric control unit and converts these signals to an actuator motion that positions the engine throttle properly. The actuator is composed of a control valve, a piston, and a linkage assembly.

(2) The electro-hydraulic control valve receives its control signals from the magamp output in the electrical control unit. The control valve converts the proportional push pull electrical input to a proportional push pull hydraulic output. The control valve requires a constant hydraulic input of 2 gallons/minute at 300 psi.

(3) The push pull hydraulic output of the control valve operates a piston. Whenever the push pull hydraulic signal is unbalanced, the piston will move in a direction depending upon

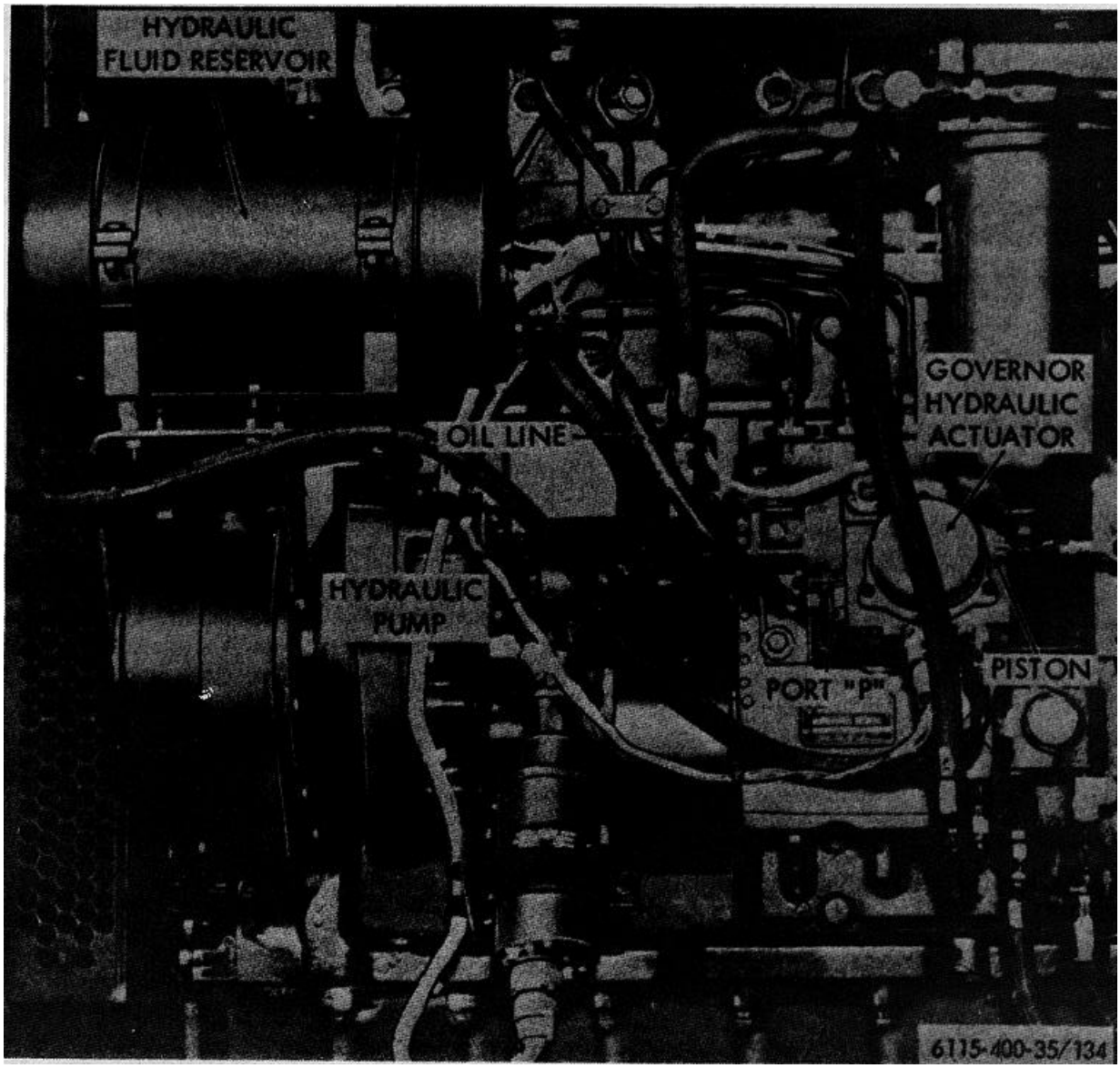


Figure 134. Electric governor hydraulic actuator.

which pressure is higher and will continue to move until

either the piston reaches the limit of its travel or the push pull pressures become equal. The velocity of piston movement is dependent upon the magnitude of pressure unbalance.

(4) The linear piston motion is used to drive the throttle. A connecting link is attached to the piston which moves the throttle position indicating transducer. The throttle position indication is positively connected to the output shaft so that the position indicating circuit gives an output exactly proportional to the throttle position.

b. Removal. Refer to figure 134 to remove the electric governor hydraulic actuator.

c. Cleaning, Inspections and Repair.

(1) Clean the hydraulic actuator filter every 200 hours or sooner if found

necessary. This filter contained within the filter housing at port "P" (fig. 134) of the hydraulic actuator and may be removed by removing the housing and screwing the filter out of the housing.

(2) Clean the assembly with an approved solvent and dry thoroughly.

(3) Inspect for cracks, breaks, leaks, freedom of movement of the linkage, and other damage.

(4) Replace a damaged or defective actuator.

d. Installation.

(1) Before installing the actuator, check the force required to move the engine throttle shaft. Any binding, sticking, or undue friction will deteriorate the performance of the electric governor.

(2) After bolting the unit to the engine the actuator piston is connected to the throttle or fuel rack linkage and adjusted so that the actuator is able to move the fuel control from full closed to full open position. Proper governor operation depends on correct adjustment of this motion. In locking these adjustments, extreme caution should be exercised to prevent twisting the piston since a means has been included in the actuator to prevent the piston from turning. Any twist introduced at the time of the connecting to the throttle linkage could place a side load on the mechanism and thereby add un-desirable binding or friction. After installation, check actuator for free movement.

(3) The throttle position transducer located on the actuator is factory aligned to the piston travel, and, therefore, should not need adjustment on a new installation.

92. Hydraulic System

a. General.

(1) The hydraulic pier supply (fig.. 134) consists of a hydraulic fluid reservoir, a hydraulic pump, and necessary line connections; the oil reservoir Capacity is about 1 gallon. The pump is driven by a power takeoff on the accessory drive.

(2) Hydraulic power is supplied to the hydraulic throttle actuating unit where it is converted to useable control pressures. The output pressure of the hydraulic power supply is between BOO and 850 pounds per square inch with the engine operating at rated -peed.

b. Cleaning and Inspection.

(1) Periodically, check the oil level in the hydraulic power supply.

(2) Change the hydraulic oil when it appears dirty. Replenish with MILL 0-5606 hydraulic fluid or SAE 10 oil.

(3) Check condition of the hydraulic oil filter. This is integral with the filter housing located in pressure port "P" of the hydraulic actuator. To remove filter, unscrew fitting and lift out. If dirty, the filter may be cleaned and re-inserted. Do not operate governor without filters except in case of emergency.

(4) Check for low oil pressure. Insert a pressure gage (0-500 psi) in the oil line running from the pressure port "P" of Me hydraulic supply to the pressure port "P" of the hydraulic actuator. With engine operating at rated speed (either under manual or governor control), the output pressure of the hydraulic power supply should be 300-350 psi.

c. Removal and Installation. Refer to figure 134 to remove and install the components of the hydraulic system.

93. Alignment of Electric Governor

a. General. The electric adjustments required at installation are made with potentiometers listed below:

Ref Designator	Description	Location
R11	Magamp bias balance adjustment (frequency null adjustment)	Electric governor control unit (fig. 132)
R12	Magamp bias level adjustment	Electric governor control unit
R14	Feedback null adjustment	Electric governor control unit
R16	Load measurement gain adjustment	Electric governor control unit
R16	Feedback gain adjustment	Electric governor control unit
R18	Frequency gain adjustment	Electric governor control unit
R1	Frequency adjust control panel	Generator set (fig. 180)
R14	Kilowatt adjust	Relay box (fig. 186)
R15	KVAR admit	Relay box

b. Isochronous Operation.

(1) With the engine not operating, set R1, R11, R14 (on governor control unit), R16 and R18 at mid-point by turning full each way and approximately the center. Set R16 (on governor control unit) full counterclockwise. Set R12 approximately 3/4 counterclockwise.

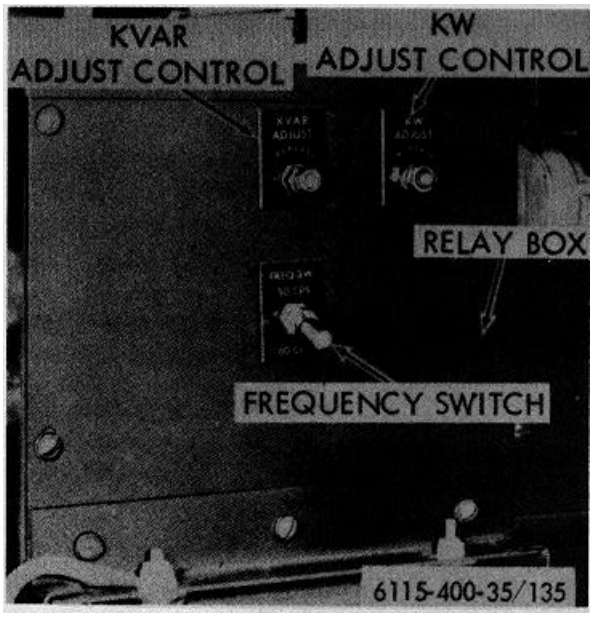


Figure 135. KFAR adjust and KW adjust.

(2) Start engine. If engine hunts, adjust until operation is stable. Possible adjustments are:

(a) If hunt is of high frequency and small amplitude possible cause is that the magamp bias level is too high. Adjust R12. counterclockwise adjustment raises bias level; clockwise adjustment reduces bias level.

(b) If hunt is of high frequency and small amplitude, possible cause could be too much feedback again. Adjust R16. Counterclockwise adjustment decreases gain; clockwise adjustment increases gain (c) If hunt is of low frequency and long amplitude, cause could be too much frequency gain. Adjust R18. Counterclockwise adjustment reduces the gain; clockwise adjustment increases the gain. If frequency gain reduction by turning R18 counterclockwise does not stop this type of hunt, a need for additional feedback gain may be indicated. Increase feedback gain by turning R16 clockwise. Also if the reduction of frequency gain and/or increase of feedback gain did not stop the slow hunt, an increase in magnetic amplifier bias level may be indicated; turn R12 more counterclockwise. If none of these adjustments stabilize the system, insufficient capacitance in C8 located in relay box may be indicated. Increase capacitance and repeat above adjustments.

(d) Load sensing gain R16 not set properly.

(3) Once set has been stabilized, connect a d.c. voltmeter (0-10 volt range) across test points 3 and 4 (4 is positive). Adjust R1 until frequency is 60 cycles (or 50 cycles) and then adjust R14 until voltage across test points 3 and 4 is zero volts at no load.

(4) Connect d.c. voltmeter across test points 1 and 2 (1 is positive). Adjust R11 and R1 for zero volts at 60 cycles (or 50 cycles). Repeat adjustment until voltage across test points 3 and 4 and 1 and 2 is zero volts and frequency is 60 cycles (or 50 cycles) with no load on the engine. If test points 1 and 2 cannot be zeroed, they must be reduced to a minimum.

(5) R12 should be adjusted to give about 5 volts across test points A and B. If this voltage is too low, response will be sluggish and if it is too high, a rapid oscillation may be caused. Exact value will depend upon engine characteristics. Normal range is from 4.5 to 6 volts.

(6) R15, the load measurement gain control, is adjusted for optimum transient performance. Fully clockwise position is maximum load measurement gain.

(7) For optimum performance R18 (frequency gain) should be set as far clockwise as possible and R16 (feedback or stability gain) set as far counterclockwise as possible without causing an oscillation for any setting of R15. Where sensitive frequency recording instruments are available the adjustments of R15, R16 and R18 can be adjusted for the desired transient shape to meet desired specifications of time and frequency deviation. The value of capacity at C8 (fig. 127) also affects the transient frequency response. Smaller values of capacity will give faster response; however, if C8 is too small the system will oscillate.

(8) Increasing the load measurement gain R15 (clockwise direction) will improve transient performance; therefore, it should be adjusted as high as possible. The adjustment of R18, R16, and R15 are interdependent. For any position of R18, there is an optimum position for R16. Therefore to improve transient performance increase frequency gain by turning R18 clockwise. If a hunt develops, re-adjust R16 for stability. If no hunt develops, apply and reject load to check for stability under transient conditions. Assuming that no hunt develops for increase in frequency gain (R18, CW) or that the hunt can be removed by re-adjustment of feedback gain (R16), again increase frequency gain R18 and note transient performance. Finally, a position may be reached where no readjustment of the feedback gain R16 can stabilize for the high frequency gain R18. Then reduce the frequency gain to the stable region and optimize stability and performance with the feedback gain R16. (It is recommended that the frequency gain be reduced to a point where the system is not on the edge of instability for long term stable operation). Transient performance improves as the frequency gain R18 is a minimum for that particular position of frequency gain adjustment. For any particular position of the frequency gain R18, there is an optimum position of feedback gain R16. If the feedback gain is reduced too much (R16 too far CCW) there will be insufficient feedback to stabilize the operation at steady state. If instability is reached (a slow oscillation in comparison with another to be mentioned) turn R16 clockwise until stability is reached. This is the optimum setting for that level of frequency gain. If R16 is turned too far clockwise, a very fast oscillation (faster than the oscillation mentioned above) may occur. Turn R16 counterclockwise to the optimum point previously mentioned. This faster oscillation may not be apparent from the sound of the engine or observation for the frequency instruments. Visual observation of the throttle movement is recommended.

(9) Should the steady state frequency at full load be slightly higher than the no load steady state frequency and adjustments of R11, R12, R16 and R18 will not correct this condition, adjust R1.

c. Parallel Operation.

(1) The voltage at test point 3 and 4 should again be checked for zero volts with no load on engine.

(2) Apply full load to engine and connect a d.c. voltmeter to paralleling receptacle terminals A and B on the rear of the control panel. Terminal A is positive.

(3) Adjust R14 (kilowatt adjust on relay box) through its range. With the parallel switch on, the voltmeter should indicate 5 to 10 volts as R14 is adjusted. Note and record the maximum voltage at full load. Be certain frequency is exactly 60 or 50 cycles.

(4) Repeat the above procedure on the other generator and governor to be paralleled.

(5) Set the paralleling voltage at A and B of both generator sets to be paralleled to the maximum equal voltage by adjusting R14 of each making certain the paralleling lines are not connected together when this is done.

(6) When the voltage A and B are equal on both sets these lines may be tied together by installing the paralleling cable. Sets are now ready to be paralleled isochronously and to share loads equally using standard paralleling procedures.

(7) Should sets tend to oscillate during parallel operation, R14 on each set should be adjusted for a lower equal voltage at A and B when sets are not in parallel operation and paralleling cables not connected.

(8) Parallel operation should again be attempted with this lower voltage at A and B as in step 6 above.

(9) Should other than equal sharing of loads be desired, adjust R14 voltage to this ratio prior to parallel operation. R14 should not be adjusted during parallel operation unless absolutely necessary; however, if a slight readjustment of load sharing between the paralleled machines is necessary it can be done with R14 while they are operating in parallel.

Section VI. OVERSPEED GOVERNOR

94. General

a. The overspeed governor (fig. 136) is an engine protective device with a manual reset.

It is coupled through an angle adapter to the upper shaft of the accessory drive. The governor is driven at one-half engine speed (900 RPM) and will trip between 120 and 125 percent of the engine rated speed. The trip speeds are as follows:

	Engine Speed	Governor Speed
Overspeed	2160 RPM	1080 RPM
Overspeed	2250 RPM	1125 RPM
Hydraulic governor switch	1400 RPM	700 RPM
Field flash and cranking	600 RPM	300 RPM

b. Removal and Installation. Refer to TM 5-6115-400-12 for removal and installation of the overspeed governor.

c. Cleaning, Inspection, and Repair.

(1) Clean all metal parts thoroughly with an approved cleaning solvent.

(2) Dry thoroughly and take care to prevent damage to the highly machined surfaces during cleaning. Keep solvent away from non metallic portions of electrical components.

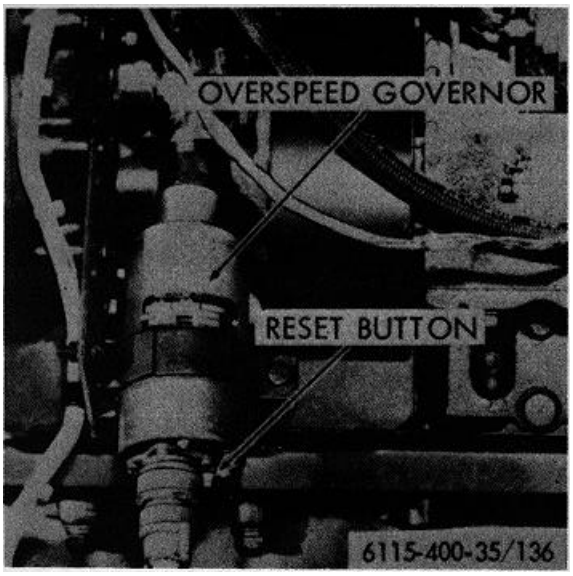
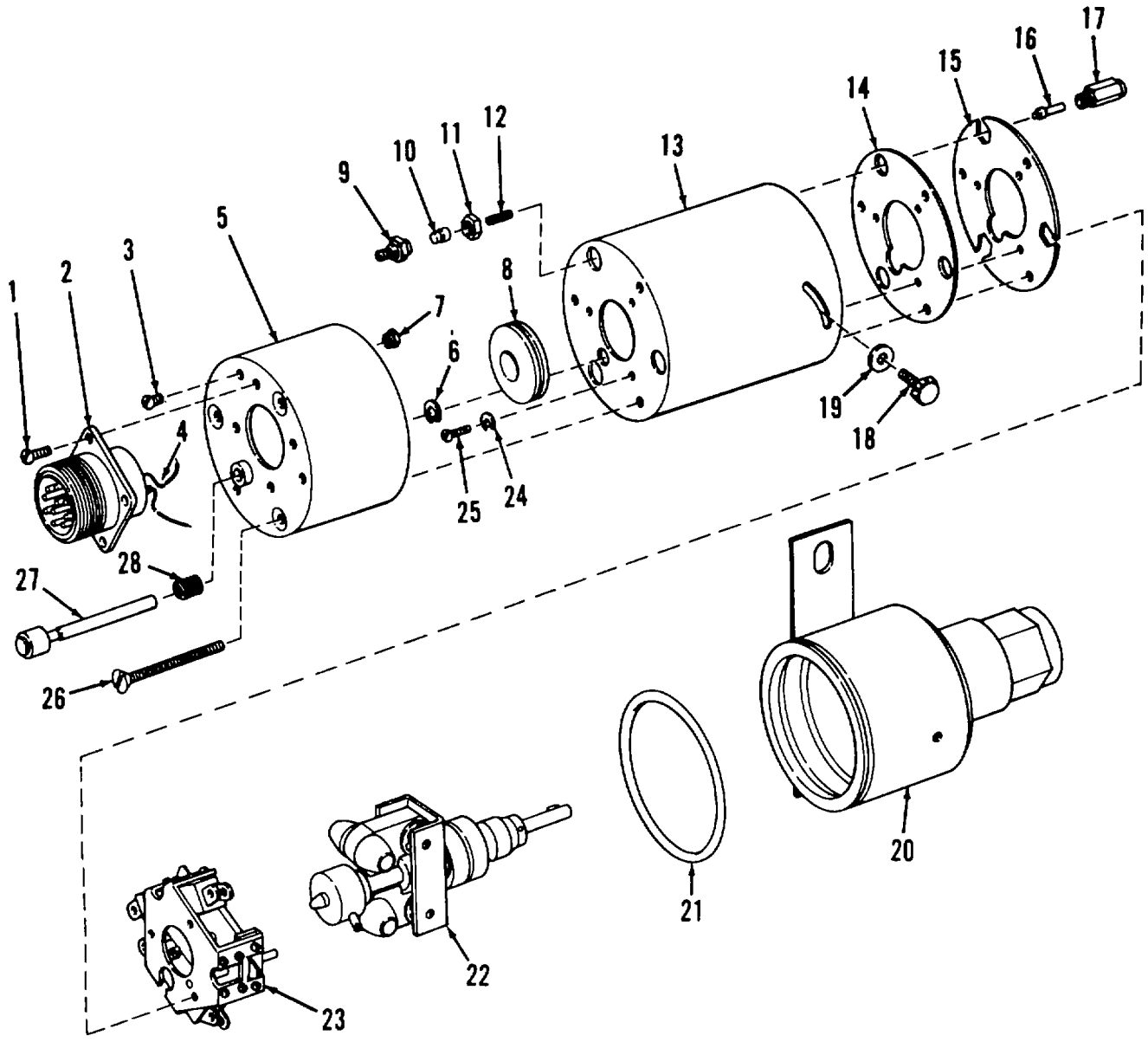


Figure 136. Overspeed governor.

(3) Inspect the terminals and contacts oh the switch assembly and the electrical connector.

(4) Inspect all parts for visual defects. Replace any part which is visually defective.

d. Assembly and Disassembly. Refer to figure 137 to assemble and disassemble the overspeed governor.



6115-400-35/137

1	Screw	11	Nut	21	Packing
2	Connector	12	Spring	22	Rotor assembly
3	Screw	13	Cap	23	Switch assembly
4	Electrical lead	14	Washer	24	Lockwasher
5	Dust cover	15	Plate	25	Screw
6	Retaining ring	16	Pin	26	Screw
7	Nut	17	Housing	27	Stud
8	Grommet	18	Screw	28	Spring
9	Nut assembly	19	Washer		
10	Cap	20	Body		

Figure 157. Overspeed governor-exploded view.

APPENDIX I
REFERENCES

1. Fire Protection

TB 5-4200-200-10	Hand Portable Fire Extinguisher.

2. Lubrication

C 9100-1L	Petroleum, Petroleum Base Products and Related Materials.
LO 5-6115-400-12	Lubrication Order.

3. Operating Instructions

TM 5-6115-400-12	Operator and Organizational Maintenance Manual

4. Painting

TM 9-213	Painting Instructions for Field Use.

5. Preventive Maintenance

TB ENG-347	Winterization Techniques for Engineer Equipment.
TM 5-764	Electric Motor and Generator Repair.
TM 38-7560	Army Equipment Record Procedures.

6. Radio Interference Suppression

TM 11-483	Radio Interference Suppression.

INDEX

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A1	THERMAL WATT CONVERTER
A2	FREQUENCY TRANSDUCER
A3	FLASHER PC BOARD ASSY
A4	CONTROL BOX PC BOARD ASSY
A5	RELAY BOX PC BOARD ASSY
A6	RESISTOR PC BOARD ASSY
A7	GOV PARALLELING CONT PC BOARD ASSY
B1	MOTOR OPERATOR SEE C1
B2,B3	FAN AND PUMP MOT SEE HR
B4	STARTER MOTOR SEE STR
BT1 THRU BT4	BATTERY/4 UNITS MS35000-4
C8	CAPACITOR SEE A6
CAM SW	CAM SWITCH SEE C1
CB1 AND CB2	HTR CKT BKR SEE HCB MS-25017
CCCT	CROSS CURRENT COMPENSATING XMFR
CHG GEN	CHARGING GENERATOR
C1	CIRCUIT INTERRUPTER
CR1 AND CR2	SEE A4 MIL-S-19500 IN 1695
CR3 THRU CR5	SEE A5 MIL-S-19500 IN 1695
CR6	SEE A5 MIL-S-19500 MR1033A
CT1 THRU CT3	CONTROL TRANSFORMER
DCCP	DC CONT POWER CKT BREAKER
DS1 THRU DS5	PANEL LT ASSY
DS6,DS7	LT ASSY PRESS TO TEST
DS8,DS9	LT ASSY PRESS TO TEST SEE HCB
F1	FAULT INDICATOR 13205E4770
FP	FUEL PUMP/4 UNITS MS51321-2
FSR	FLASHER SEE A3
F	15A FUSE MS90079-7
GA	HYDRAULIC ACTUATOR 13214E7672
GCU	GOVERNOR CONTROL UNIT 13214E7670
GEN	GENERATOR ASSY 13214E7163
	GENERATOR
CVT1 THRU CVT3	CUR V XMFR 13214E7155
FDB	FIELD DIODE BOX 13214E8693
CR1,CR3,CR5	MIL-S-19500 IN1190A
CR2,CR4,CR6	MIL-S-19500 IN1190AR
LR	LINEAR REACTOR 13214E7156
RI3	MIL-R-26 RW33V250
RI5	MIL-R-26 RW33V100
SP2	13214E7158
T4	TRANSFORMER 13205E4822
HCB	HEATER CONTROL BOX 2/UNITS 13212 E3155
HR	ENGINE HEATER 13214E7385
K1	LOCK-ON RELAY SEE A-4 13211E6944
K2	OVERVOLTAGE RELAY
K3	CRANK LIMIT RELAY
K4	GOV PAR CONT RELAY SEE-A7 13211E6944
K5	FIELD FLASHING RELAY SEE-A5 13211E6944
K6	RMTE SENSING RELAY SEE-A5 13211E6944
K7	PARALLEL V CONT REL 13211E6944
K8	FUEL LEVEL RELAY SEE-A5 13211E6944
K9	CIRCUIT BREAKER CONTROL
K11	UNDERVOLTAGE RELAY
K12	STARTER RELAY SEE STR
K13	SHORT CIRCUIT RELAY
K14	OVERLOAD RELAY
K15	REVERSE POWER RELAY
K16	C1 RELAY
K21A	RMTE SENSING REL ACTR (GFE)
K21 AND K22	RMTE SENSING REL (GFE)
L1 AND L2	FUEL SHUTDOWN SOL. 13214E7485
L3	ETHER STARTING AID SOL. 13214E7480
L4,L5	FUEL SOL. SEE HR
LMU	LOAD MEASUREMENT UNIT 13214E7671
LP	LOAD CONNECTION PANEL 13214E7604
M1	PRESSURE INDICATOR
M2	TEMPERATURE INDICATOR
M3	LIQUID LEVEL INDICATOR
M4	BAT. CHARGING DC AMMETER
M5	RUNNING-TIME METER
M6	FREQUENCY METER
M7	WATTMETER
M8	AC AMMETER
M9	AC VOLTMETER
MT1	OIL PRESSURE SENDING UNIT
MT2	WATER PUMP SENDING UNIT
MT3	FUEL GUAGE TRANSMITTER
PR	PARALELLING RECEP/2 UNITS
PVCS	PARALELLING V CONT SYS
R1,R2	FREQ/VOLT ADJUST
R3,R8 SEE A5,A6	MIL-R-26 RW68V152
R4,R7 SEE A5	MIL-R-26 RW68V242
R5,R6 SEE A5	MIL-R-26 RW68V512
R9,R10 SEE A6	MIL-R-18546 RE70G3000
R11 THRU R13	MIL-R-26 RE75G7R50
C4	MIL-C-12889 CA36KFW104
D1/4 UNITS	MIL-S-19500 1N1908
D3	MIL-S-19500 1N4723
D5/4 UNITS	MIL-S-19500 1N2107
D6	MIL-S-19500 1N2864
D7/2 UNITS	"DOUBLER" 13214E7162
L1	REACTOR 13205E4836
Q1	MIL-S-19500 2N1132
Q2	MIL-S-19500 2N2646
R1	MIL-R-26 RW33V501
R3	MIL-R-26 RW59V201
R4	MIL-R-26 RW59V392
R5,R12	MIL-R-26 RW59V502
R6	MIL-R-26 RW59V100
R7	MIL-R-26 RW59V200
R10,R17	-R-26 RW59V272
R11	MIL-R-26 RW33V252
R16	MIL-R-26 RW33V250
R15	MIL-R-26 RW33V100
R18	MIL-R-26 RW33V102
SCR	MIL-S-19500 2N1774A
SP1	13214E8718
T1	13214E8706
T2	13214E8709
T3	13205E4809
Z1	MIL-S-19500 IN1525A
Z2	MIL-S-19500 IN1526
VR2	VOLT REG ASSY-DC- 13214E7650

NOTE: NUMBERS SHOWN WITH >> SEE WIRING DIAGRAM JACK PART NUMBERS

R14 AND R15	KW/KVAR ADJUST
R16	FLASHER — SEE A3
RCN	RECONNECTION PANEL
RSU	RMTE SENSING UNIT (GFE)
S1	ETHER START SWITCH
S2	START-RUN-STOP SWITCH
S3	CKT BKR SWITCH
S4	PANEL LIGHT SWITCH
S5	RMTE SENSING UNIT SW
S6	PARALLEL VOLT CONT SW
S7	PROTECTION BYPASS SW
S8	VA SELECTOR SW
S9	50-60 CYCLE SW
S10 AND S11	HEATER SW SEE HCB
S12	FUEL LEVEL SWITCH 13214E7348
S13	WINTER THERMO SW 13214E7804
S14 AND S15	OVERHEAT SWITCH SEE HR
S16 AND S17	FLAME SWITCH SEE HR
S18	OIL PRESSURE SW 13214E7446
S19	WATER TEMP SW 13214E7443
S20	SPEED SW 13214E7435
SH	SHUNT 13214E7668
SR	SLAVE RECP MS 75058-1
STR	ENGINE STARTER 13214E7545
VR1	VOLTAGE REG ASSY 13214E7159

VOLTAGE REGULATOR

C1,C3,C5	MIL-C-18312	CH04AINC405K
C2	MIL-C-25	CP09AIKC474K3
C3'	MIL-C-18312	CH04AINC205K

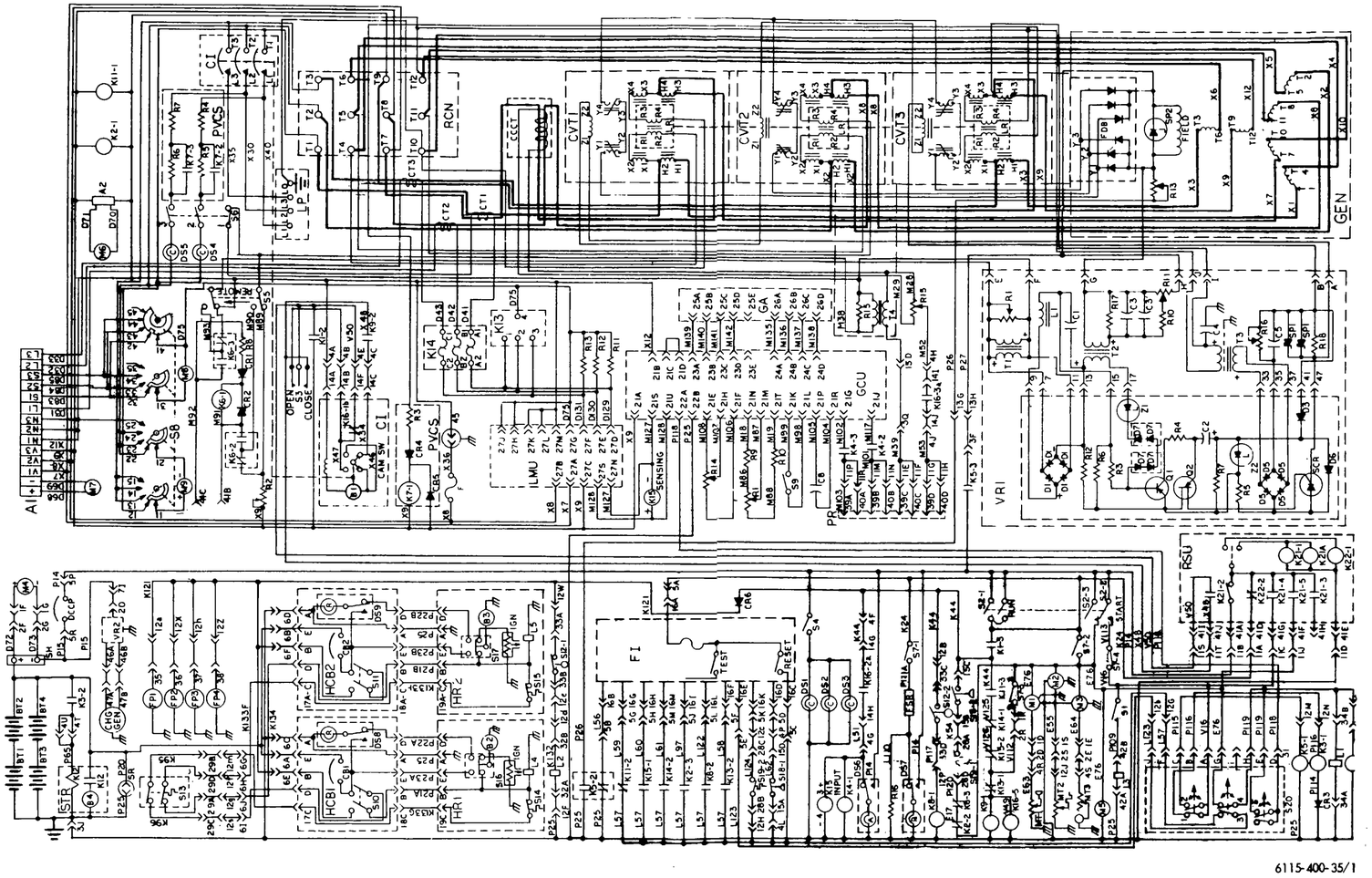
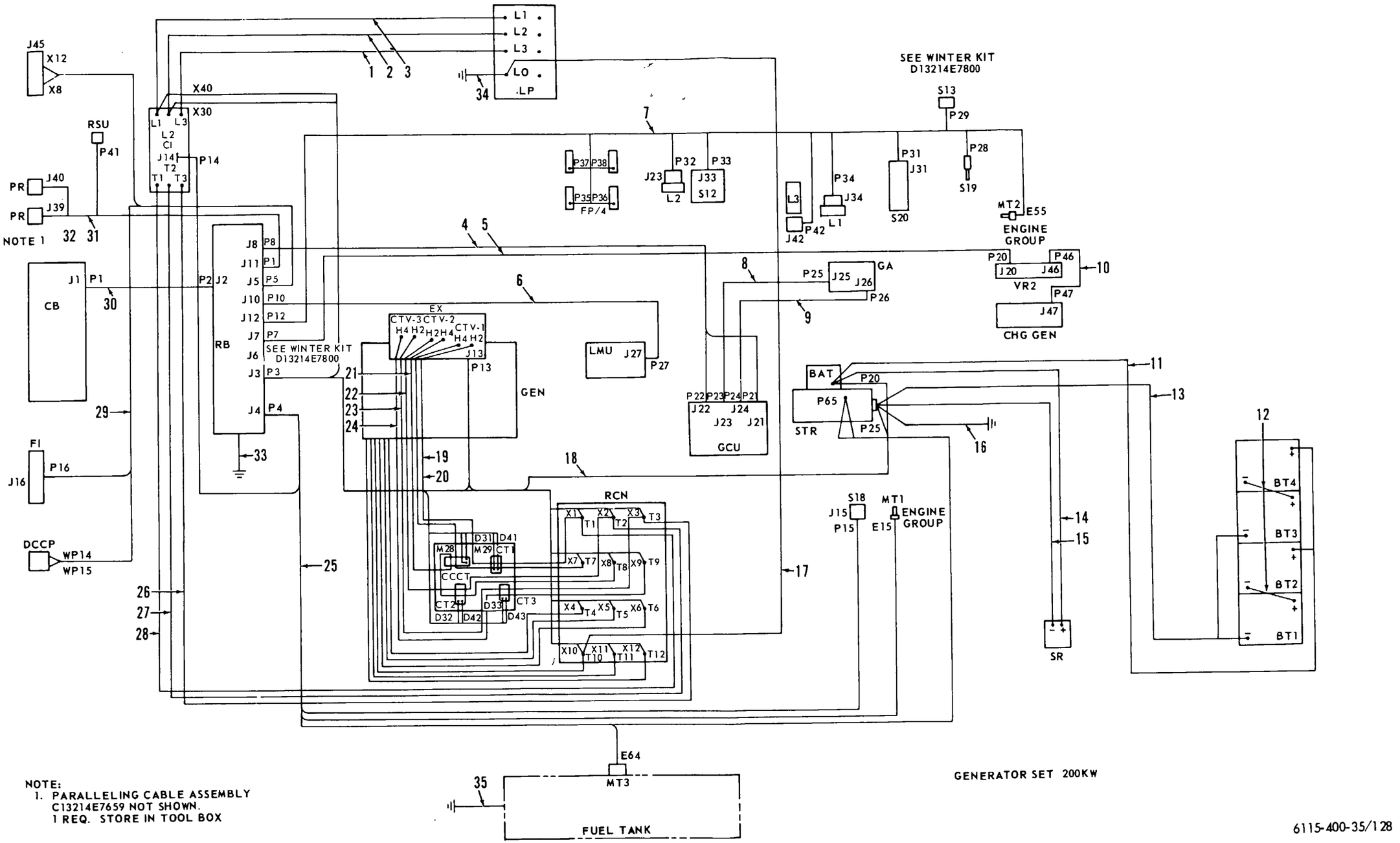


Figure 1. Schematic wiring diagram



NOTE:
1. PARALLELING CABLE ASSEMBLY C13214E7659 NOT SHOWN. 1 REQ. STORE IN TOOL BOX

6115-400-35/128

Figure 128. Wiring diagram-interconnecting wiring harness

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS

THEN...JOT DOWN THE DOPE ABOUT IT ON THIS FORM. CAREFULLY TEAR IT OUT, FOLD IT AND DROP IT IN THE MAIL.

SOMETHING WRONG WITH PUBLICATION

FROM: (PRINT YOUR UNIT'S COMPLETE ADDRESS)

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BE EXACT PIN-POINT WHERE IT IS

PAGE NO.	PARA-GRAPH	FIGURE NO.	TABLE NO.

IN THIS SPACE, TELL WHAT IS WRONG AND WHAT SHOULD BE DONE ABOUT IT.

PRINTED NAME, GRADE OR TITLE AND TELEPHONE NUMBER	SIGN HERE

DA FORM 1 JUL 79 2028-2

PREVIOUS EDITIONS ARE OBSOLETE.

P.S.--IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS AND GIVE IT TO YOUR HEADQUARTERS.

The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 decagram = 10 grams = .35 ounce
1 hectogram = 10 decagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	*To*	*Multiply by*	*To change*	*To*	*Multiply by*
inches	centimeters	2.540	ounce-inches	Newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	Newton-meters	1.356	metric tons	short tons	1.102
pound-inches	Newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

PIN: 025628-000