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NAVSHIPS 361-1458

Instruction Book

1500-KW A-C GEARED-TURBINE DRIVEN GENERATOR UNIT(S)

for

UNITED STATES OF AMERICA
NAVY DEPARTMENT

[illegible] AIRCRAFT CARRIERS

WESTINGHOUSE ELECTRIC CORPORATION
Steam Division
ESSINGTON, PENNSYLVANIA, U.S.A.

NAVY CONTRACT NObs-51436

WESTINGHOUSE ORDER [illegible]

INSTRUCTION BOOK 1430-C45[illegible]

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NAVSEA 0361-LP-164-7002
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Replace the following pages in NAVSEA 0361-164-7000 with the enclosed change pages as follows:

1. Pages 127& 128: Remove and replace with enclosed pages 127,127A, 128, and 128A.

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CHANGE INSTRUCTIONS
NAVSEA 0961-LP-005-1001
1500 KW ac STEAM TURBINE DRIVEN GENERATOR SET

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7 June 1968

INSTRUCTION SHEET

TECHNICAL MANUAL NAVSHIPS 361-1455

Ⓦ 1430-C45

CHANGE 1 JUNE, 1968

This change reflects the furnishing of the governor modification kits for installation on the 1500KW Geared-Turbine Driven Generators. Figure G-13 is the awaited illustration. The technical manual is changed as follows:

1. Title page: Remove and replace with attached Title page and page ii.
2. Page i: Remove and replace with attached page iii.
3. Pages 100.1 through 100.3: Remove and replace with attached pages 100.1 through 100.3.
4. Pages 109 through 112: Remove and replace with attached pages 109 through 112.
5. Insert attached Woodward Governor Bulletin 36002E immediately following page 112.
6. Insert attached Woodward Governor Bulletin 36404 (4 pages) immediately after Bulletin 36002E.
7. Pages 113 through 120: Remove and replace with attached pages 113 through 120.
8. Pages 133 and 134: Remove and replace with attached pages 133 and 133A.
9. Insert attached pages 133B and 134.
10. Insert attached Plan List Drawing 849A116 (21 pages) immediately after pages 135/136.
11. Pages 137 and 138: Remove and replace with attached pages 137 and 138.
12. Insert attached page 139.
13. Figure T-1: Remove and replace with attached Figure T-1.
14. Figure T-2: Remove and replace with attached Figure T-2 (4 sheets).
15. Figure T-12: Remove and replace with attached Figure T-12.
16. Figure T-13: Remove and replace with attached Figure T-13.

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INSTRUCTION SHEET (cont)

TECHNICAL MANUAL NAVSHIPS 361-1455

Ⓦ 1430-C45

CHANGE 1 JUNE, 1968

17. Figure T-14: Remove and replace with attached Figures T-14A and T-14B.
18. Figure T-20: Remove and replace with attached Figure T-20 (3 sheets).
19. Insert attached tab indices 34, 35 and 36 with attached corresponding foldout illustrations (Chapter 1).
20. Figure G-13: Remove and replace with attached Figure G-13 (Tab 5 in Chapter 2).
21. Insert this instruction sheet between cover and Title page.
22. Dispose of superseded pages and figures in accordance with current Navy Department directives.

Instruction Book

1500-KW A-C GEARED TURBINE GENERATOR UNITS

TURBINE(S) AND REDUCTION GEAR(S)
A-C GENERATOR(S)
D-C ROTOTROL(S) EXCITER(S)
GENERATOR VOLTAGE REGULATOR(S)
TEMPERATURE INDICATING EQUIPMENT

STANDARD NAVY STOCK NO. S-17-G-74645-6260

FOR

UNITED STATES OF AMERICA
NAVY DEPARTMENT

CVA 60 AIRCRAFT CARRIER

WESTINGHOUSE ORDER WG-70070-TPY

WESTINGHOUSE ELECTRIC CORPORATION
MARINE DIVISION
SUNNYVALE, CALIFORNIA. U.S.A.

MAY, 1955

INSTRUCTION BOOK 1430-C45

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CHAPTER 1
TURBINE, REDUCTION GEAR AND CONDENSING EQUIPMENT

SECTION A—TURBINE, REDUCTION GEAR AND CONDENSING EQUIPMENT CHARACTERISTICS

1-A-1 GENERAL APPLICATION

(a) Each unit consists of a high speed condensing turbine, arranged to drive an A-C generator and D-C-exciter through the medium of a double reduction gear, which serves to reconcile the high speed required for efficiency in the turbine to the lower practicable generator speed. The turbine reduction gear and generators are mounted on a common bedplate, to which are secured also the oil cooler, condenser etc. An outline arrangement plan of the units is shown in Figure T-1.

1-A-2 TURBINE RATINGS

(a) The nominal rating of each unit is 1500 kw on a 80% power factor, 3 phase, 60 cycle, 450 volt, a-c generator; including 10 kw on a 69.4 volt, 144 amp., d-c exciter.

(b) The turbine is designed to operate on steam at a throttle pressure of 1050 psig with 940°F total temperature, with an exhaust pressure of 2.5 inches Hg. The turbine is capable of operating with a maximum pressure of 1200 psig and 1000°F total temperature.

(c) The following steam consumptions are guaranteed when the units are operating under the designed steam conditions of 1050 psig, 940°FTT.

Load Kw	Exhaust Vac.	Steam Rate 16/Hr/kw
375	28.78 inches	15.00
900	28.28 inches	9.75
1125	28.04 inches	9.55
1500	27.50 inches	9.40

(d) Gland sealing steam, supplied from a separate source of approximately 10 psig, is required at loads below 300 kw. The required quantity of sealing steam will vary up to a maximum of 51 lb/hr, at no load. The normal gland sealing pressure is 1-2 psig.

(e) The gland leakage to the gland condenser is as follows:

At full load:	HP gland	14 lb/hr Steam (1370 BTU)
		5 lb/hr Air
	LP gland	6 lb/hr Steam (1370 BTU)
		5 lb/hr Air
At 1/4 load:	HP gland	6 lb/hr Steam (1337 BTU)
		5 lb/hr Air
	LP gland	6 lb/hr Steam (1337 BTU)
		5 lb/hr Air

Governor Valve Steam Leakoff 10 lb/hr.

(f) The turbine exhausts into the auxiliary condenser at 2.5 inches Hg. exhaust pressure.

(g) The normal operating speed of the turbine is 9532 rpm and that of the generator is 1200 rpm.

(h) The turbine overspeed trip mechanism is set to operate at 10,500 rpm (with an rpm tolerance of 2% plus or minus).

1-A-3 REDUCTION GEAR RATINGS

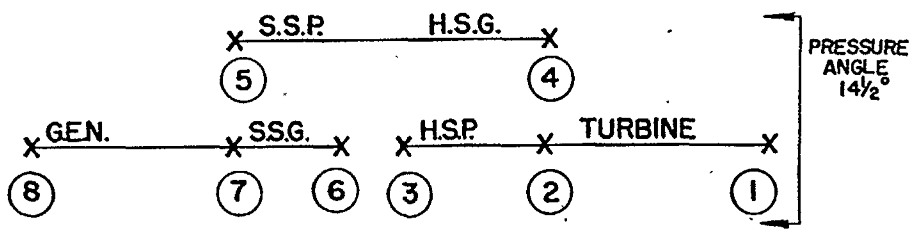
(a) The pinions and gears of the high speed and low speed rotating elements are of the single helical type and the reduction gear is designed to transmit a normal load of 2,115 BHP with the high speed pinion operating at 9,532 rpm and the low speed gear at 1,200 rpm.

1-A-4 OIL SYSTEM CAPACITY

(a) Oil system capacity: at high level 80 gallons; normal level 76 gallons and at low level 72 gallons.

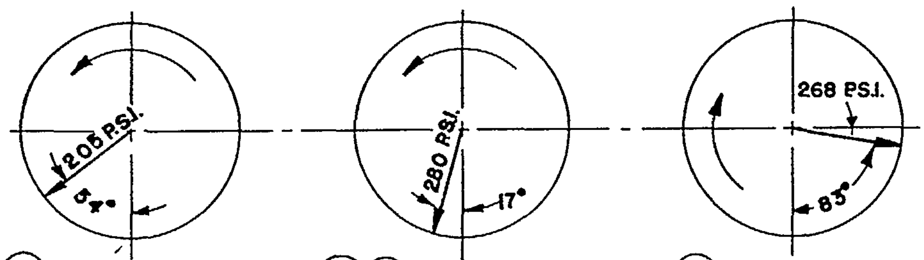
1-A-5 BEARING LOADS AND PRESSURES

RADIAL BRG. LOADS & PRESSURES
PARTIAL ADMISSION STATIC LOADS, & TORQUE



SUMMARY OF JOURNAL LOADS ON BEARINGS

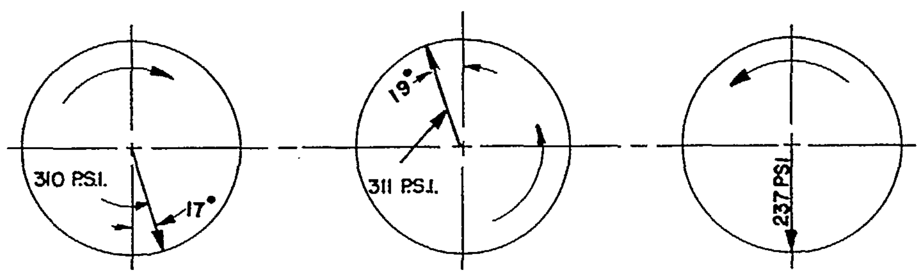
BRG.	VERT. FORCE	HORIZ. FORCE	RESULANT	BRG. SIZE	AREA	PRESSURE	ANGLE
1	482	663	820	2 X 2	4	205	54°
2	2013	610	2100	3 X 2½	7½	280	17°
3	2013	610	2100	3 X 2½	7½	280	17°
4	200	1600	1610	3 X 2	6	268	83°
5	5910	1830	6190	5 X 4	20	310	17°
6	3530	1225	3740	4 X 3	12	311	19°
7	3530	1225	3740	4 X 3	12	311	19°
8	2840	——	2840	4 X 3	12	237	0°



(1) TURBINE (THRUST END)

(2)(3) HIGH SPEED PINION

(4) HIGH SPEED GEAR



(5) SLOW SPEED PINION

(6)(7) SLOW SPEED GEAR

(8) GENERATOR (EXCITER END)

1-A-6 AUXILIARY CONDENSER DATA

Reference: Certification Data, Drawing No. 1-JC-6121 Buships No. CVA60-S4600-C-1475310

(a) TOTAL SURFACE . . . 1,265 sq. ft.

(b) STEAM CONDITIONS

Steam Condensed - Aux.
Turb. Exhaust . . . . 14,073 lbs/hr
Steam Enthalpy at Exhaust . 1,081 Btu/lb
Total Heat to Condenser . . 14,133,500 Btu/hr
Condenser Vacuum . . . . . 27.5 inches Hg.

(c) CIRCULATING WATER CONDITIONS

Flow . . . . 1,785 Gallons/min.
Tube Velocity . . . . 6.0 Ft/Sec.
Temperature, Inlet . . . . $75^{o}F$
Temperature, Outlet . . . $90.9^{o}F$
Friction Drop . . . . 10.6 Ft. of water

(d) TUBE DATA

Total Number 877
Size. . . . . 5/8 in. Diam.
Gauge . . . . 18 BWG
Effective Tube Length . . . . . 8 ft. 9-7/8 in.
Total Tube Length . . . . 9 ft. 00 in.
Material . . . . 70-30 Copper-Nickel Alloy

(Mtl. Spec. MIL-C-15726)

1-A-7 AUXILIARY EJECTOR DATA

Reference: Certification Data, Drawing No. 1-JC-6122 BuShips No. CVA60-S4600-C-1475701

(a) STEAM CONDITIONS

Steam Pressure at Ejectors . . . . 135 psig
Steam Temperature . . . . $395^{o}FTT$

(b) STEAM CONSUMPTION

First Stage . . . . 141 lbs/hr
Second Stage . . . . 94 lbs/hr
Total . . . . 235 lbs/hr

(c) The two stage ejector unit shall remove free dry air plus associated vapors under the following conditions:

1) Free Dry Air, lbs/hr 12.6
2) Absolute Pressure, Ins. Hg. Abs. . . 29.0
3) Saturated Vapor, Temp. Deg. F. . . . 71.5
4) Cooling Water, gpm Min. 25.0
5) Cooling Water Inlet Temp. Deg. F . . 79.0
6) Pressure Drop through Cond., psi . . 5.0
7) Condensate Temp. Rise for Min. Flow Deg. F 26.5

(d) The gland condenser is designed for condensing 50 lbs/hr of gland leakoff steam mixed with 25 lbs/hr of air.

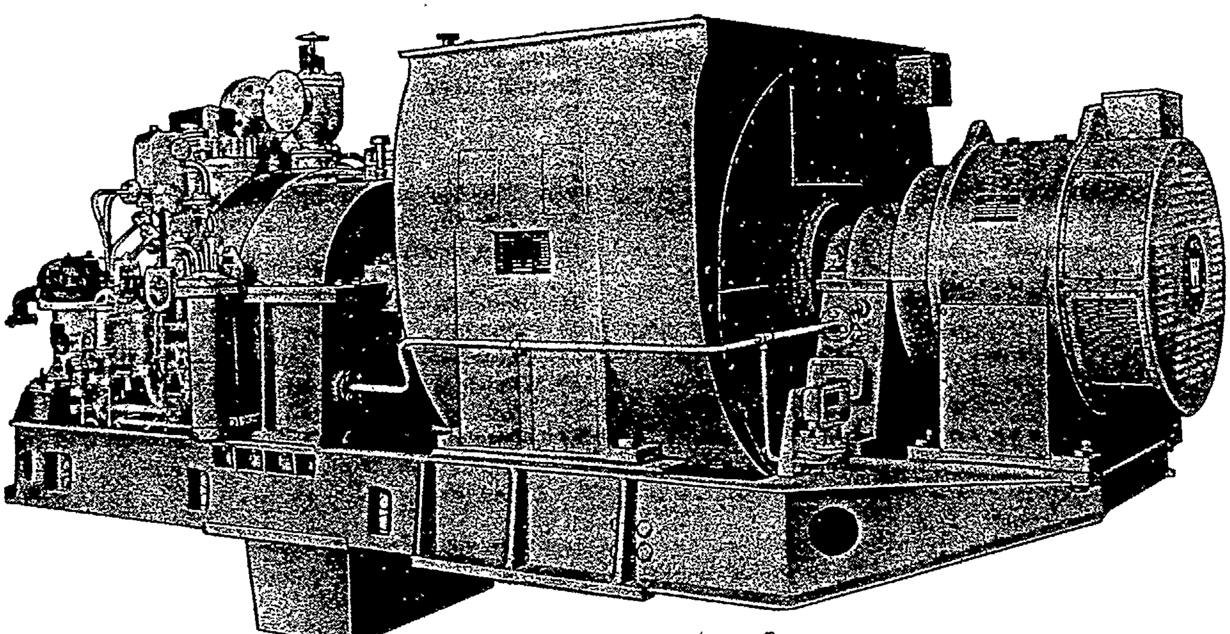
(e) COOLING SURFACES OF CONDENSER

Inter-Condenser #1 . . . . 28.5 sq.ft.
Inter-Condenser #2 . . . . 28.5 sq.ft.
After and Gland Condenser. . . . . 57.0 sq.ft.
Total . . . . 114.0 sq.ft.

(f) TUBE DATA

Total Number 160
Size. . . . . 5/8 inches O.D.
Gauge . . . . 18 BWG
Effective Tube Length. . 4 ft. 3-15/16 inches
Total Tube Length . . . 4 ft. 6 inches
Material . . . . Admiralty Metal

(Mtl. Spec. WW-T-756 Type A).



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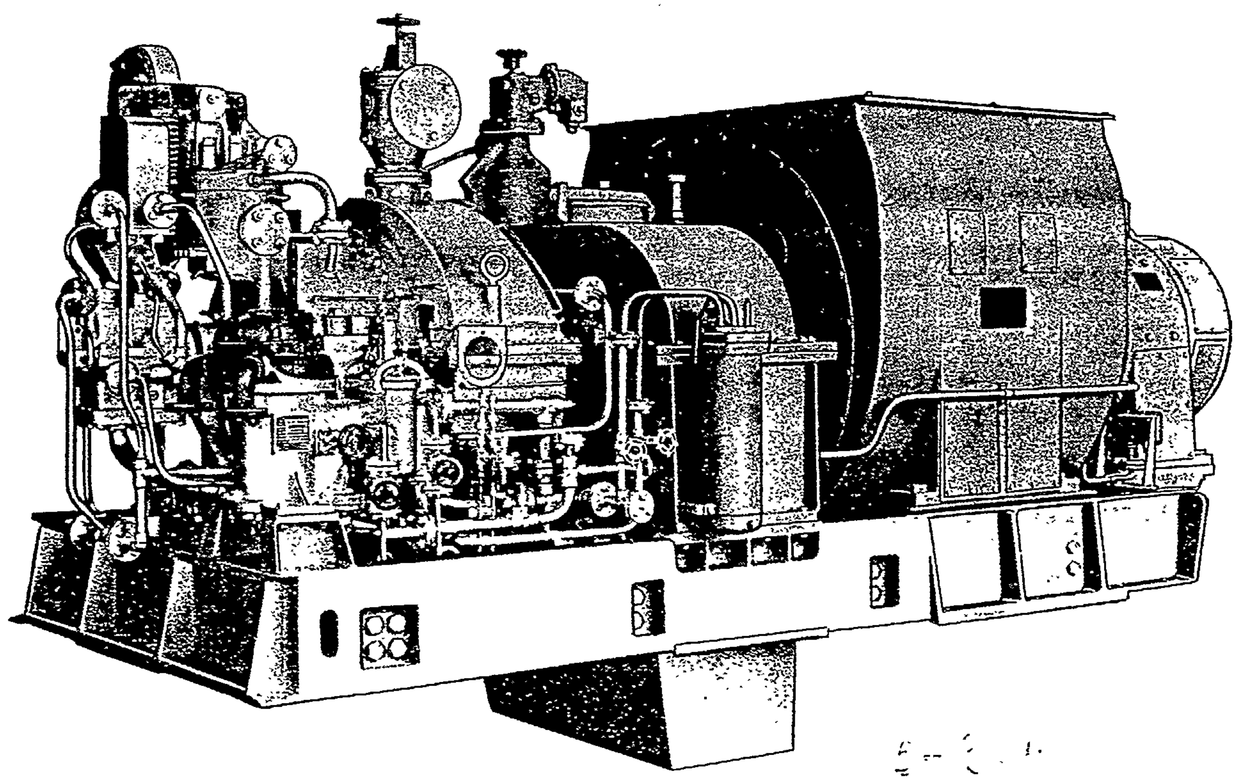


Turbine, Gear and Generator Assembled on Bedplate
Ready for Shipping

SECTION B—DESCRIPTION OF TURBINE AND ACCESSORIES

1-B-1 GENERAL

(a) The turbine, of straight-impulse type, a longitudinal section of which is shown in Figure T-2 consists of a combination of Curtis and Rateau stages. The Curtis element consists of one pressure stage with two velocity stages. This is followed by six Rateau stages.

(b) The steam, after passing through the throttle valve and the steam chest valves, enters the first-stage nozzles where it is expanded to the pressure existing in the impulse chamber. The velocity energy, acquired in this expansion, is converted into rotative energy by the impulse blades. The steam is then expanded successively through the Rateau stages to the pressure maintained in the condenser thus imparting further rotative energy to the rotor.

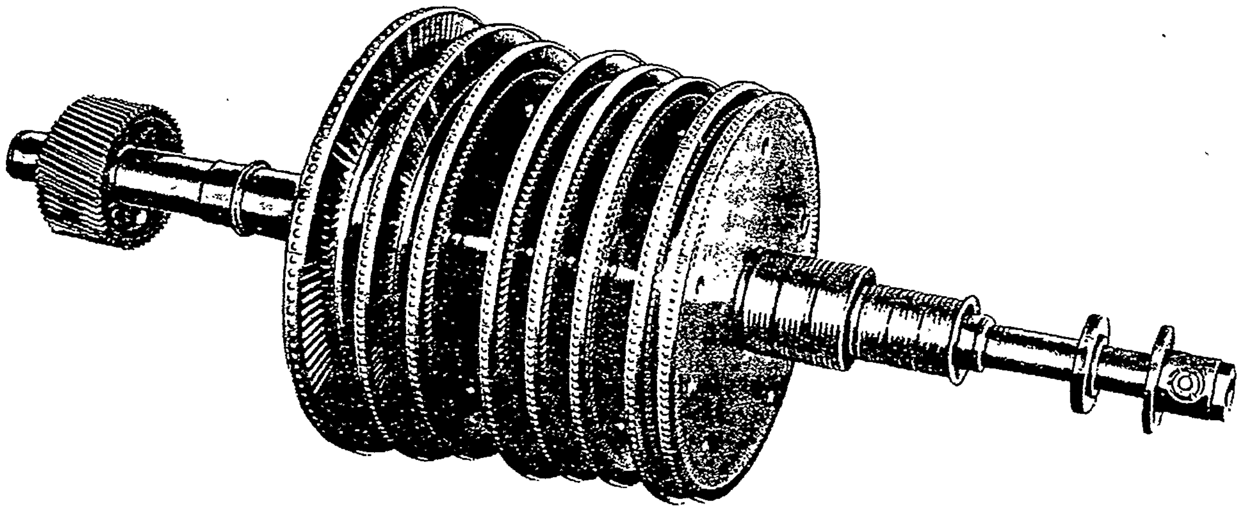
(c) The turbine exhaust end cylinder is secured to the gear case by stud bolts mounted in a half flange. The half flange has been machined with a spigotted fit as shown in the illustration Figure T-2, by means of which the alignment of the turbine and gear are held to a common plane and base line. The thrust end is supported by a transverse plate which is bolted to the cylinder and the bedplate. The web of the transverse plate provides the necessary flexibility for longitudinal expansion and contraction of the cylinder.

1-B-2 CYLINDER

(a) The turbine cylinder consists of a base and cover, bolted together on a horizontal joint and each made in two pieces, joined at a vertical joint between the fourth and fifth blade stages. This vertical joint is made up permanently at initial assembly and the two pieces are henceforth treated as one. The horizontal joint flanges have been carefully machined to provide a true metal to metal joint. The horizontal joint of the two pieces that form the cylinder cover has been relieved, as shown in Figure T-29, by means of which joint sealing compound can be used to insure an absolute tight joint, in the event that at some future date leaks develop. The vertical joint has been treated in the same manner, the flanges of the inlet end cylinder base and cover being relieved as shown in Figure T-29.

(b) The pieces that make up the cylinder inlet end are cast from a high grade of cast alloy steel, the steam chest being cast integral with the inlet end cylinder cover. The exhaust end cylinder pieces are fabricated from a high grade of plate steel and the joint flanges are carefully machined to a full bearing surface, with metal to metal joints.

(c) The cylinder is protected from excessive steam pressures by the atmospheric relief valve illustrated in Figure T-27 which is set to open at 10 psig. This atmosphere relief valve is



Turbine Rotating Element and High Speed Pinion Assembly capable of relieving the full throttle flow of steam to atmosphere with the turbine exhaust casing pressure not exceeding 30 psig.

(d) The turbine cylinder is also protected by a back-pressure trip which will close the throttle valve when the back-pressure at the turbine casing reaches 5 psig pressure.

1-B-3 TURBINE ROTOR

(a) The turbine rotor shown in Figure T-2, is made from a high grade alloy steel forging. The blade discs are inegrally machined from the solid forging. The rotor forging is bored out on the centerline through the greater part of its length to permit examination of the internal quality of the forged metal. The hole is afterward plugged and the plug serves as a lathe center during machining.

(b) The axial drilled passages through each of the rotor blade disc, are provided for the purpose of balancing the steam pressure on both sides of the disc, thereby substantially equalizing axial thrust on the rotor.

(c) The overspeed trip body and thrust collar are mounted on and secured to one end of the rotor shaft and the high speed pinion is rigidly connected to an integral flange at the other end.

(d) After the blades have been installed and locked in place and the final machining completed, the overspeed trip body thrust collar and high speed pinion are secured in place. The rotor is then dynamically balanced.

1-B-4 NOZZLE BLOCK

In order to insure that a proper nozzle area will be employed for any given operating load condition, four nozzles are provided in the nozzle block which is constructed of forged alloy steel. The block is bolted to a machined face on the cylinder cover and is connected to the steam chest valves by internal passage machining. The arrangement of the nozzle element is shown in the illustration, Figure T-2.

1-B-5 IMPULSE BLADING, CURTIS STAGE

(a) The first stage of impulse blading in the turbine is shown in Figure T-3 and is of the velocity compounded type, having two moving rows of blades on the rotor and part of a stationary row between them, secured to the cylinder cover. The steam from the nozzles is directed to the first rotating row of blades, passing into the segment of stationary blades between the moving rows; and thence to the second rotating row of blades.

(b) The rotating blades are secured to the disc by means of a side entry type of fastening, the blade roots being pressed into axial machined slots, broached in the rim of the rotor disc. After all of the blades have been entered, the metal of the blade root ends are peened into a recess in the disc rim, to lock the blades in place. The blades are then shrouded into 26 groups, 18 of which consist of 6 blades and the remaining 8 groups of 5 blades each. The shroud strips are secured by riveting over the tenons on the ends of each blade.

(c) The stationary blades are mounted in "L" shaped grooves machined in the cylinder and locked in place and stiffened against vibration by a series of short keys which are caulked partly in the "L" of the groove and partly in a notch machined in the side of each blade root. The blades are milled from bar stock of stainless steel and are provided with an integral shroud, thus forming a closed passage for the steam flow. To provide additional strength, the blades are also banded together in groups. The blade shanks are machined accurately, to fit closely to one another and to give the correct spacing for the steam passage area.

(d) Blade shields are secured to the cylinder and extend around that portion of the circumference which is not utilized for the steam admission nozzles. These shields isolate the blade path from the remainder of the steam space and thus decrease the windage loss due to the blades rotating in the comparatively dense steam. In order to prevent any accumulation of condensation in the bottom of the shields, holes are drilled at the bottom, on the vertical centerline, to allow condensation to flow to drain.

1-B-6 IMPULSE BLADING, RATEAU STAGES

(a) The Curtis element is followed by the six Rateau stages shown in Figure T-3, which are divided from the former, and from each other, by interstage nozzle diaphragms. The nozzles for the Rateau stages are vane sections welded to inner and outer rings to make the complete diaphragm assembly. The diaphragms are made in halves and extend completely around the rotor, and each is fitted with the proper number of nozzle vane passages. Each stage of blading absorbs a part of the energy of the steam, reducing its velocity, after which it is further expanded through the next set of nozzles, regaining a high initial velocity, to be absorbed in the next row of blades. The diaphragms are centered by means of radial disposed crushing pins. Retaining screws, through the diaphragm upper half into the cylinder cover, serve the dual purpose of preventing diaphragm rotation and also permit the cylinder cover to be lifted with the diaphragm upper half in position. Tapped holes for lifting eyes are provided in each diaphragm half, at the horizontal joint, whereby they may be lifted with ease.

(b) The diaphragm nozzles of the first three stages occupy only a portion of the circumference, varying in area in accordance with the increase in volume of the progressively expanded steam. The nozzles of the fourth, fifth and sixth stages however occupy the full circumference of the diaphragm. In order to prevent any accumulation of condensation between the diaphragms, holes are drilled at the bottom on the vertical centerline, to allow the condensation to flow to drain.

(c) The rotating blades of the first four rows of these single row Rateau stages are similar to the Curtis blade stages, being secured to the disc by means of a side entry type of fastening. The blade roots are pressed into axial machined slots, broached in the rim of the rotor disc. After all the blades have been entered, the metal of the blade root ends are peened into a recess in the disc rim, locking the blades in place. The blades are then shrouded into groups in the same manner as used in the Curtis stage.

(d) The rotating blades of the last two Rateau blade stages are secured to the turbine rotor by a type of fastening consisting of a "T" Root, with lugs machined on the blade shank which straddle and hold in the sides of the groove, thus resisting the tendency of the blade pull to spread the side of the blade groove. The blades are held against the top of the groove by half-round segments, caulked in place at the bottom. With this type of fastening, it is of course necessary to widen the groove at one point, in order to enter the blades in the "T" shaped groove and the last blade installed at this starting point is secured with pins, as shown in the illustration Figure T-3.

1-B-7 INTERSTAGE DIAPHRAGM SEALS

(a) Steam leakage from stage to stage between the stationary diaphragms and the rotor shaft is minimized by means of the seal rings shown in Figure T-6. These seals are stepped toothed labyrinth strips, integrally machined leaded brass rings, made in four segments and mounted in "L" shaped grooves machined in the diaphragms. The rings are held away with a small clearance from the grooved surface of the rotor shaft by the shoulders machined in the groove. The actual designed clearance dimension is shown in Figure T-24. The rings are held against the shoulders by flat springs and are prevented from rotating within the grooves by means of pins, that engage recesses, at the horizontal joint.

(b) The radial clearance between the rotor and the seal rings is indicated in Figure T-24, and is the designed "cold" clearance. The seal rings have been machined with small gaps between the segments to provide for circumferential expansion. The ring segments have been match-marked and numbered with their corresponding groove number to facilitate correct reassembly.

1-B-8 CURTIS WHEEL CHAMBER LABYRINTH SEALS

(a) In order to minimize leakage of high pressure steam from the Curtis wheel chamber and to lighten the load on the gland at the high pressure end of the turbine, a group of three seal rings, shown in Figure T-7, is mounted in the cylinder base and cover between the Curtis wheel chamber and inlet end gland.

(b) Each of these three leaded brass seal rings is fitted with twelve rows of integrally machined labyrinth strips, by means of which the steam escaping outward along the shaft is throttled to a much lower pressure. The rings are made in four segments and mounted in "L" shaped grooves machined in the cylinder, and are held away with a small clearance from the grooved surface of the rotor shaft by the shoulders machined in the groove. The rings are held against the shoulders by flat springs and are prevented from rotating by means of pins, that engage recesses, at the horizontal joint.

(c) The radial clearance between the rotor and the seal rings is indicated in Figure T-24 and is the designed "cold" clearance. Small gaps have been machined between the ring segments, to provide for circumferential expansion. The ring segments have been match-marked and numbered with their corresponding groove number to facilitate correct reassembly.

1-B-9 TURBINE GLANDS

(a) At the point where the turbine rotor shaft extends through the ends of the cylinder, leakage of steam from, or air into cylinder is prevented by means of glands of the stepped tooth labyrinth type. These glands consist of a group of three leaded-brass rings, each fitted with ten rows of integrally machined labyrinth strips, made in four segments, set in "L" shaped grooves in the gland cases, and held against the shoulder of the "L" by means of flat springs. As shown in the illustration Figure T-7, the rings are prevented from turning by the pins, that engage recesses at the horizontal joint.

(b) The radial clearances between the rotor and the gland seal rings are indicated in the illustration, Figure T-24. These radial clearances are the designed "cold" clearances. In addition to the radial clearances, the alloy metal seal rings have small gaps between the segments, when cold, to provide for expansion and the segments are match-marked so they may be reassembled correctly.

(c) The seal rings are numbered consecutively starting with the outer-most ring at the thrust end of the unit, hence the gland and labyrinth seal rings at that end are numbered 1 through 6 and at the exhaust end, 7 through 9.

(d) Examination of the longitudinal section Figure T-2, shows that internal passages have been machined between the various ring assemblies. The cavity between rings No. 1 and 2 at the inlet end and that between No. 8 and 9 at the exhaust end are connected to the gland leakoff connections. The cavity between rings No. 3 and 4 at the inlet end is connected to the gland steam seal system as shown in the Steam Drain and Gland Piping Diagram, Figure T-8.

1-B-10 TURBINE BEARING, COMBINED THRUST AND JOURNAL

(a) Examination of the longitudinal section Figure T-2, shows that a thrust collar is located on and keyed to, the steam inlet end of the turbine rotor. The overspeed trip body, which is threaded on the rotor shaft, secures the thrust collar in its position, and it is at this point that the net rotor end thrust is transferred to the stationary parts by means of the thrust bearing shown in Figure T-4.

(b) The thrust bearing is of the Kingsbury double thrust type, having babbitted faced shoes on both sides of the thrust collar. The thrust bearing is mounted in a common cage with the journal bearing.

(c) The thrust bearing consists of four babbitted shoes "2" mounted on each side of the thrust collar "1", which are supported on the upper and lower leveling plates "8" and "9" and by rocking upon each other they allow the shoes to move relatively to one another, so that the babbitted faces of all the shoes on either side, are pressed against the thrust collar with equal force. Thus it can be seen that each shoe takes an equal share of the thrust load. On each side of the thrust collar, the upper leveling plates "8", supporting the shoes "2", rest upon the lower leveling plates "9", which in turn are carried in the casing "5" and base ring "14", both of which are made in halves. As may be seen in the longitudinal assembly, Figure T-2, the casing "5" and base ring "14" are supported in the cylinder base and enclosed by the bearing cover. Stop pins, mounted in the bearing cover, extend into milled keyways cut in the casing and base ring upper halves, preventing both of these from having any rotary movement.

(d) The correct axial position of the thrust bearing, and hence the correct axial location of the rotor is determined by the thickness of the inner and outer filler rings "16" and "17" which are made in halves. The inner filler ring "16" is located between the split casing "5" and the cylinder base and bearing cover. The outer filler ring "17" is located between the end ring "18" and the cylinder base and bearing cover. The thickness of these filler rings must be such that the clearance as shown in Figure T-24 will be produced when the rotor is jacked toward the exhaust end of the turbine.

(e) The actual internal clearance of the thrust bearing should be .010 inch in order to permit establishment of a proper oil film between the thrust collar and the shoes. After filler rings of correct thickness have been installed and the proper running clearance is obtained, the clearance should be checked by rolling the rotor and jacking it from one extreme axial position to the other and measuring the end travel by means of a dial type indicator.

(f) Oil for thrust bearing lubrication is supplied to the cylinder base and by means of machined internal passages, the oil is directed to the journal bearing and the opposite side of the thrust collar. Oil flowing from the journal bearing along the rotor shaft, in turn lubricates the adjacent side of the thrust collar. The oil control ring "19" directs the oil escaping from the periphery of the shoes to an outlet, hence the thrust bearing operates under a constant oil bath.

(g) The rotating element, which consists of the turbine rotor, the rigidly connected pinion and the overspeed trip body is carried in three journal bearings which are similar in general design. The bearings are shown in the illustrations Figures T-4 and T-5 and may be located in the longitudinal assembly, Figure T-2.

(h) The turbine rotor journal bearing, shown in Figure T-4 is mounted in a common casing with the thrust bearing, and is of the articulated self adjusting type. The split casing "5" has been internally machined to accommodate five babbitt lined journal shoes "11" each pivoted on the longitudinal disposed pin "13". The pins locate the journal shoes and permit the small angular movement necessary for the formation of an oil film between the shoes and rotor shaft, but the actual journal loading is transmitted to the casing proper through a land on the shoes as indicated in section B-B.

(i) Oil for the journal bearing lubrication is supplied to the cylinder base (through the same flanged connection which supplies the thrust bearing) and by means of internal passages, the oil is directed to the annular groove machined on the outer surface of the split casing "5". Radial passages drilled in this groove, permit the oil to flow to and lubricate the journal bearing shoes "11", then escaping from the ends of the bearing, the oil flows along the rotor shaft to lubricate the adjacent thrust bearing collar and shoes before flowing to drain.

1-B-11 OIL SEAL RING

(a) The bearing oil seal ring, which is used to prevent the escape of oil along the shaft from the bearing housing is shown in Figure T-2. The ring, made in halves, of leaded brass, is of the labyrinth type and is fitted into a groove machined in the cylinder base and bearing cover. The seals are machined in the bore of the ring and are integral with it. The correct running clearance between the seal ring and the rotor is shown in Figure T-24.

(b) Any oil which creeps along the shaft is caught in the grooves in the oil ring and flows through a series of radial drain holes in the pocket, in the lower half of the ring. Holes are drilled in the baffle which permit the oil to flow to drain, however, these holes are drilled at sufficient height to maintain an oil level in the pocket, thus preventing the escape of oil vapor through the drain holes.

1-B-12 STEAM GLAND AND DRAIN SYSTEM

(a) The diagram of the steam gland and drain piping is shown in Figure T-8. Sealing steam for the glands is supplied in part from the auxiliary exhaust at approximately 10 psig. The gland steam supply is controlled at the steam seal manifold. A gauge is provided to indicate the supply pressure. The quantity of sealing steam required will be variable, up to 51 lb/hr maximum at no load, depending upon the operating load conditions of the unit. The steam pressure at the glands should be maintained at not more than 2 psig. The proper sequence of operation of the manifold valves is tabulated in Figure T-8.

(b) When starting the unit and during operation at light loads, steam is admitted from the auxiliary exhaust line to satisfy the sealing requirements. During operation at heavy loads, the amount of steam obtained from the high pressure gland leakoff, is more than enough for the sealing requirements, hence the supply from the auxiliary exhaust is shut off, and the supply to the low pressure glands is reduced by adjusting the valves. The excess steam is discharged into the turbine at the fourth stage of Rateau blading. Thus it can be seen that in the line from the high pressure end, steam is fed to, or drawn from this gland, as determined by the pressure existing in the system.

1-B-13 STEAM SEAL MANIFOLD

(a) The steam seal manifold which is shown in Figure T-9 and located diagrammatically in Figure T-8, is the means by which the flow of gland sealing steam may be controlled. The operation of this manifold under various load conditions is fully explained in paragraph 1-B-12.

1-B-14 ROTOR POSITION INDICATOR

(a) The rotor position indicator, which is mounted in the thrust bearing housing end cover is shown in Figure T-23. A reading is taken by pushing lightly on the pad on the pointer "1" until the plunger "7", makes contact with the end of the rotor. Immediately after installation, the rotor should be jacked toward the steam exhaust end and while in this position the pointer set at zero by loosening the socket head cap screw "9" to adjust it and then tightening up securely. Thereafter when a reading is taken, the displacement of the pointer from zero, will indicate the axial displacement of the rotor, one division on the graduated scale representing a rotor displacement of .002 inch. The spring "6" holds the plunger "7" out of contact with the turbine rotor, when the indicator is not being used.

(b) The indicator readings should be taken with the unit carrying a load or with the rotor jacked toward the steam exhaust end, otherwise the clearance in the thrust bearing will give an erroneous reading.

1-B-15 STEAM STRAINER

(a) Steam is admitted to the throttle valve through the "Y" type flanged steam strainer illustrated in Figure T-10. The steam strainer body is cast from a high grade of chrome-moly steel and machined to accommodate a basket type strainer of perforated stainless steel. A cover of chrome-moly steel, secured to the strainer body proper with stud bolts, forms the closure. A stainless steel asbestos gasket is used to prevent joint leakage. The steam strainer body is fabricated to the cylinder cover.

1-B-16 THROTTLE VALVE

(a) The throttle valve shown in Figure T-11 is for the purpose of starting the unit by admitting steam or stopping the unit by shutting off the flow of steam. This valve is of the plug type and closes against a diffuser shaped inlet nozzle or valve seat. The valve actuating force is oil pressure, acting within an operating cylinder upon a piston and against the resistance of a compression spring.

(b) As shown in the illustration, the handwheel is secured to a threaded shaft "9" which can be screwed in or out through the cover "5", and butts against a ball thrust bearing "22" which is mounted in a recess in the piston "2" and held in place by the retaining ring "23". The piston "2" is secured to the end of the valve stem "7" which closes against the valve seat "19". Three compression piston rings "25" are mounted in annular grooves machined in the piston which reduce oil leakage to a minimum.

(c) The pressure of the operating oil admitted to the operating cylinder from the oil pump discharge, tends to move the piston "2" and hence the valve stem "7" in an opening direction, but such movement is dependent upon backing off the shaft "9" by rotating the handwheel "18". The compression spring "24" provides a force tending always to close the valve, which is normally overbalanced by the force of the oil pressure acting in the opposite and opening direction.

(d) It will be seen that the valve is held open only by the oil pressure acting against the piston. Consequently, if any one of the tripping devices are actuated, causing loss of the oil pressure in the system and hence in the operating cylinder, the compression of the spring "24" will immediately force the valve against the seat, thus shutting off the steam supply to the turbine. When the valve has been tripped shut, restoration of the oil pressure in the cylinder will automatically reopen it slowly as the oil pressure is built up, unless the handwheel has, in the meantime, been turned to the closed position.

(e) The valve stem "7" is guided by four bushings, mounted in the operating cylinder "3", and the flange "4". The inner and outer bushings "21" are so arranged in the operating cylinder, so as to permit any oil bleeding along the valve stem, to drain off through the provided connection, as shown. The inner and outer bushings "21" and "13", mounted in the flange are so arranged to permit any steam leakage along the valve stem to be carried off through the flanged connection.

(f) A valve is formed on the valve stem "7" which seats upon the inner surface of the valve stem bushing "13", when the throttle valve is in the fully open position. Hence at this time, steam leakage along the stem is reduced to a minimum.

(g) The valve seat "19" is mounted in the cylinder and secured in position by the expansion ring "20" which is seal welded to the valve seat and the cylinder as shown in the illustration.

1-B-17 STEAM CHEST AND VALVES

(a) The flow of steam to the turbine nozzles is controlled and regulated over a wide range of operating load conditions by means of four valves located within the steam chest as shown in Figure T-12. The valves are carried by a lift bar formed on the end of the stem "9". The valves "8" are single seated plug type. Each valve seat "7" is countersunk into the steam chest, and secured by an expansion ring "27" which is seal welded all around. The steam passages from each of the steam-chest valves to the nozzles are machined integral with the cylinder cover.

(b) The stem "9" is connected to the steam-valve operator by a lever and links and is guided through the steam-chest cover by bushings. The stem is held against rotation by the guide pin "26" which is mounted in the cylinder and extends upward through the lift bar. The valves are numbered one through four and each has the specified drop below the bottom of the lift bar, such that for example: Valve No. 4 reaches its valve seat sooner than any of the others when the stem is lowered in the steam chest. By the same token, a lifting movement of the stem unseats each of the four valves in a sequence predetermined by the setting of the nuts "16" on each valve. An instruction plate is affixed to the linkage lever where the valve adjustment-nut setting for each valve can be read. There is an unbalanced steam force in the chest, tending to close the valves. The valves have sufficient clearance from the lift bar so that they will seat themselves under steam pressure whenever the lift bar reaches the closed position.

(c) The steam-chest cover opening through which the valve stem extends to the linkage above, is sealed against steam escape to the atmosphere by the provision of close fitting bushings "23", "18", and "24". Two separate steam leakoff passages are provided in the bushing area. One, the high-pressure steam-leakoff passage, is located between lower bushing "24" and bushing "18" and the other, a low-pressure steam-leakoff passage opens in an annular groove around the upper bushing. The steam from the high-pressure leakoff is led to a zone of lower pressure within the turbine cylinder, while the low-pressure leakoff is led to the gland eductor system.

(d) To establish the proper lifts for the several valves, a special fixture is provided the application of which is shown in the tool illustration, Figure T-28. It comprises a temporary cover to be bolted in place on the steam chest instead of the steam-chest cover, an indicator mounting rod, and a rod to be set up on the valve stem.

(e) To use this fixture proceed as follows: Disconnect the steam-chest linkage and remove the steam-chest cover. Bolt in its place the valve setting fixture assembly, as shown in Figure T-28, setting it so that four holes in the cover come over the four valves. Set up the rod "4". Drop the rod "3" through the proper hole in cover plate "2" so that it rests on top of No. 1 valve. Clamp two dial indicators to the rod and set one against the top of the valve lifting stem and the other against the top of the rod "3", compressing them sufficiently, to insure positive response when the stem is lifted.

(f) Set both indicator dials at zero. Lift the valve stem until a reading shows on each of the indicators. The difference of the two readings will be the clearance for No. 1 valve. Three or four check readings should be taken and the differences should be the same in every instance.

(g) Repeat this procedure until all the valves have been checked. In this manner you will then have a series of differences, thus for example:

Reading	No. 1	No. 2	No. 3	No. 4
Stem	0.049	0.144	0.267	0.348
Valve Rod	0.009	0.018	0.055	0.050
Difference	0.040	0.126	0.212	0.298

(h) These differences are the clearances of the several valves between the valve lift bar and the valve nuts and should be the same as listed in the tabulation of valve settings as shown in Figure T-12.

(i) The amount the valve stem is raised in the above operation is immaterial as long as it is enough to obtain readings on both indicators and that successive trials show the same difference between the stem and valve readings.

1-B-18 TURBINE GOVERNOR

(a) The dial-type governor (PGD) detects variations in turbine rotor speed and through hydraulic and mechanical connections with the components of the control system provides accurate and positive control of turbine speed under all load conditions; changes in electrical load are compensated for with practically no noticeable change in turbine speed. A manually operated speed adjusting knob and remotely controlled motor-operated speed changer are provided.

(b) Use only new or purified oil in the governor of the same type as used in the turbine.

(c) The governor was properly adjusted at initial installation. It should require no further attention other than maintenance; if a malfunction develops during operation, refer to enclosed Woodward Service Bulletin 36404. Adjustments between the governor and steam-valve operator are described in paragraph 1-H-11.

NOTE

> Although the Woodward Bulletin was written for applications using the PGD governor with internal combustion engines, the material presented is directly applicable to turbine operation. Instead of controlling the flow of fuel to an internal combustion engine, the PGD governor controls the flow of steam to the turbine by hydraulically controlling the steam-valve operator which in turn controls the steam-chest valves.

(d) A schematic illustration of the governor with hydraulic piping is shown in Figure T-20. The hydraulic system within the governor is shown in the enclosed Woodward Bulletin 36002E.

1-B-19 STEAM-VALVE OPERATOR

(a) The steam-valve operator is provided to operate the steam-valve linkage to open or close the steam-chest valves and thereby control steam flow to the turbine under all conditions of load on the turbine-generator set. See Figures T-14A and T-14B.

(b) To meet a new load condition the operator must be repositioned. A change in turbine load causes a change in turbine speed and the change in speed causes the pilot valve plunger in the governor to move from its centered position, resulting in a change in control oil pressure to the valve operator. This pressure is the input signal to the bellows in the operator.

(c) As shown in Figure T-14B, pilot valve plunger "57" controls the flow of oil to and from the area above spring loaded output piston "3"; the linkage assembly is connected to the piston. The pressure in bellows "5" tends to raise plunger "57", and restoring spring "54" acting through the restoring linkage tends to move plunger "57" down. With the TG set operating under a steady-load condition, these opposing forces cancel one another and the plunger remains centered. When plunger "57" moves above its centered position, high-pressure oil from the supply line forces piston "3" down to increase steam flow to the turbine. When plunger "57" moves below its centered position, oil in the area above piston "3" flows to drain. Load spring "53" forces the piston up to decrease the steam flow to the turbine.

(d) A flow-control valve, refer to paragraph 1-B-21, regulates the flow of oil to the oil motor located in housing "1". The oil motor rotates plunger "57" to minimize static friction.

(e) When the turbine is at rest, the steam-chest valves can be opened by developing enough oil pressure through the start-sequence valve using the hand oil pump. Refer to paragraph 1-B-21.

(f) Adjustments between the governor and steam-valve operator are described in paragraph 1-H-11.

1-B-20 START-SEQUENCE VALVE

(a) The start-sequence valve, shown schematically in Figure T-20 and diagrammatically in Figure T-34. operates as a slave unit to the governor. The governor will not control the steam-valve operator when first starting up the turbine. Consequently, the steam-chest valves must be opened by some other means prior to governor control, and this is the function of the start-sequence valve. The sequence valve is hydraulically actuated through the operation of the turbine hand-operated oil pump. The sequence valve's hydraulic connections in the 75-psig control-oil line serve to accomplish the following:

1. When first starting the turbine—Directs oil pressure under the plunger in the steam-valve operator, displacing it upward, to admit oil to the top of the piston in the operator and causing the steam-chest valves to open.

2. When main oil pump and governor begin operating—Allows control oil to flow from the plunger start chamber to drain to the oil reservoir, thereby releasing the plunger to full governor/ valve-operator control.

(b) When using the hand-operated oil pump the start-sequence valve directs oil under plunger ("57", Figure T-14B) displacing the plunger upward to admit supply oil to the top of piston ("3", Figure T-14B) which opens the steam-chest valves. When the main oil pressure is approximately 60 psig, and the turbine is under governor control, the sequence valve relay advances, switching from supply oil under pressure to the plunger, to draining the plunger start chamber. During shutdown, the sequence valve relay returns to the start position when the main oil pump pressure decreases to approximately 20 psig.

(c) If the manual trip mechanism is operated, the throttle valve will snap shut and will not admit steam until reset. If the manual method for shutdown by closing the throttle valve is selected, the sequence valve will act upon the operator to open the steam-chest valves as in starting the turbine. This will continue the turbine operation until steam supply is completely shut off.

NOTE

As in starting, use the hand pump to maintain control pressure as well as pressure to the bearings.

(d) The start-sequence valve setting instructions are given in Figure T-34.

1-B-21 FLOW-CONTROL VALVE

The flow-control valve is a constant-differential-type valve and is shown schematically in Figure T-20. This valve provides a constant downstream pressure, limiting oil flow to the oil motor in the steam-valve operator.

WOODWARD®

TYPE PG GOVERNORS

ANALYSIS AND CORRECTION OF GOVERNING TROUBLES

SERVICE BULLETIN 36404

GENERAL: It is impossible to anticipate every kind of trouble that will be encountered in the field. This bulletin covers the most common troubles experienced. Poor governing may be due to faulty governor performance, or it may be due to the governor attempting to correct for faulty operation of the engine or turbine auxiliary equipment. The effect of any auxiliary equipment on the overall control required of the governor must also be considered.

Approximately 95% of all trouble may be corrected by following these instructions. The other 5% may be of a nature requiring the services of a governor engineering specialist.

GOVERNOR OIL LEVEL: Governor oil level MUST be kept BETWEEN THE LINES on the oil level gauge glass WITH THE UNIT OPERATING. The CORRECT level is at the joint line of the power case and column — the upper line on the gauge glass — and NO HIGHER. Instructions given on decals near the oil gauge should be strictly adhered to.

For more complete information on oils to use, and when to change the governor oil, see Woodward Bulletin 25007, "Oils for use in Hydraulic Governors".

DIRTY OIL CAUSES APPROXIMATELY 50% OF ALL GOVERNOR TROUBLES: Use CLEAN new or filtered oil. Containers used to fill governors from bulk containers should be PERFECTLY CLEAN. Oil contaminated with water may cause foaming, will break down rapidly and corrode internal governor parts.

COMPENSATING ADJUSTMENTS: The compensating needle valve must be correctly adjusted with the governor controlling the engine or turbine, even though the compensation may have been previously adjusted at the factory or on governor test equipment. Although the governor may appear to be operating satisfactorily because the unit runs at constant speed without load, the governor still may not be correctly adjusted.

High overspeeds and low underspeeds, or slow return to speed, after a load change or speed setting change, are some of the results of an incorrect setting of the compensating needle valve.

Bulletins applicable to the various types of PG governors contain detailed instructions for adjusting the compensation:

Bulletin 36002 — PG Dial and Lever Governors
Bulletin 36006 — PG Locomotive Governors
Bulletin 36012 — PG Governors with Pneumatic Speed Setting

ANALYSIS AND CORRECTION OF GOVERNING TROUBLES: The chart on the following pages may be used to determine the probable causes of faulty operation, and to correct these troubles.
Terms used in the chart are defined as follows:

1. **Hunt:** A rythmic variation of speed which can be eliminated by blocking governor operation manually, but which will recur when returned to governor control.
2. **Surge:** A rhythmic variation of speed, always of large magnitude, which can be eliminated by blocking governor action manually and which will not recur when returned to governor control, unless speed adjustment is changed or the load changes.
3. **Jiggle:** A high frequency vibration of the governor fuel rod end (or terminal shaft) and fuel linkage. Do not confuse this with normal controlling action of the governor.

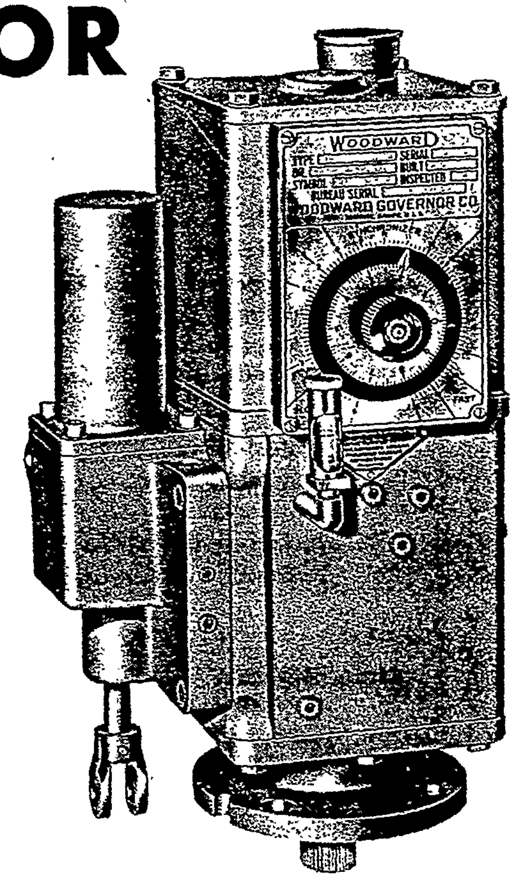
WOODWARD GOVERNOR COMPANY
ROCKFORD, ILLINOIS
SCHIPHOL, NETHERLANDS **FORT COLLINS, COLORADO**
SLOUGH, ENGLAND

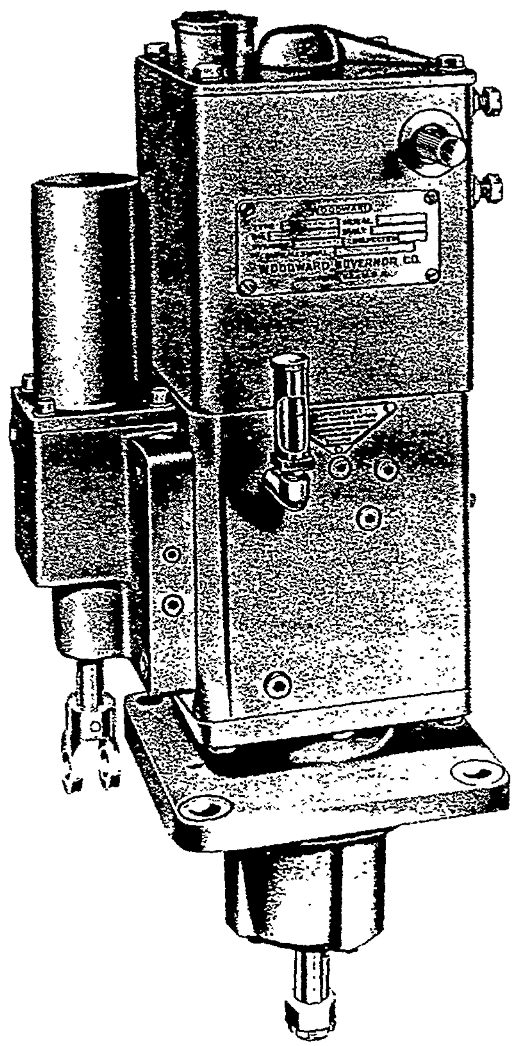
TROUBLE	CAUSE	CORRECTION
1. Engine hunts or surges.	A. Needle valve adjustment incorrect.	Adjust needle valve as described in governor bulletin.
	B. Buffer springs too light. This may occur on a new installation — or on an old installation by reason of deterioration of engine or fuel linkage, or as a result of a radical change in load conditions.	Install heavier buffer springs (consult governor manufacturer).
	C. Fuel linkage incorrectly set. This might occur if the governor has been changed or removed and replaced. Relationship of governor travel to power output of engine should be linear.	Rework or reset the linkage from governor to unit to obtain the linear relationship.
	D. Engine gas valve is not properly shaped to give linear relationship between governor travel and horse power output of the engine. Engine may hunt with light loads and be stable with heavy load.	Re-shape gas valve, or (if possible) adjust linkage from governor to gas valve to obtain linear relationship between governor travel and engine output.
	E. Lost motion in engine linkage, fuel pumps, or gas valve.	Repair linkage, fuel pumps, or gas valve.
	F. Binding in engine linkage, fuel pumps, or gas valve.	Repair and re-align linkage, fuel pumps or gas valve.
	G. Governor stroke too short. This may occur on a new installation.	Re-design or rework the fuel linkage to require more governor stroke. (Consult manufacturer of engine and governor).
	H. Low oil level. No harm will be done if top of oil is still visible in gauge glass.	Add oil — slowly — to the correct level in gauge.
	I. Dirty oil or foaming oil in governor.	Drain governor oil, flush governor to clean, and refill with proper clean oil. See Bulletin 25007. Bleed air and adjust the needle valve as described in governor bulletin.
	J. Governor worn or not correctly adjusted.	Repair and adjust governor. See governor instruction bulletin: a. Check flyweight pins and bearings for wear. b. Check flyweight toes for wear and/or flat spots. c. Check flyweight head thrust bearing, also centering bearing. d. Pilot valve plunger may be sticking — clean and polish if necessary. CAUTION — DO NOT break corners of control land. e. Check vertical adjustment of pilot valve plunger and correct if necessary. f. Clean and polish all moving parts to ensure smooth and free operation.
	K. Power piston rod bent and/or power piston sticking in cylinder.	Repair if possible. If rod is bent, install new piston and rod assembly.
	L. Engine is misfiring. This applies principally to gas engines.	Check pyrometer readings of each cylinder, and take steps to eliminate misfiring, if possible. Installation of preloaded buffer springs may be desirable. (Consult governor manufacturer).

WOODWARD®

PG GOVERNOR

DIAL AND LEVER SPEED CONTROL





This bulletin covers the basic type PG dial and lever governors as used on diesel, gas or dual fuel engines or steam turbines, driving pumps, variable speed D.C. generators or marine propulsion units.

WOODWARD GOVERNOR COMPANY

ROCKFORD, ILLINOIS

FT. COLLINS, COLORADO SCHIPHOL, THE NETHERLANDS SLOUGH, ENGLAND TOKYO, JAPAN

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ARE NOT IMAGED

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GENERAL

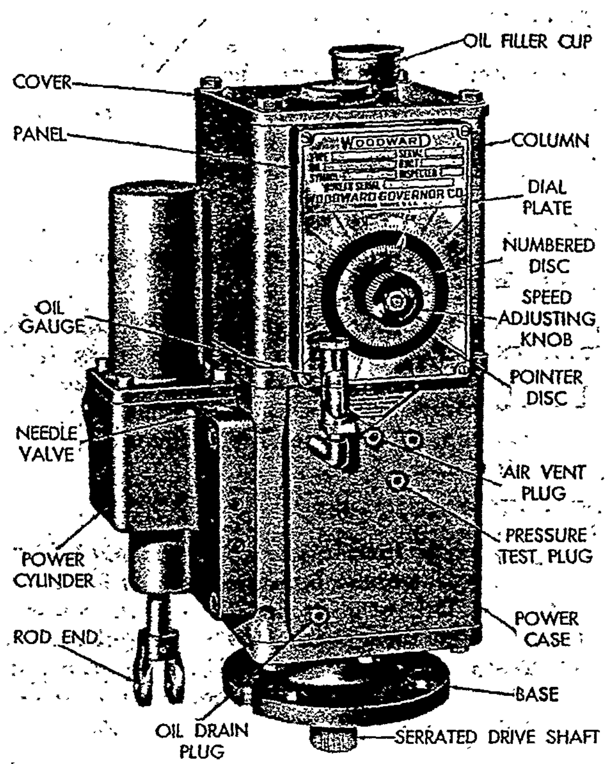


Figure 1, Dial Type Governor

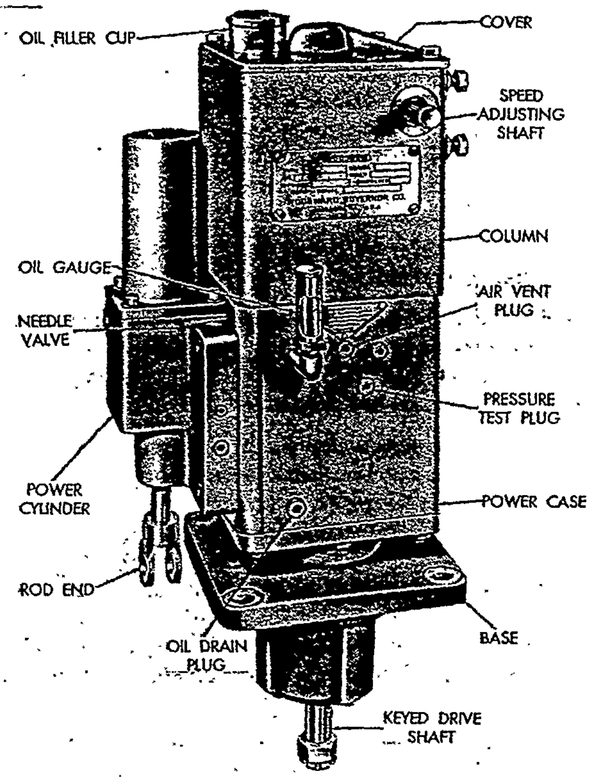


Figure 2, Lever Type Governor

DESCRIPTION

The dial and lever type PG governors, figure 1 and 2, are hydraulic speed governors with differential pressure compensation. Each governor is normally isochronous, that is, if the engine is not overloaded it maintains the same speed regardless of load, except momentarily at the time a load change occurs.

As is the case with any governor of any type, it is desirable that the engine be equipped with a separate overspeed device to prevent runaway in the event of any failure which may render the governor inoperative.

AUXILIARY EQUIPMENT

Either type of PG governor (dial or lever) can be furnished with the servomotor in any quadrant and the column in any position as shown in figures 8 and 9. The round or square base, also the serrated or keyed drive shaft, are available for either model to suit engine manufacturers' requirements — see figure 9b. A splined shaft, shown in figure 9b, is available with the round base. The following features are available in various combinations:

1. Speed adjusting motor (page 31).
2. Electric, pneumatic, hydraulic or manual shut-down.
3. Pneumatic or selsyn speed adjustment.
4. Speed droop (page 33).
5. Torque limiting control.
6. Discharge or suction pressure control.
7. Wide range of speed adjustment (up to 10 to 1) with governor oil cooler.
8. Remote servomotor.
9. Servomotor rate control in fuel increase direction.

INSTALLATION

When the governor is installed on the engine, particular care should be exercised to see that it is mounted squarely and that the drive connection to the engine is aligned properly. A gasket should be placed between the base of the governor and the mounting pad on the engine. If the governor is equipped with a serrated drive shaft, it should slip into the internal serrations of the drive freely enough to drop into place of its own weight.

CAUTION: Do not drop or rest the governor on its drive shaft.

If a keyed type governor drive shaft is used, the gear placed on this shaft should be checked to insure that it is meshing properly. There should be neither binding nor excessive backlash. Irregularities caused by uneven gear teeth, shaft runout, etc., will be picked up by the governor, transmitted to the fuel control system, and will result in erratic governing.

The linkage from the governor to the fuel system and to the speed control station should also be properly aligned; any friction or lost motion should be eliminated. Adjustments of fuel linkage must provide for control of fuel from "OFF" to "FULL FUEL" within the limits of the stroke of the governor rod end. For specific information on fuel linkage installation, refer to engine instruction manual.

OIL SPECIFICATIONS

The oil used in the governor should have a minimum tendency to foam, retain air, form sludge, or deposit varnish. It should protect governor parts from corrosion, but not be detrimental to seals or paint.

The oil selected should have a high viscosity index; the viscosity should be within the range of 100 to 200 Saybolt Universal Seconds at normal operating temperatures. If the average operating temperature of the governor oil is below 120° F., S.A.E. 10 oil is satisfactory; if between 120° F. and 140° F., S.A.E. 20 oil; from 140° F. to 160° F., S.A.E. 30 oil; from 160° F. to 180° F., S.A.E. 40; and above 180° F., S.A.E. 50 oil. If the engine oil meets these requirements, it may be used in the governor as well.

Oil contamination is the major cause of governor troubles. Use only new oil or filtered oil. Containers used for governor oil must be clean, and should be rinsed with a light grade of the same oil before using.

Anytime the governor oil appears to be dirty or breaking down from contaminants or excessive temperatures, drain the governor while it is hot, flush with the lightest grade of the same oil, and refill with fresh oil.

INSTALLATION ADJUSTMENTS

Speed setting and compensating needle valve adjustments are the only external adjustments to be made. Speed settings and speed limit stops are set at the factory on new or rebuilt governors and should not need changing.

When the engine is started for the first time — or after the governor has been drained and cleaned — the governor must be filled with oil, and any air trapped in the governor hydraulic system must be removed. To bleed off the trapped air, set the governor or speed control at the idle speed position, start the engine, and open the compensating needle valve (figures 1 and 2) several turns. This should cause the engine to hunt.

Loosen the air vent plug far enough to establish a leak, and allow the engine to hunt a sufficient length of time to permit all air, trapped in the governor oil passages, to escape at the vent plug. When no more air bubbles are apparent, tighten the vent plug, and if necessary add oil to the governor to restore the correct level in the gauge glass.

The compensating needle valve can now be closed gradually until hunting is just eliminated. The proper setting depends upon the characteristics of the engine.

Keep the valve as far open as possible to prevent sluggishness. After the needle valve is adjusted correctly for the engine, it should not be necessary to change the setting except for a large permanent temperature change affecting the viscosity of the governor oil. The needle valve setting will vary from 1/8 turn open to 2 turns open.

On some installations, opening the needle valve will not cause the engine to hunt. In such cases, bleed the air from the governor by disturbing engine speed to cause the governor to move through full stroke in both directions a sufficient number of times to force out all trapped air.

SPEED LIMIT ADJUSTMENT

If it is necessary to establish or change speed limit adjustments or the pointer indication use the following procedure. Do not make the adjustments unless the linkage from the governor to the engine fuel racks or gas valve (or turbine valve) has been properly adjusted. Make certain that the engine is at idle speed or lower when the governor is set for low speed.

Shut down the engine and remove the governor cover and dial plate. Back off the elastic stop nut securing the speed adjusting knob, as shown in Figure 3, until the fibre insert in the nut comes off the threads of the dial shaft. The nut will turn much easier once it has reached this point.

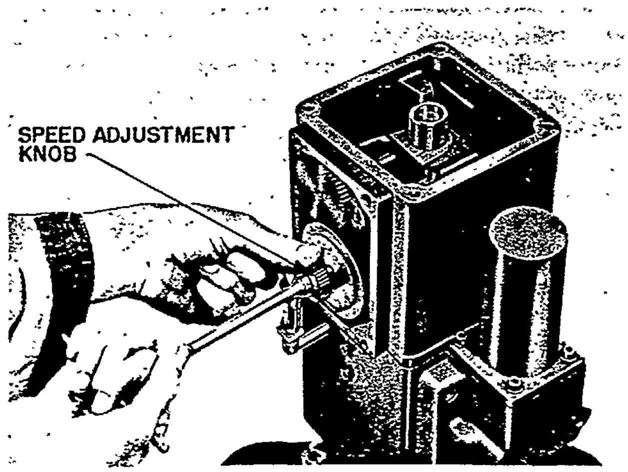


Figure 3

Now, before the nut is turned off the threaded end of the dial shaft, hold the inside end of the dial shaft with a screwdriver, as shown in Figure 4, to prevent it from being forced back through the bushing by the dial shaft spring. (See Figure 27, for arrangement of parts.) With the screwdriver firmly in place, remove the elastic stop nut, speed adjusting knob and numbered disc. Replace the knob and stop nut temporarily. Remove the screwdriver and pull the pointer disc and indicator gear out of mesh with the gear shaft, as shown in Figure 5.

Start the engine and adjust to the desired high speed with the knob. Remesh the indicator gear with the high speed stop pin of the indicator gear against the pin in the face of the panel. Replace the dial plate to check the pointer reading. If the pointer does not indicate the desired position on the dial plate, pry the pointer disc off and reposition it on the indicator gear.

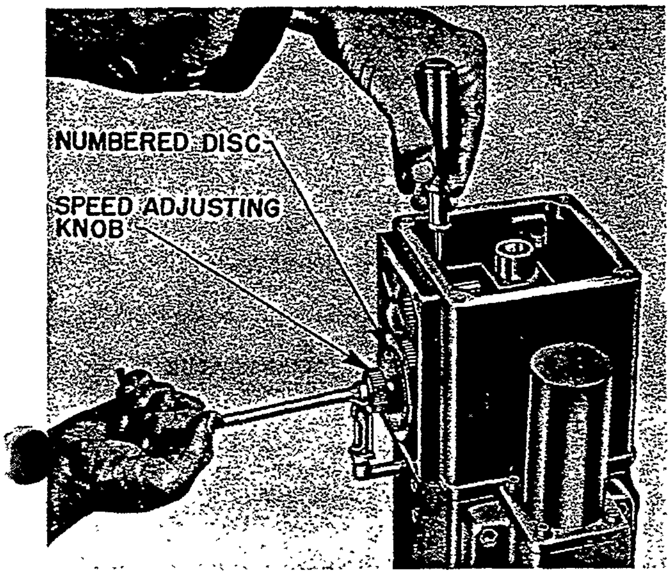


Figure 4

Check the low speed by turning the speed adjusting knob until it contacts the low speed stop. (On dials calibrated in rpm, an error of 10% between engine speed and pointer reading may be expected at low speed.)

When the desired high and low speeds have been obtained, shut down the engine, remove the elastic stop nut and speed adjusting knob as before. Reassemble all parts in proper order.

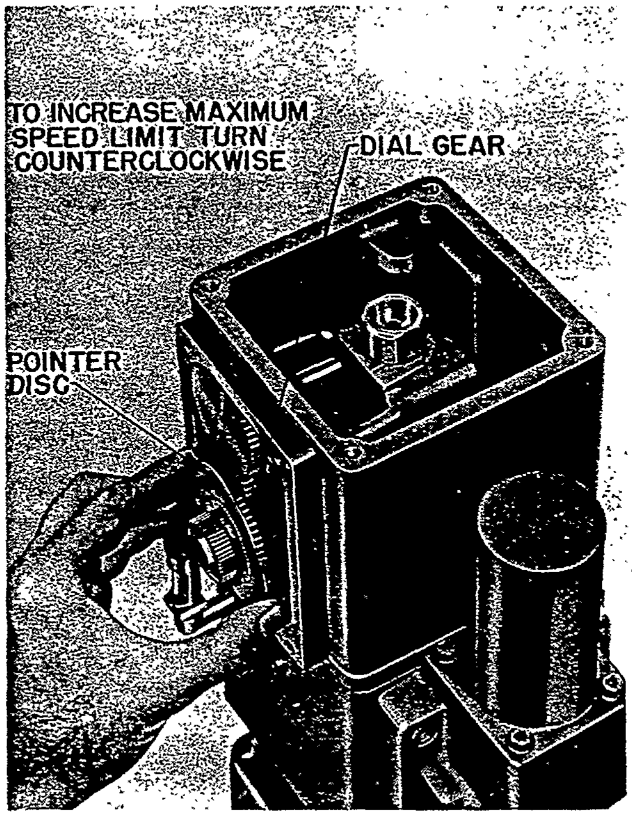


Figure 5

Section II OPERATION

DESCRIPTION

The cross-sectional view, figure 6, shows the position of the governor parts with the engine running at a constant speed under a steady load. The centrifugal force of the fly weights (due to the speed of rotation), balances the opposing force of the speeder spring with the flyweights in the vertical position. In this position the flyweights hold the pilot valve plunger in its centered position, with the control land covering the control ports in the pilot valve bushing assembly. When the control ports are closed the buffer piston is centered in its cylinder by the buffer springs and the balanced oil pressure across the piston. The power piston is held stationary.

PRINCIPLE OF OPERATION

The schematic diagram, figure 7, shows the essential parts of the governor. The power spring acts to shut off fuel to the engine. Oil pressure is used only to increase the supply of fuel.

The governor drive shaft, pump, pilot valve bushing assembly and flyweights rotate together. The drive shaft speed may be either engine speed or some ratio of engine speed as determined by the drive from the engine. The drive shaft may rotate in either direction.

Two accumulators are provided for pressure oil storage capacity; the maximum pressure of governor oil is regulated by a by-pass port in one of the accumulator cylinders.

A "buffer" piston centered by springs is in the hydraulic circuit between the pilot valve plunger and the power piston. It is by-passed by the needle valve, and also by passages which are uncovered when it moves more than a certain distance away from its central position. Any difference in oil pressure on the two sides of the buffer piston is transmitted to the receiving compensating land on the pilot valve plunger.

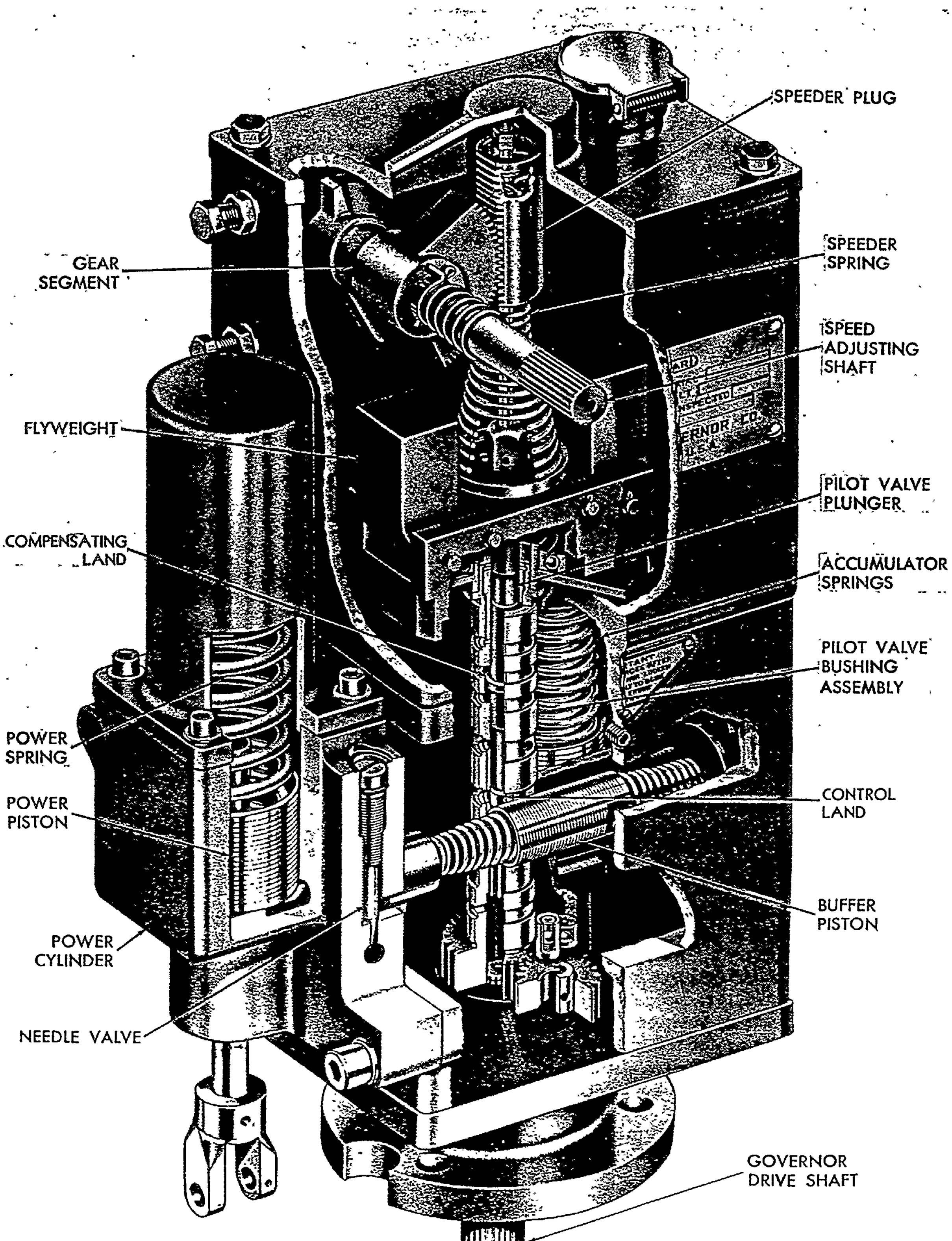


Figure 6, Sectional Cutaway of Lever Type Governor

INCREASE OF LOAD

Assume the load on the engine is increased resulting in a decrease in speed. As speed decreases, the flyweights move in, lowering the pilot valve plunger and uncovering the control port in the pilot valve bushing. The opened control port admits pressure oil (red) to the buffer piston area (blue) causing the buffer piston to move to the left and to transfer an equal volume of oil (green) to the power cylinder, forcing the power piston up, in the direction to increase fuel to the engine.

As the power piston moves up and the buffer piston is forced in the direction of oil movement (from pilot valve to power cylinder) the left hand buffer spring is compressed and the right hand buffer spring relieved. The buffer piston movement against its spring produces an intermediate oil pressure (blue) which is higher than the power cylinder oil pressure by an amount proportional to the buffer piston displacement.

The receiving compensating land on the pilot valve plunger is acted on by the intermediate and power cylinder oil pressures. The higher intermediate oil pressure existing momentarily in the fuel increase movements, causes an upward force on the receiving compensating land. This force added to the force of the flyweights balances the speeder spring and the pilot valve plunger moves up enough to cover the control port, though the speed is still below normal.

As the control port is covered, the power piston is stopped at a position corresponding to the increased amount of fuel required to operate the engine under the increased load, and the engine speed continues to return to normal. Oil leaking through the compensating needle valve equalizes the pressure on each side of the buffer piston and above and below the receiving compensating land. As the oil pressures equalize, the buffer springs return the buffer piston to its centered position, gradually reducing the force of the oil pressure holding the pilot valve plunger and flyweights in their centered position. During the same time the oil pressures are being equalized, the engine speed is increasing and the centrifugal force of the flyweights gradually increases because of the increasing engine speed until it is in balance with the force of the speeder spring.

The governor is so designed that, if the compensating needle valve is correctly adjusted, the differential oil pressures on the receiving compensating land and the flyweight-speeder spring forces equalize at the same rate, and the pilot valve plunger is held in a centered position. At the end of this sequence of governor operations, the engine will again be running at normal speed, but with an increased load and increased fuel setting.

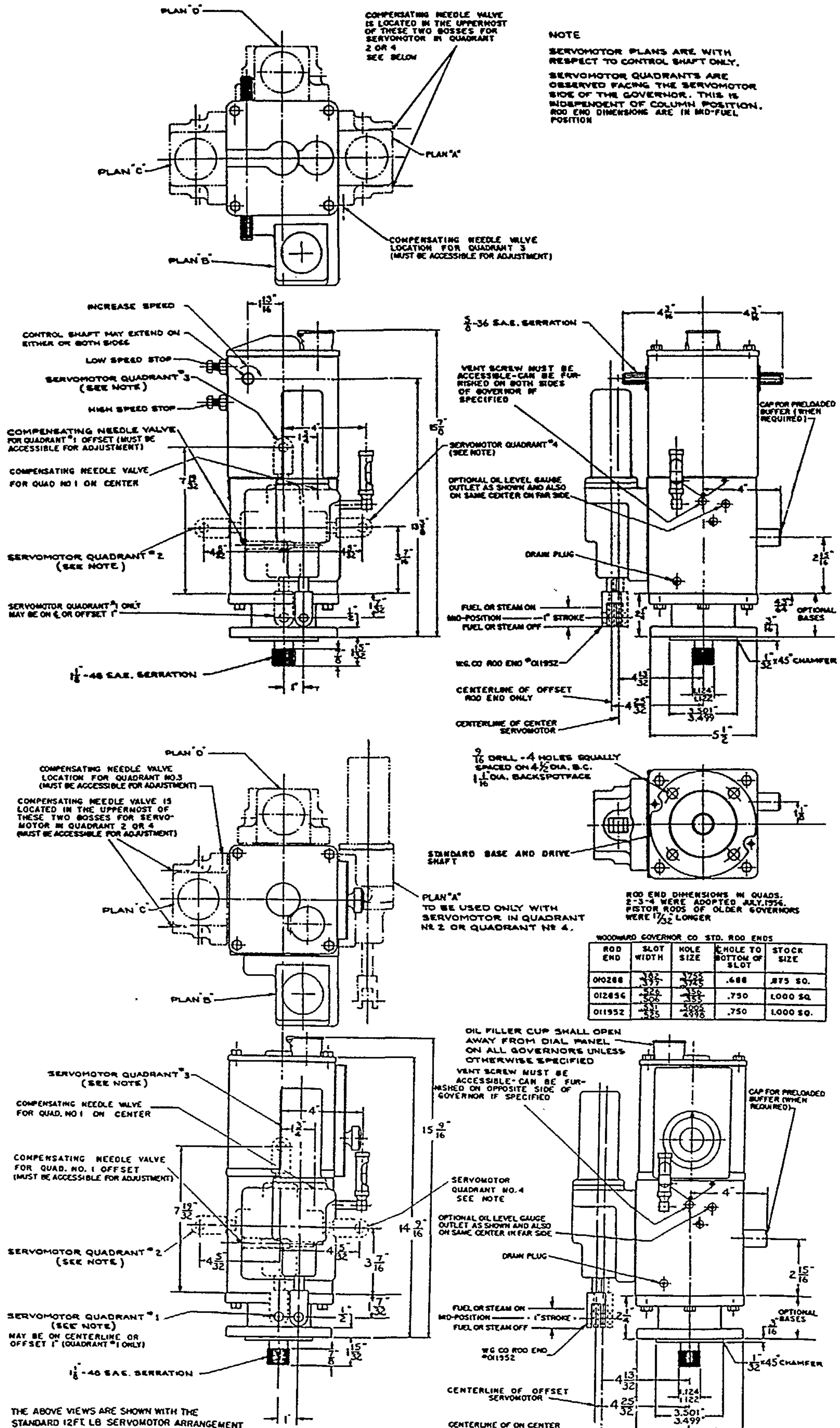
DECREASE OF LOAD

Assume now that the load on the engine is decreased and the speed increases. As the speed increases, the flyweights move out, raising the pilot valve plunger and uncovering the control port in the pilot valve bushing. The opened control port opens the right hand buffer area to sump and allows the power spring to force the power piston down in the direction to decrease fuel.

As the power piston moves down and the buffer piston is forced in the direction of oil movement (from power cylinder to pilot valve) the right hand buffer spring is compressed and the left hand spring relieved. The buffer piston movement against its spring produces an intermediate oil pressure (blue) which is lower than the power cylinder oil pressure (green) by an amount proportional to the buffer piston displacement.

The decreased intermediate oil pressure now existing results in a downward force on the receiving compensating land of the pilot valve plunger which (added to the downward force of the speeder spring) balances the force of the flyweights and the pilot valve plunger moves down enough to cover the control port though the speed is still above normal. As the control port is covered, the power piston is stopped at a position corresponding to the decreased fuel requirements for the engine under reduced load, and the engine speed continues to return to normal.

Oil leaking through the compensating needle valve again equalizes the pressures on each side of the buffer piston, allowing the buffer springs to return the piston to its centered position. At the same time, the same pressures above and below the receiving compensating land are equalized, gradually reducing the force which was holding the pilot valve plunger and flyweights in their centered position. As the oil pressures are being equalized, the engine speed is decreasing and the centrifugal force of the flyweights



WOODWARD GOVERNOR CO STD. ROD ENDS

ROD END	SLOT WIDTH	HOLE SIZE	℄ HOLE TO BOTTOM OF SLOT	STOCK SIZE
010288	.382/.377	.3755/.3745	.688	.875 SQ.
012856	.526/.506	.356/.355	.750	1.000 SQ.
011952	.531/.525	.5005/.4995	.750	1.000 SQ.

Figure 8, Outline Drawing

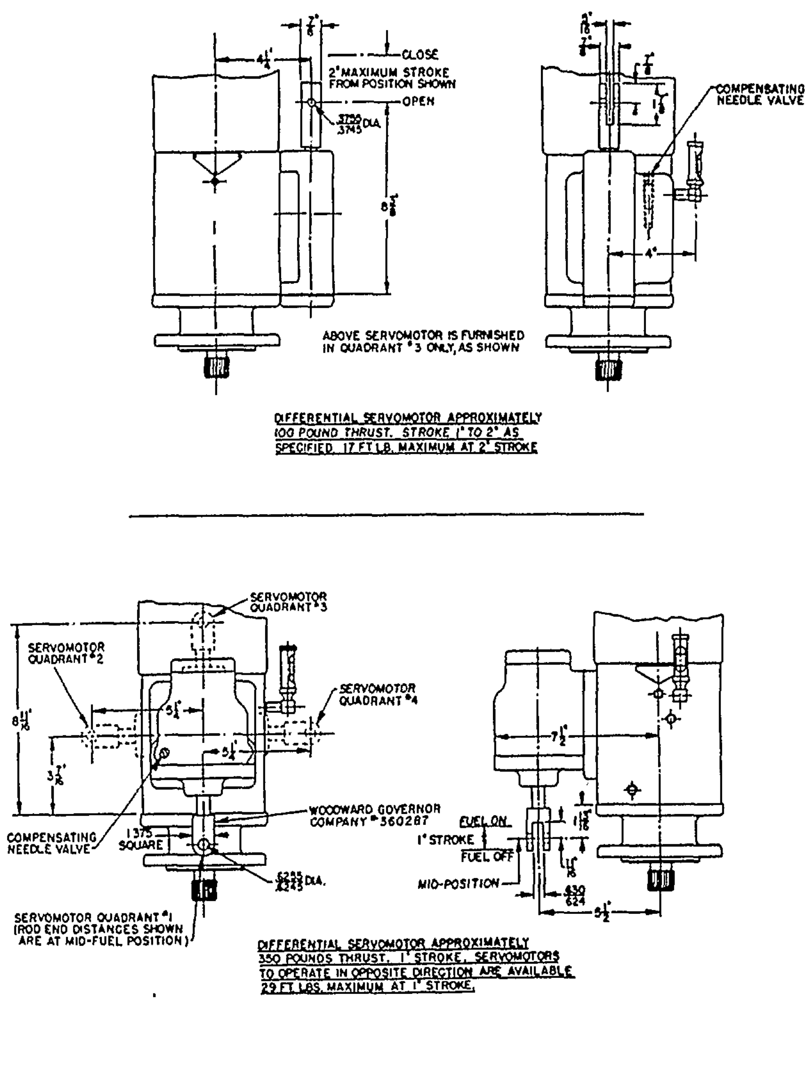


Figure 9, Differential Type Servomotors

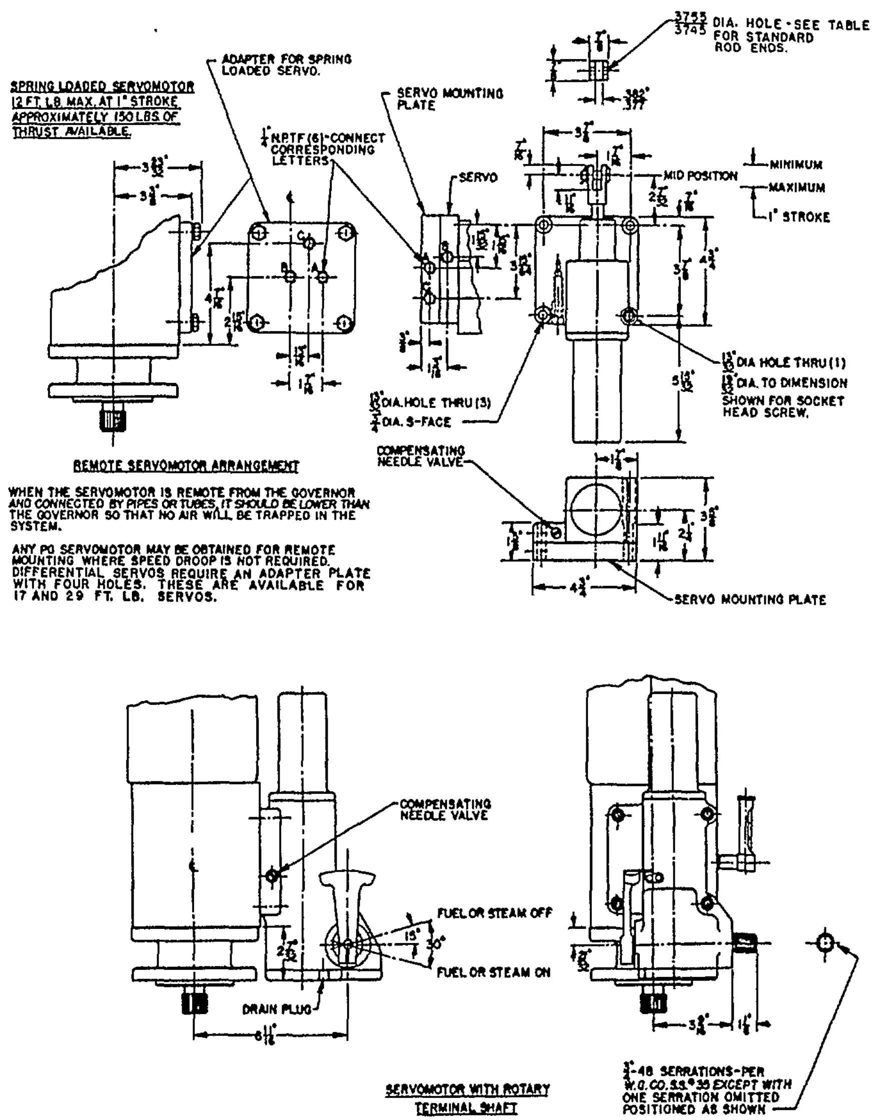


Figure 9a, Remote and Rotary Type Servomotors

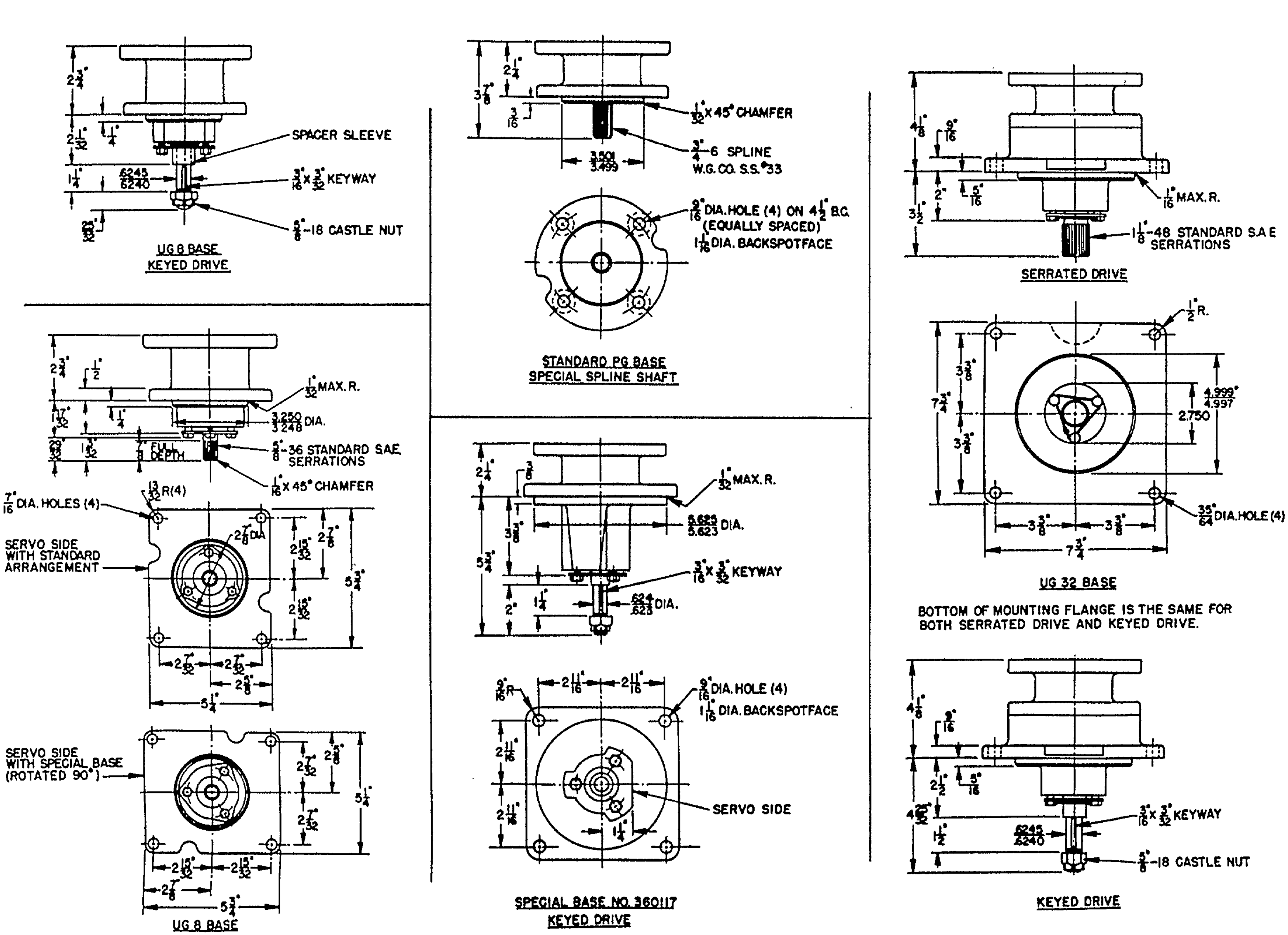
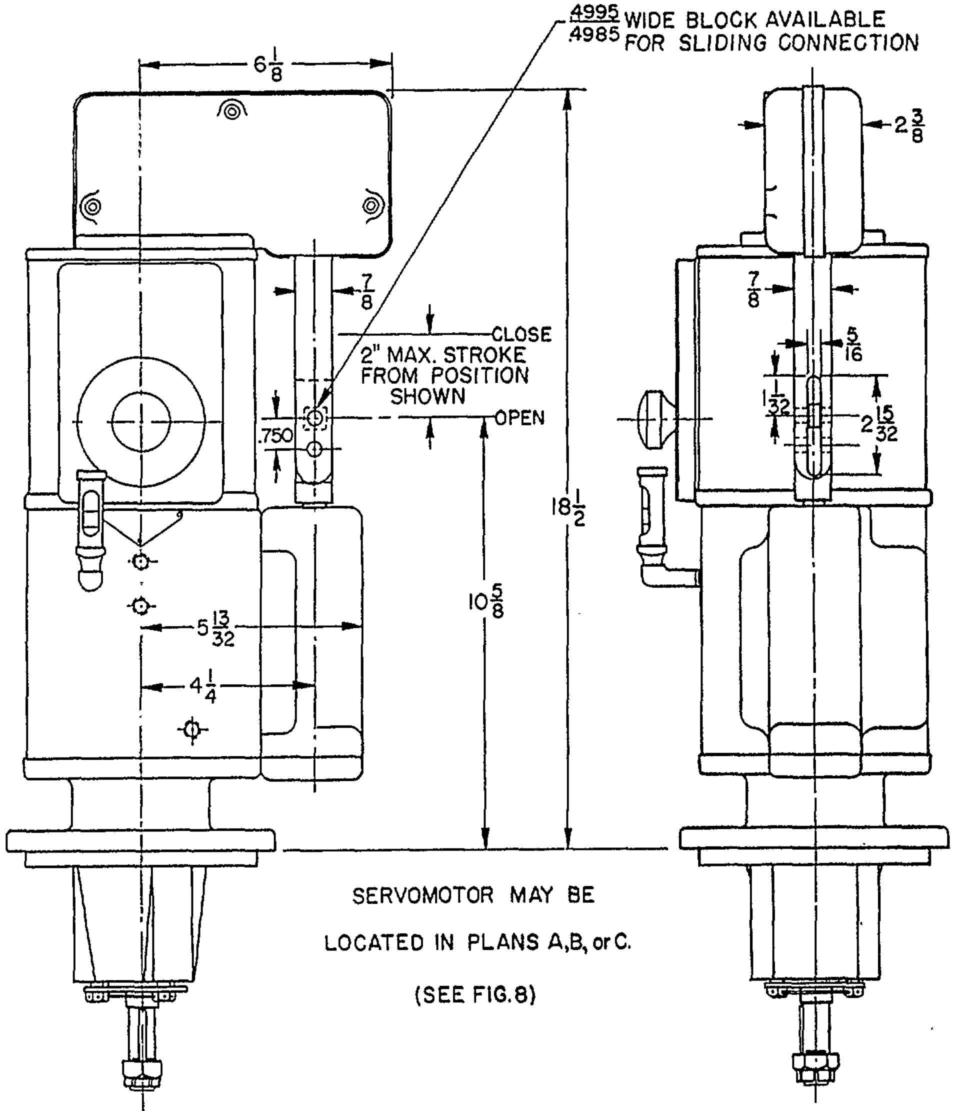


Figure 9b, Optional Bases

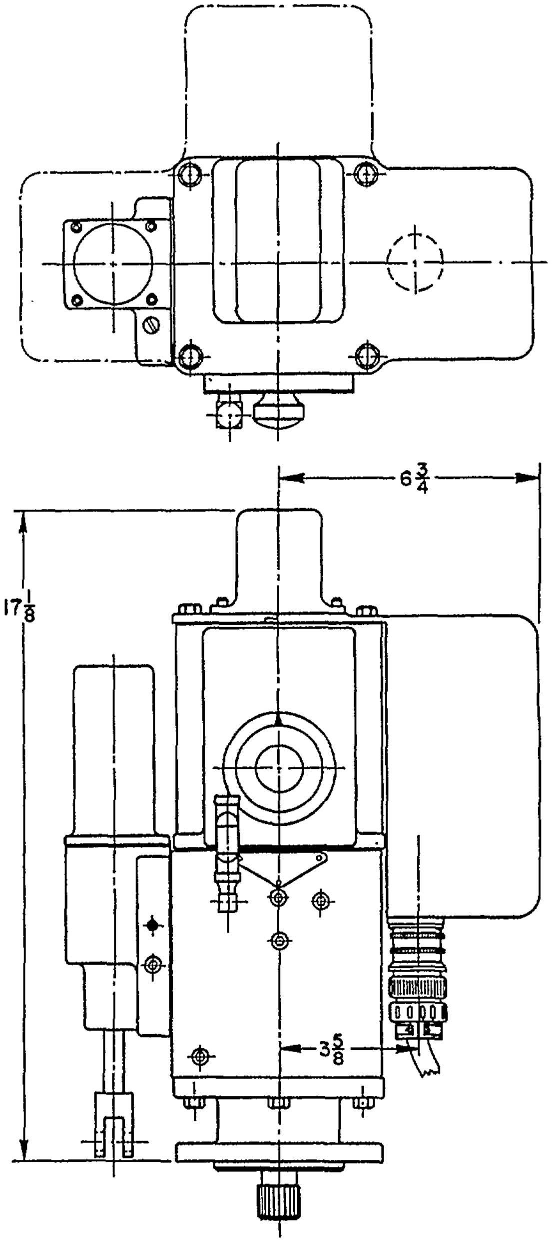


SERVOMOTOR MAY BE

LOCATED IN PLANS A,B, or C.

(SEE FIG.8)

OUTLINE OF GOVERNOR
WITH SPEED DROOP



OUTLINE OF GOVERNOR
WITH SYNCHRONIZING MOTOR

Figure 9C, Auxiliary Devices

Section III
MAINTENANCE

GENERAL

When requesting information concerning governor operation and maintenance or ordering replacement parts, it is essential that the following information be included:

1. Governor serial number (shown on name plate). The serial number is needed since the reference numbers shown in this bulletin do not identify the exact part number required for any one governor.
2. Bulletin number. (This is bulletin No. 36002)
3. Part reference number, name of part, or description of part.

It is suggested that the best mechanic available (preferably one experienced with small parts assembly) be permanently assigned to all governor repair work. Cleanliness of tools and work space is essential. A work bench, vise, arbor press, speed lathe, air line, and containers for cleaning solvents should be provided if possible. The usual small hand tools are required, and a few special Woodward Governor tools are desirable if sub-assemblies are to be disassembled.

LUBRICATION

The upper rotating parts of the governor are lubricated from an oil hole leading upward through the center of the pilot valve plunger. Oil is metered to the ballhead thrust bearing, then to the flyweight bearings and generally throughout the upper part of the governor. Governor pump gears, pilot valve plunger, power piston and buffer piston are all lubricated directly by pressurized oil from the governor pump and accumulator system.

INSPECTION AND TEST

Governor faults are usually revealed in speed variations of the engine, but it does not necessarily follow that all such speed variations indicate governor faults. Therefore, when improper speed variations appear, the following procedure should be carried out:

1. Check the load to be sure that the speed changes observed are not the result of load changes beyond the capacity of the engine.
2. Check the engine operation to be sure that all cylinders are firing properly, and that the injectors are in good operating condition.
3. See that the operating linkage between the governor and engine is free from binding or lost motion.

If neither load nor engine irregularities are found to be the cause of the speed variation, the cause may be either in the governor or in the engine to governor drive.

If the speed variations are erratic but small in magnitude, the fault may lie in the engine drive to the governor. Excessive backlash or a tight meshing of the gears driving the governor, may be the cause. No amount of adjustment or other work on the governor can correct this condition.

If the speed variations of the governor are large and erratic, and unaffected (except, perhaps in magnitude) by changes of adjustment, or if the governor fails to control at all, it should be repaired or replaced.

Check the setting of the compensating needle valve. It is impossible for the governor to function correctly if the needle valve is closed tight.

As a last resort, to prove whether the engine or governor is at fault, another governor, known to be in good condition, should be installed on the engine. When this is done, see that the test governor is the same type as the one being removed.

If the above checks show that a governor overhaul is necessary, the instructions outlined below will apply.

REMOVAL OF GOVERNOR FROM ENGINE

In cases of major repairs or a complete governor change, the unit may be removed from the engine as follows:

1. Remove oil drain plug (figure 1 or 2). Drain oil from governor and replace the drain plug. NOTE: Governor may be equipped with drain cock for draining.
2. Disconnect linkage from fuel rod end.
3. For a lever type governor, disconnect speed adjusting linkage from governor speed control lever. Do not remove lever from speed control shaft without first marking its position.
4. Remove the four stud nuts holding governor assembly to governor mounting pad and lift governor off the studs and away from the engine. Remove the gasket between governor and governor mounting pad.

NOTE: At all times use care in handling and setting down the governor; be particularly careful to avoid striking the end of the drive shaft a sharp blow. Such treatment might damage the governor drive shaft, drive shaft bearing, and governor oil pump gears.

Section IV
DISASSEMBLY

TOP COVER (Figures 10 and 12)

Dial or Lever Governor:

1. Remove cover screws (A) and washers (B).
2. Remove cover (C) and gasket (D).

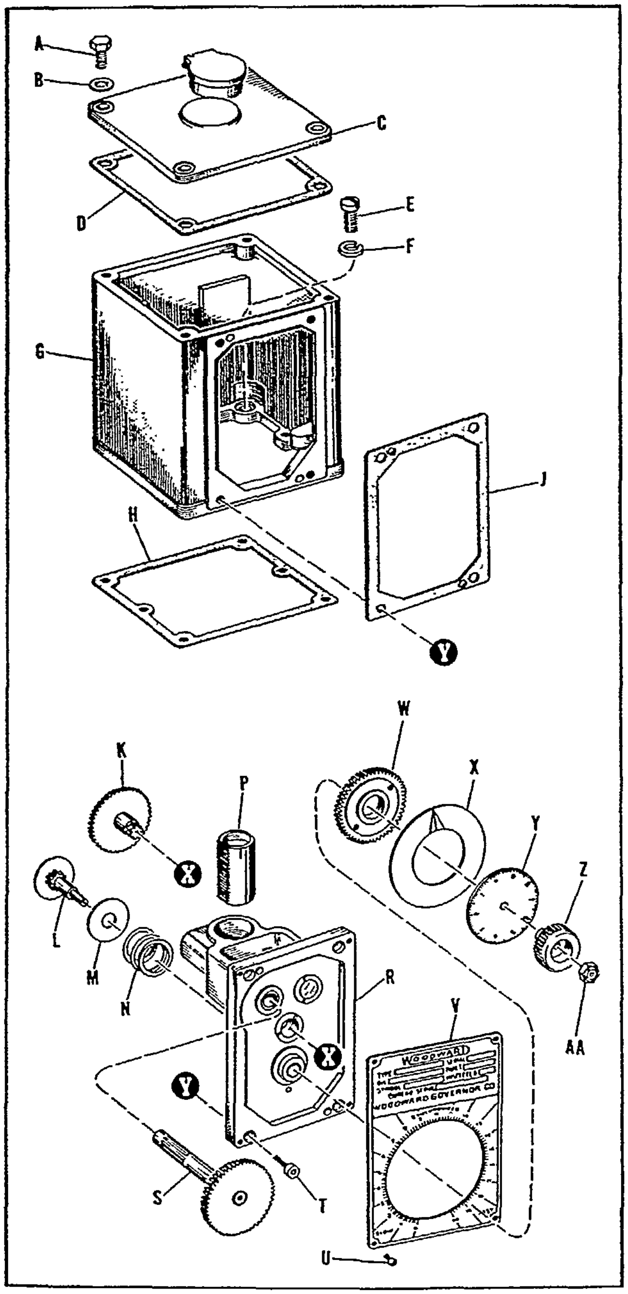


Figure 10, Dial Type PG Governor

COLUMN ASSEMBLY

Dial Governor (Figure 10):

1. Back out four fillister head screws (E) (located at lower inside corners of column) and lift column (G), lockwashers (F) and screws (E) vertically from the power case as shown in figure 11. Discard case-column gasket (H).
2. Turn speed indicating dial counter clockwise against the low speed stop.
3. Measure and record the distance from the top of the speeder plug (P) to top of column (G).
4. Remove round head screws (U) and take off dial plate (V).
5. Back off elastic stop nut (AA) and remove the speed setting knob (Z), numbered disc (Y), dial shaft assembly (L), pinion assembly (K), washer (M), spring (N), indicator gear (W), pointer disc (X), gear shaft assembly (S) and speeder plug (P).

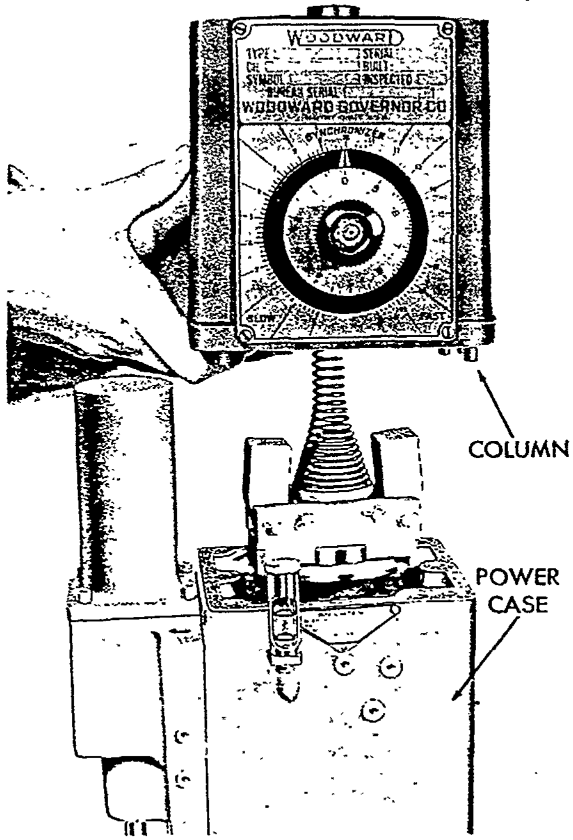


Figure 11, Removing Column

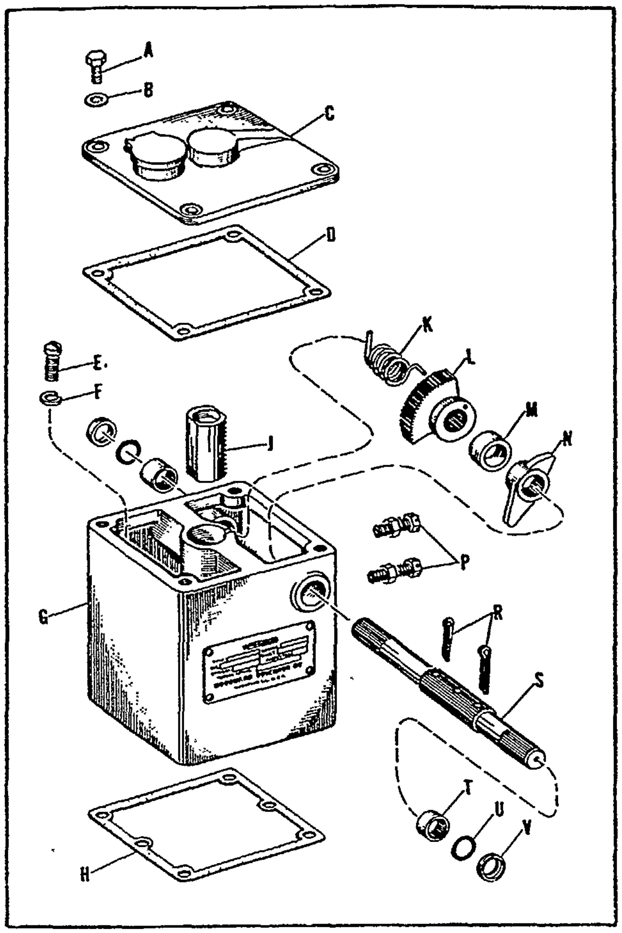


Figure 12, Lever Type PG Governor

6. Remove screws (T) and panel (R). Discard panel gasket (J).

Lever Governor (Figure 13):

1. Mark relative position of segment gear (L) to speeder plug (J).
2. Back out four fillister head screws (E) (located at lower inside corners of column) and lift column (G), lockwashers (F) and screws (E) vertically from power case (figure 11). Discard case-column gasket (H).
3. Back off hex head screws with hex nuts (P). Remove the two cotter pins (R) holding the segment gear. Push the speed adjusting shaft (S) in until the speed stop arm (N) is out of mesh with the serrations. Rotate speed adjusting shaft until speeder plug gear teeth come out of mesh with those in the segment gear (L) and lift out speeder plug (J).
4. Drive the speed adjusting shaft (S) from the column. (The shaft will carry one needle bearing (T), "O" ring (U) and retainer (V) with it when it is driven out.)
5. Support speed stop arm (N), spacer (M), segment gear (L), and torsion spring (K) when shaft is removed.
6. Use shaft in opposite direction to remove remaining needle bearing, "O" ring and retainer.

ROTATING SLEEVE ASSEMBLY (Figure 13)

Dial or Lever Governor:

1. Lift assembly from power case.
2. Remove speeder spring (A).
3. Remove pilot valve cotter pin (B) and back off pilot valve plunger nut (C).
4. Lift out speeder spring seat (D), thrust bearing (E), washer (F) and adjusting spring (G).
5. Turn assembly over, loosen two round head retaining screws (M), turn flyweight head retaining washers (L) 180° and lift flyweight head (K) from pilot valve bushing assembly (V).
6. Remove flyweight pin cotter pins (P), flyweight pins (N), and flyweights (H).
7. Press rubber coupling (J) from flyweight head (K).
8. Remove pilot valve bushing body snap ring (R) and lift out pilot valve plunger (T) and compensating bushing (S).
9. Remove bearing (U) from pilot valve bushing assembly (V).

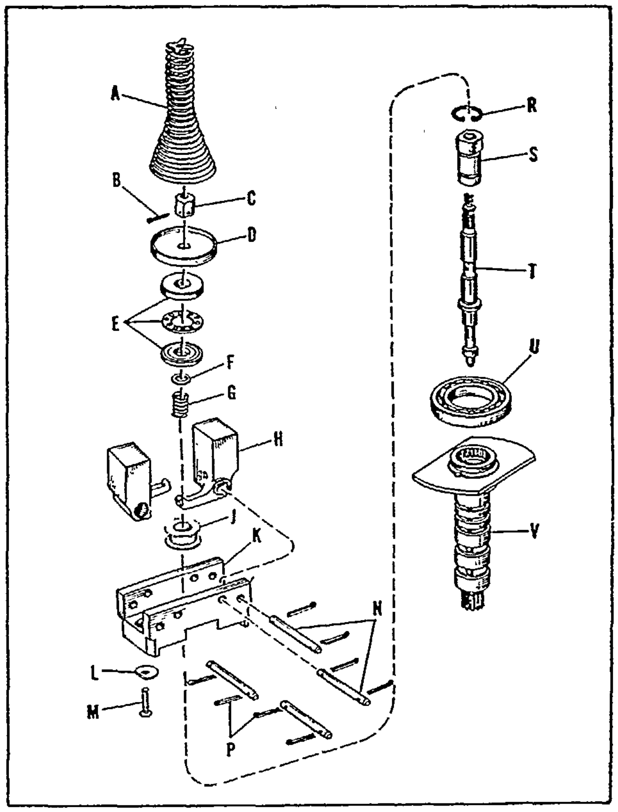


Figure 13, Rotating Sleeve Assembly

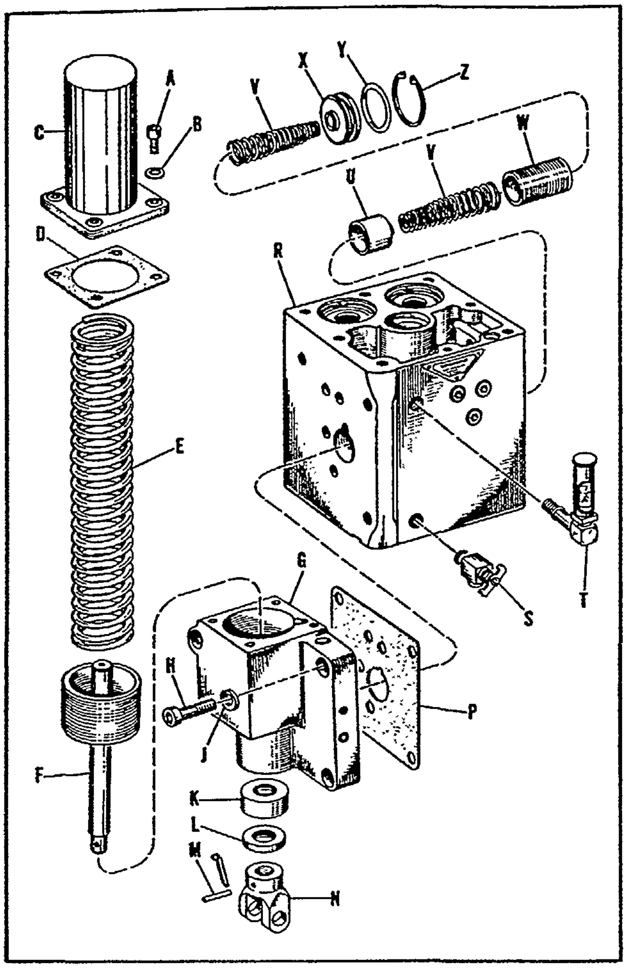


Figure 14 , Power Cylinder Assembly

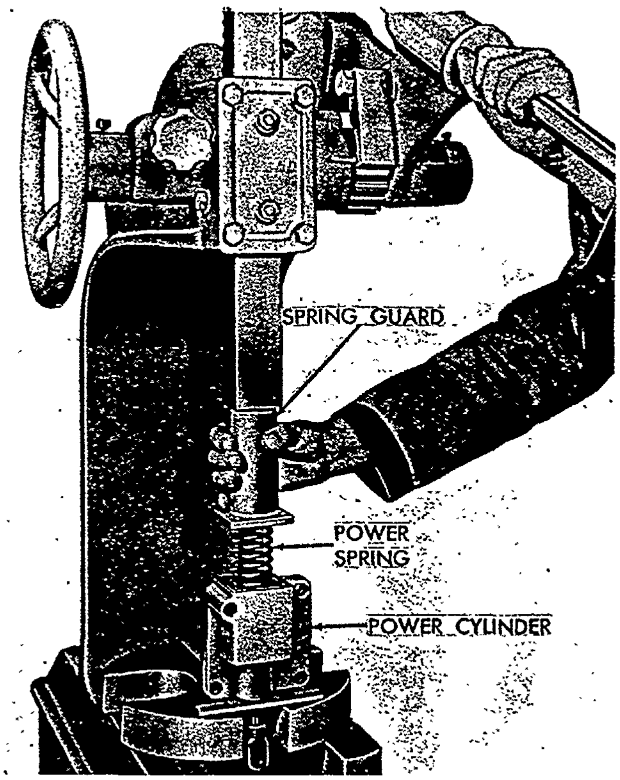


Figure 15, Removing Spring Guard

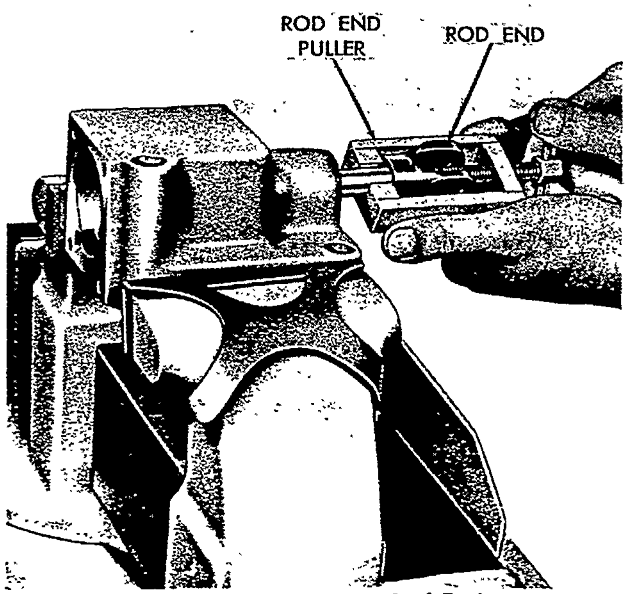


Figure 16, Removing Rod End

POWER CYLINDER ASSEMBLY (Spring Loaded) (Figure 14)

Dial or Lever Governor:

1. Remove oil gauge (T) and drain cock (S). Remove buffer cylinder snap ring (Z). Insert a 1/4-28 screw into plug (X) and remove plug with "O" ring (Y), buffer springs (V), buffer piston (W) and spring seat (U).
2. Back out four 3/8 inch socket screws (H) and lock washers (J), and remove power cylinder (G) and power cylinder-case gasket (P) from power case (R).
3. Position power cylinder in arbor press to hold spring guard (C) in place against power spring (E). Remove four 1/4 inch socket head screws (A) and lockwashers (B); slack off on arbor press and lift off spring guard (C), spring (E) and spring guard-power cylinder gasket (D). See figure 15 for removal operation.
4. Remove cotter pin and taper pin (M) in rod end (N). Use care not to bend power piston assembly (F).
5. Use rod end puller to remove fuel rod end (N). See figure 16 for use of puller.
6. Push power piston assembly (F) from power cylinder (G).
7. Grip power cylinder in a vise and remove oil seals (L) and (K). See figure 17 for method of removal.

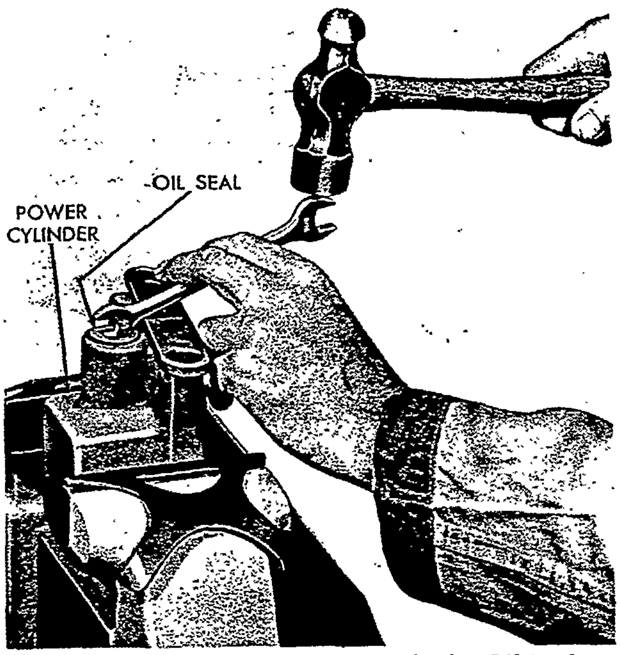


Figure 17, Removing Power Cylinder Oil Seal

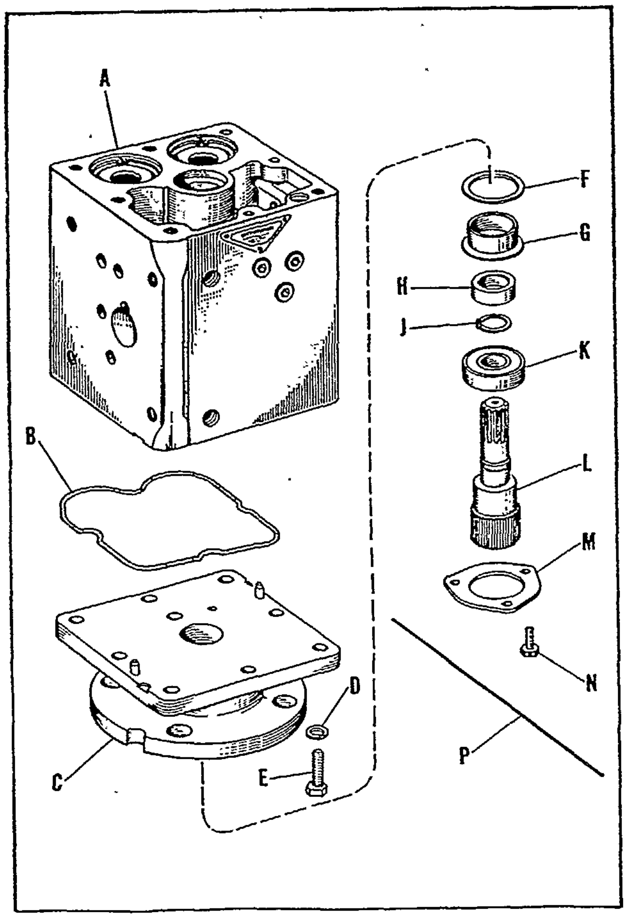


Figure 18, Drive Shaft and Base

DRIVE SHAFT ASSEMBLY (Figure 18)

Dial or Lever Governor:

1. Tip governor on its side and remove the brass lockwire (P) from the three hex head cap screws (N) that secure the bearing retainer (M) to the governor base.
2. Remove cap screws and retainer and pull the drive shaft assembly from the base.
3. Remove oil seal retainer (G), gasket (F) and snap ring (J) and press bearing (K) from the serrated drive shaft (L).
4. Press oil seal (H) from the retainer (G). See figure 19 for removal operation.

BASE (Figure 18)

Dial or Lever Governor:

1. The power case (A) and base (C) are aligned with two straight dowels and secured with eight hex head screws and split lockwashers. Remove screws (E) and washers (D).
2. Insert large screw driver in slots at the bottom of the power case to aid in prying off the base (C).
3. Remove case-base oil seal ring (B) from power case.

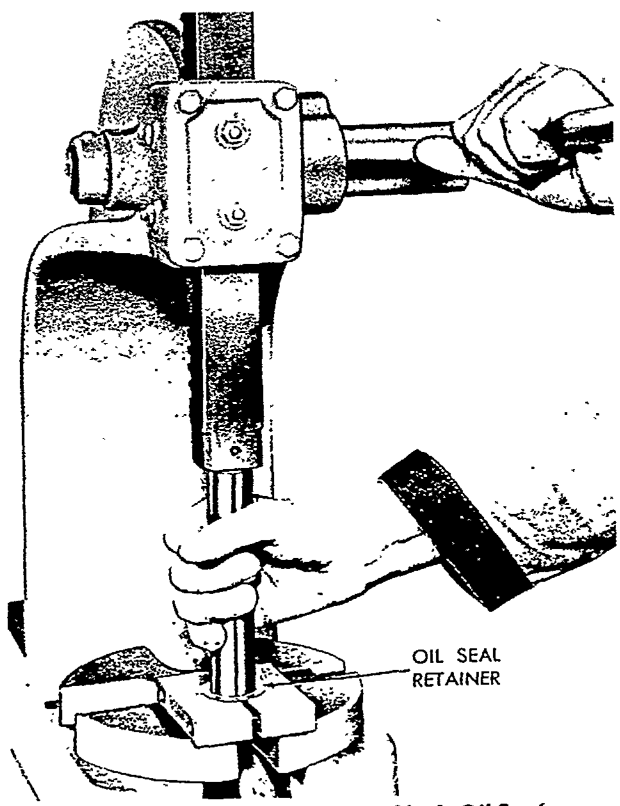


Figure 19, Removing Drive Shaft Oil Seal

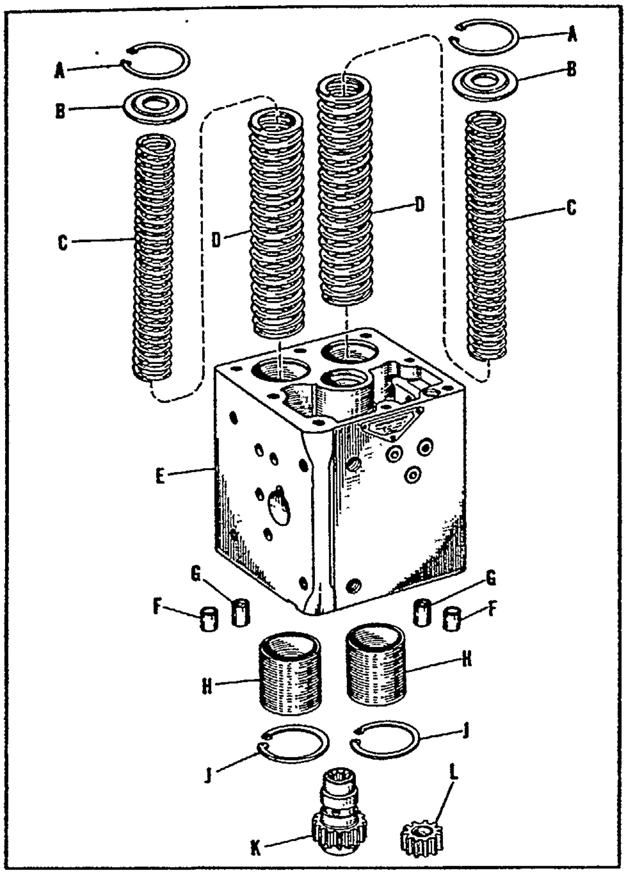


Figure 20, Power Case Parts

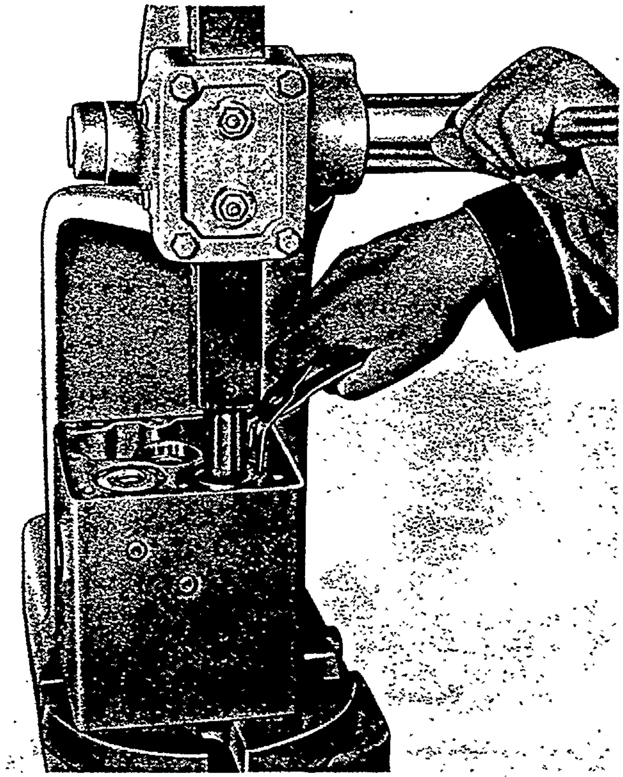


Figure 21, Removing Accumulator Springs and Pistons

POWER CASE (Figure 20)

Dial or Lever Governor:

1. Lift drive gear (K) and idler gear (L) from power case.
2. Invert power case (E) and position in arbor press or a small drill press. Place a rod against accumulator spring seat (B), compress small and large accumulator springs (C) and (D) and remove snap ring (A). See figure 21 for removal operation.
3. Slack off on arbor press and remove spring seat (B) and small and large accumulator spring (C) and (D).
4. Invert power case and remove snap rings (J) and accumulator pistons (H).
5. If necessary, remove check valve assemblies (F) and (G) from power case as follows: Inner check valves (G) — Pry retainer plate from check valve assembly and remove springs and balls. Outer check valves (F) — Press balls through and out of check valve case. Thread all four check valve cases with a $\frac{1}{4}$-28 tap, and using a $\frac{1}{4}$-28 bolt with a small plate as a jack, pull the four valve cases. See figure 22 for method of removal. Remove two balls from lower case.

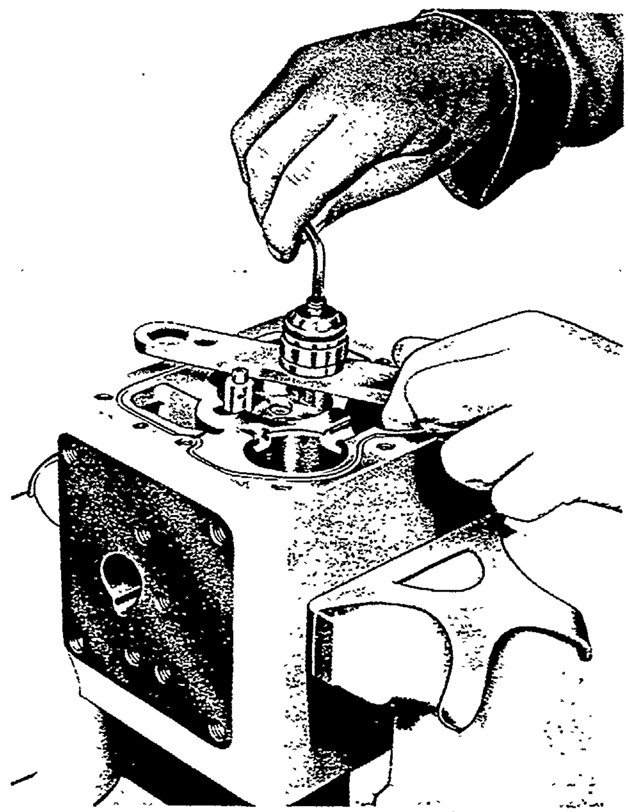


Figure 22, Removing Check Valve Case

INSPECTION AFTER DISASSEMBLY

After disassembling the governor, wash all parts in clean fuel oil and carefully inspect for wear. Generally, most of the repair work consists of cleaning and polishing the governor parts.

Inspect the check valves in bottom of governor power case. They must be clean, operating freely and seating properly.

The flat, joint surfaces at top and bottom of both governor case and base should be free of burrs and high spots. Carefully avoid scratching or scoring these faces, particularly the top of the base and bottom of the case. Avoid damage to the neoprene seal ring and the groove in the bottom face of the governor power case.

Wear points which should be inspected and checked include:

1. Pump gear teeth and the idler gear bushing and stud.
2. Pump gear pockets — depth and O.D.
3. Pilot valve bushing — O.D. above and below the pump gear. Also the I.D. of the bores in power case for the pilot valve bushing and buffer piston.
4. The pilot valve plunger should move freely in the pilot valve bushing assembly. If the plunger surfaces are scratched they may be dressed with a hard Arkansas stone.

   CAUTION: The edges of the control land and compensating piston MUST be left sharp.
5. The power piston assembly should move freely in the power cylinder, and the buffer piston should move freely in the buffer cylinder.
6. Ballhead flyweights must work freely on the needle bearings and pivot pins. If the toes of the flyweights have flat spots, it will be necessary to disassemble the ballhead, and round off the worn spots with emery cloth. If wear is excessive, install new flyweights.
7. Ball races and bearing balls of the flyweight thrust bearing should be in perfect condition.

Section V
ASSEMBLY

GOVERNOR ASSEMBLY

While assembling the parts into the governor, care must be taken to insure that no lint — from wiping rags — or other foreign matter is present on the parts. The governor may be assembled dry, or if preferred a small amount of clean lubricating oil can be applied to the parts as they are placed into the governor. When the governor is assembled and before replacing the cover, apply a liberal amount of clean lubricating oil over all the moving parts, to insure initial lubrication. Replace all plugs removed from the governor case, using a good joint compound on the threads of the plug — NOT IN THE HOLE.

POWER CASE (Figure 20)

Dial or Lever Governor:

1. Press check valve assemblies (F) and (G) into power case (E).

   CAUTION: Special inserters must be used to press valves into power case.
2. Insert accumulator pistons (H) and snap rings (J) at gear pocket end of power case.
3. Invert power case. Insert small and large accumulator springs (C) and (D) and spring seats (B) and position in arbor press. Compress spring seats and insert snap rings (A).
4. Place drive gear (K) and idler gear (L) into gear pockets in power case.

BASE (Figure 18)

Dial or Lever Governor:

1. Insert oil seal (B) into groove of power case.
2. Position base (C) on power case (A), aligning dowel pins and idler stud with clearance hole in base.
3. Secure with eight hex head screws (E) and lock washers (D).

DRIVE SHAFT ASSEMBLY (Figure 18)

Dial or Lever Governor:

1. Press oil seal (H) into oil seal retainer (G) flush with end opposite flange.
2. Press bearing (K) onto serrated drive shaft (L) and secure with snap ring (J). Insert drive shaft through base and turn until splined end slips into splines in the pump drive gear. Continue turning to check alignment and free rotation of the pump drive gear and idler gear. Withdraw drive shaft and install oil seal retainer (G) and retainer gasket (F).
3. Install drive shaft assembly into base (C), and secure with bearing retainer (M) and three hex head cap screws (N). NOTE: Tighten cap screws evenly. DO NOT try to bring retainer into contact with base.
4. Thread brass lockwire (P) through holes provided in cap screws and fasten.

POWER CYLINDER ASSEMBLY (Spring Loaded) (Figure 14)

Dial or Lever Governor:

1. Press oil seals (K) and (L) into power cylinder. (Seal (K) is stamped with the number 182172 and it should be inserted with the number facing out.) Place oil seal (L) on top of oil seal (K) and press into power case .005 below flush. (Seal (L) is stamped 182171 and should also be inserted with the number facing out.)
2. Place an oil seal inserter over rod of power piston assembly (F) and insert into power cylinder (G). (The oil seal inserter is a special tool used to prevent damaging the oil seals.)
3. Position in arbor press, align taper pin holes and press rod end (N) onto end of power piston rod as shown in figure 23. (Place a small steel block in the rod end slot so that pressure is applied against bottom of slot.)
4. Insert taper pin (M), tap lightly and tightly into place and secure with cotter pin.
5. Position power cylinder (G) in arbor press. Place power spring (E), a new spring guard-power cylinder gasket (D), and spring guard (C) on power-cylinder and press into position. Secure with four socket head screws (A) and washers (B).
6. Place a new power cylinder-case gasket (P) on power case and install power cylinder assembly to power case.

   CAUTION: When positioning the gasket align it with the holes in the power case instead of those in the power cylinder.
7. Secure with four 3/8 inch socket head screws (H) and lock washers (J).
8. Insert spring seat (U), buffer springs (V), buffer piston (W), "O" ring (Y) and plug (X) into power case (R) and secure with snap ring (Z).

ROTATING SLEEVE ASSEMBLY (Figure 13)

Dial or Lever Governor:

1. Place pilot valve plunger (T) and compensating bushing (S) into pilot valve bushing assembly (V) and secure with snap ring (R).
2. Press the rubber coupling (J) into the ballhead (K). The two brass plates of the coupling are serrated and each has a missing tooth for positioning. The plates also have different diameters, the plate marked "top" is the larger of the two. Line up the missing serration of the coupling and ballhead; slip the bottom plate of the coupling through the ballhead from the top. Then press the top plate of the coupling flush with the bottom of the slot in the ballhead.

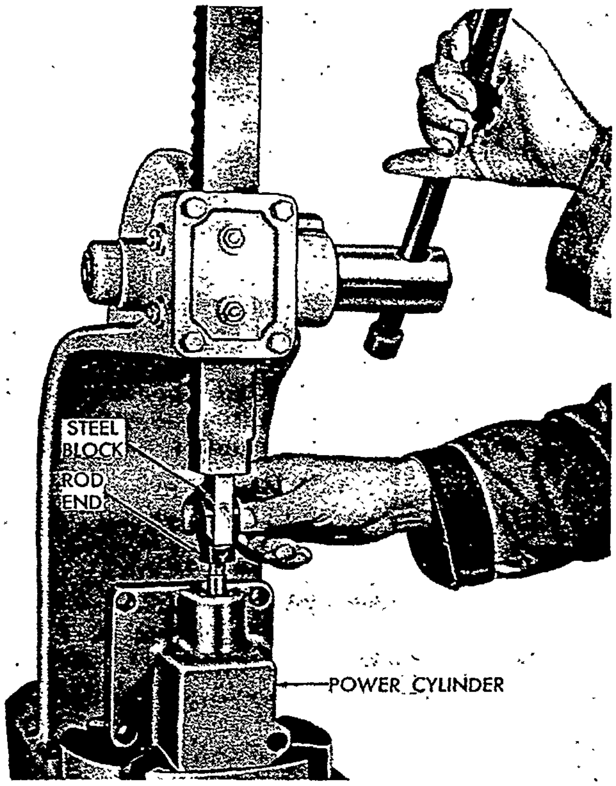


Figure 23, Installing Rod End

3. Place flyweights (H) in ballhead (K), insert ballarm pins (N) and secure with cotter pins (P).
4. Place ballhead assembly on the bench with the flyweights down. Insert pilot valve bushing assembly (V) into the ballhead being careful to line up the missing serrations in the rubber coupling with those in the rotating bushing. Turn ballhead retaining washers (L) 180° and tighten round head screws (M).
5. Install the adjusting spring (G), washer (F), thrust bearing (E), speeder spring seat (D) and secure with pilot valve plunger nut (C). (The thrust bearing race with the smaller hole fits against the spring collar.)
6. Center the pilot valve. With a slight pressure on the speeder spring seat (D), adjust the pilot valve plunger nut (C) until, as the flyweights are moved from their extreme inward to their extreme outward position, there is the same amount of control land showing in the control port. The control ports are the bottom row of holes in the pilot valve bushing assembly (V). See figures 24 and 25 for control port openings.
7. Secure with a cotter pin (B) through the pilot valve plunger nut (C) and pilot valve plunger.
8. Insert the speeder spring (A) into the spring seat. (Spring must fit tight in seat.)
9. Place rotating sleeve assembly into power case.

COLUMN ASSEMBLY

Dial Governor (Figure 10):

1. Install panel (R) with screws (T). Use new panel gasket (J).
2. Install shaft assembly (S) and speeder plug (P).
3. Place the spring (N) and washer (M) in position with one hand, and with the other replace the pinion assembly (K) and the dial shaft assembly (L).
4. Holding the dial shaft in position, install indicator gear (W) and turn the dial shaft until the speeder plug (P) is the same distance from the top of the column as before. See pages 3 and 4 for detailed speed adjustment instructions.
5. Position the indicator gear against the idle speed stop and install pointer disc (X), numbered disc (Y), speed setting knob (Z) and secure with elastic stop nut (AA).
6. Replace dial plate (V) and round head screws (U).
7. Install a new case-column gasket (H).
8. Place lockwashers (F) and fillister head screws (E) in holes in lower flange of the column. Align speeder spring check plug so that it will seat in top of bore in speeder plug (J) — NOT resting on check plug stop pin in speeder plug. Align dowel pins (in column) with holes in power case and place column (G) on power case. Secure with screws (E) and lock washers (F).

Lever Governor (Figure 12):

1. Install speed adjusting shaft (S), torsion spring (K), segment gear (L), spacer (M) and speed stop arm (N). Press needle bearings (T) into the column (G) and install "O" rings (U) and retainers (V).
2. Engage speeder plug (J) with segment gear (L) in the same relative position as they were before dismantling.
3. Position speed stop arm (N) and insert cotter pins (R).
4. Install new column gasket (H).
5. Place lock washers (F) and fillister head screws (E) in holes in lower flange of the column. Align speeder spring check plug so that it will seat in top of bore in speeder plug (J) — NOT resting on check plug stop pin in speeder plug. Align dowel pins (in column) with holes in power case and place column (G) on power case. Secure with screws (E) and lock washers (F).
6. High and low speed limit stop screws (P) should be adjusted to suit and secured with lock nuts, by checking desired speed limits with the engine running.

TOP COVER (Figures 10 and 12)

Dial or Lever Governor:

1. Position column-cover gasket (D) and cover (C).
2. Secure with hex head screws (A) and lock washers (B).

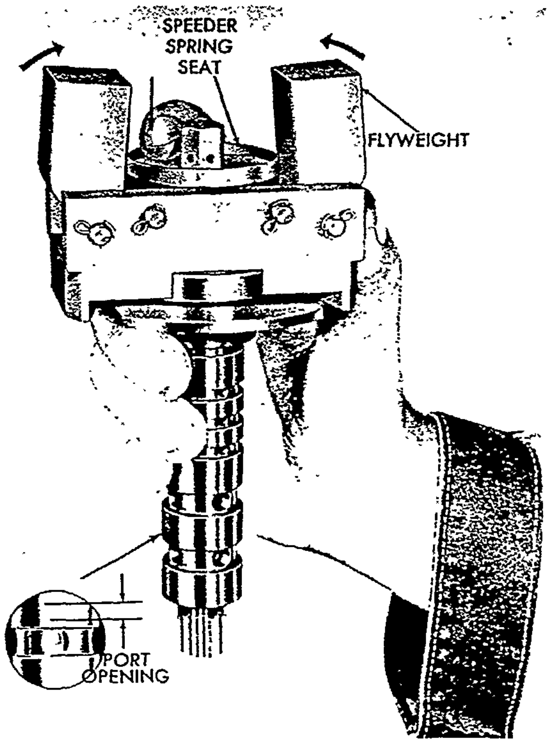


Figure 24, Centering Pilot Valve

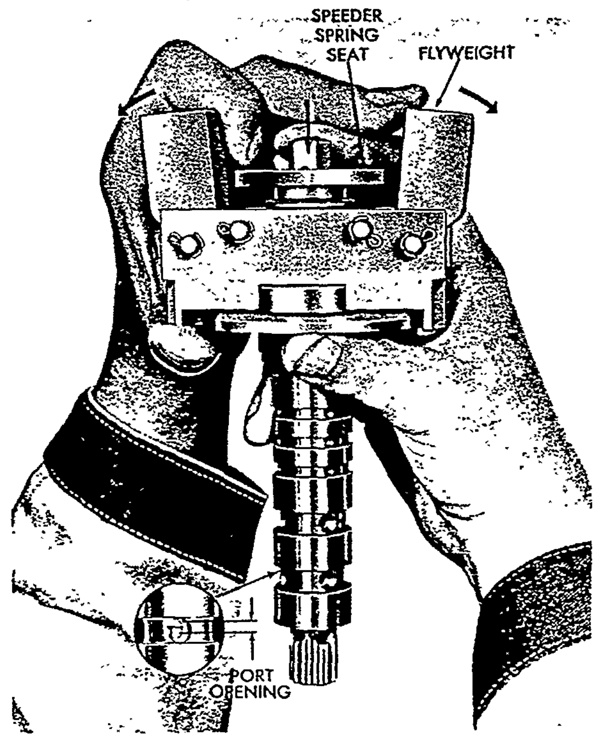


Figure 25, Centering Pilot Valve

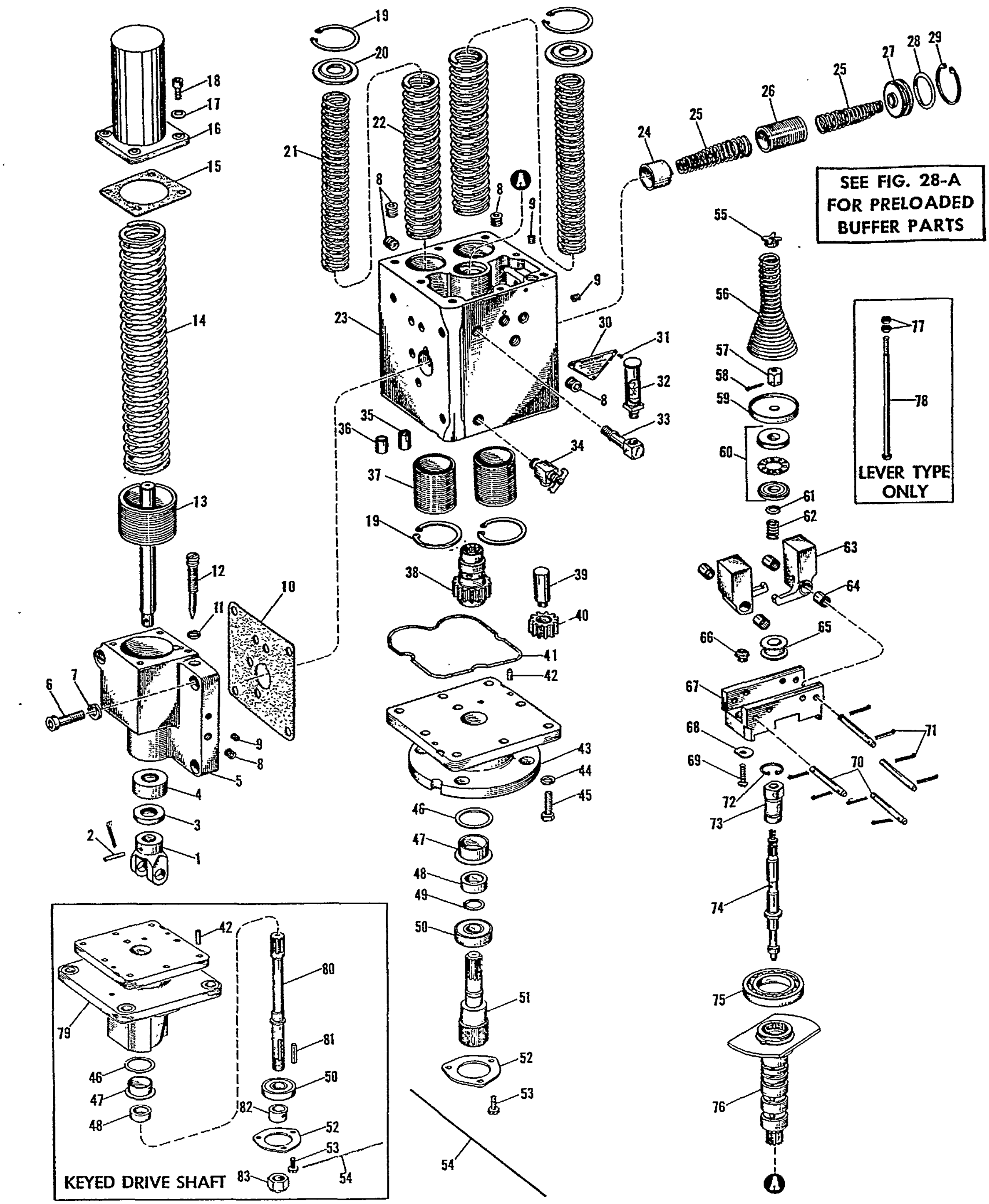


Figure 26, Lever and Dial Type Governor Power Case and Base Parts

INFORMATION AND PARTS REPLACEMENT: When requesting additional information concerning governor operation, or when ordering repair parts, it is very essential that the following information accompany the request.

1. Governor serial number (shown on name plate). The serial number is needed since the reference numbers shown in this bulletin do not identify the exact part number required for any one governor.
2. Bulletin number. (This is bulletin number 36002).
3. Part reference number, name of part, or description of part.

Parts List for Lever and Dial Type Governor Power Case and Base Parts

REF. NO.	PART NAME	NO. REQ'D
36002 - 1	Rod End	1
36002 - 2	No. 2 x 1¼" Taper Pin	1
36002 - 3	Oil Seal	1
36002 - 4	Oil Seal	1
36002 - 5	Power Cylinder	1
36002 - 6	⅜"-16 x 1¼" Socket Head Screw	4
36002 - 7	⅜" Split Lockwasher	4
36002 - 8	⅛" Pipe Plug	As Req'd
36002 - 9	1/16" Pipe Plug	As Req'd
36002 - 10	Power Cylinder — Case Gasket	1
36002 - 11	"O" Ring	1
36002 - 12	Needle Valve	1
36002 - 13	Power Piston Assembly	1
36002 - 14	Power Cylinder Spring	1
36002 - 15	Spring Guard—Power Cylinder Gasket	1
36002 - 16	Spring Guard	1
36002 - 17	¼" Shakeproof Washer	4
36002 - 18	¼"-28 x ¾" Socket Head	4
36002 - 19	Snap Ring	4
36002 - 20	Spring Seat	2
36002 - 21	Small Accumulator Spring	2
36002 - 22	Large Accumulator Spring	2
36002 - 23	Power Case	1
36002 - 24	Spring Seat	1
36002 - 25	Buffer Spring	2
36002 - 26	Buffer Piston	1
36002 - 27	Plug	1
36002 - 28	"O" Ring	1
36002 - 29	Snap Ring	1
36002 - 30	Instruction Plate	1
36002 - 31	Round Head Drive Screw	3
36002 - 32	Oil Gauge	1
36002 - 33	Elbow	1
36002 - 34	Drain Cock	1
36002 - 35	Check Valve, Spring Loaded	2
36002 - 36	Check Valve, Plain	2
36002 - 37	Accumulator Piston	2
36002 - 38	Drive Gear	1
36002 - 39	Idler Stud	1
36002 - 40	Idler Gear	1
36002 - 41	Case-Base Oil Seal Ring	1
36002 - 42	¼" x ¾" Dowel Pin	2
36002 - 43	Base-Round	1
36002 - 44	21/64" Split Lockwasher	8
36002 - 45	5/16"-18 x 1" Hex. Head Screw	8
36002 - 46	Gasket	1
36002 - 47	Oil Seal Retainer	1
36002 - 48	Oil Seal	1
36002 - 49	Snap Ring	1
36002 - 50	Bearing	1
36002 - 51	Serrated Drive Shaft	1
36002 - 52	Bearing Retainer	1
36002 - 53	¼"-28 x ⅝" Hex. Head Screw	3
36002 - 54	.035 Brass Lockwire	10"
36002 - 55	Spring Check Plug	1
36002 - 56	Speeder Spring	1
36002 - 57	Pilot Valve Plunger Nut	1
36002 - 58	1/16" x ⅝" Cotter Pin	1
36002 - 59	Speeder Spring Seat	1
36002 - 60	Thrust Bearing	1
36002 - 61	Washer	1
36002 - 62	Adjusting Spring	1
36002 - 63	Flyweights	2
36002 - 64	Flyweight Bearing	4
36002 - 65	Rubber Coupling	1
36002 - 66	Splined Elastic Stop Nut	2
36002 - 67	Flyweight Head	1
36002 - 68	Retaining Washers	2
36002 - 69	10-32 x ¾" Round Head Screw	2
36002 - 70	Flyweight Pin	4
36002 - 71	1/16" x 1" Cotter Pin	8
36002 - 72	Snap Ring	1
36002 - 73	Compensating Bushing	1
36002 - 74	Pilot Valve Plunger	1
36002 - 75	Bearing	1
36002 - 76	Pilot Valve Bushing Assembly	1
36002 - 77	Shutdown Nuts	2
36002 - 78	Shutdown Rod	1
36002 - 79	Base-Square	1
36002 - 80	Keyed Drive Shaft	1
36002 - 81	Straight Key	1
36002 - 82	Spacer Sleeve	1
36002 - 83	⅝"-18 Castle Nut	1

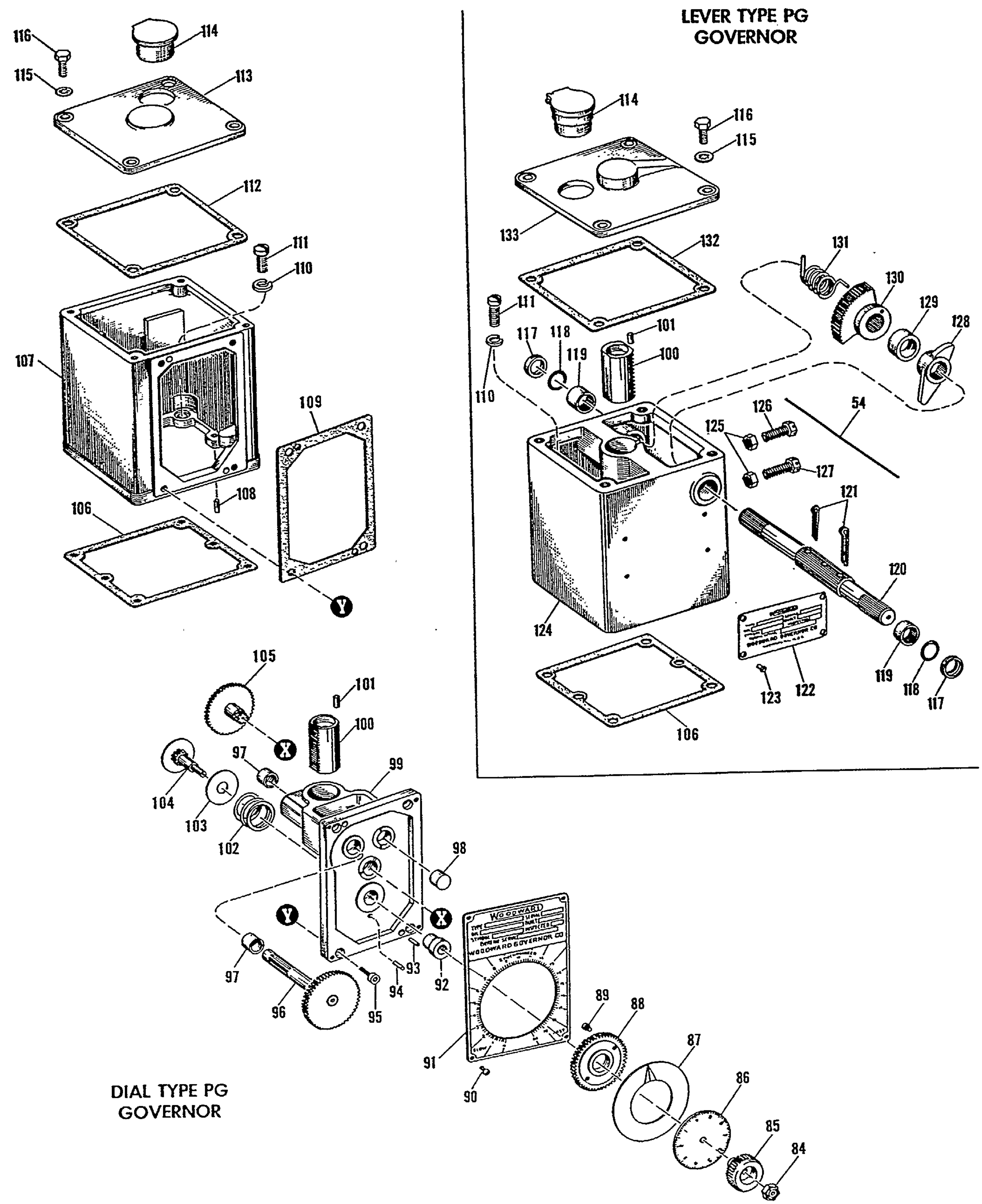


Figure 27, Column Parts

INFORMATION AND PARTS REPLACEMENT: When requesting additional information concerning governor operation, or when ordering repair parts, it is very essential that the following information accompany the request.

1. Governor serial number (shown on name plate). The serial number is needed since the reference numbers shown in this bulletin do not identify the exact part number required for any one governor.
2. Bulletin number. (This is bulletin number 36002).
3. Part reference number, name of part, or description of part.

Parts List for Lever and Dial Type Governor Column Parts

REF. NO.	PART NAME	NO. REQ'D
36002-84	1/4"-20 Thin Elastic Stop Nut	1
36002-85	Knob	1
36002-86	Numbered Disc	1
36002-87	Pointer Disc	1
36002-88	Indicator Gear	1
36002-89	Stop Pin	2
36002-90	6-32 x 1/4" Round Head Screw	4
36002-91	Dial Plate	1
36002-92	Bushing	1
36002-93	Dowel Pin	2
36002-94	Stop Pin	1
36002-95	10-24 x 1/2" Fillister Head Screw	4
36002-96	Shaft Assembly	1
36002-97	Bushing	2
36002-98	Plug	1
36002-99	Panel	1
36002-100	Speeder Plug	1
36002-101	Spring Check Pin	1
36002-102	Spring	1
36002-103	Washer	1
36002-104	Dial Shaft Assembly	1
36002-105	Pinion Assembly	1
36002-106	Case-Column Gasket	1
36002-107	Column	1
36002-108	1/4" x 9/16" Dowel Pin	2
36002-109	Panel Gasket	1
36002-110	5/16" Split Ring Lockwasher	4
36002-111	5/16"-24 x 5/8" Fillister Head Machine Screw	4
36002-112	Column-Cover Gasket	1
36002-113	Cover	1
36002-114	Oil Filler Cup	1
36002-115	5/16" Shakeproof Lockwasher	4
36002-116	5/16"-24 x 3/4" Hex. Head Machine Screw	4
36002-117	Retainer	2
36002-118	"O" Ring	2
36002-119	Needle Bearing	2
36002-120	Speed Adjusting Shaft	1
36002-121	Cotter Pin	2
36002-122	Nameplate	1
36002-123	6-32 x 1/4" Round Head Screw	4
36002-124	Column	1
36002-125	3/8"-24 Hex. Nut	2
36002-126	3/8"-24 x 1" Hex. Head Screw	1
36002-127	3/8"-24 x 1 1/4" Hex. Head Screw	1
36002-128	Speed Stop Arm	1
36002-129	Spacer	1
36002-130	Segment Gear	1
36002-131	Torsion Spring	1
36002-132	Column-Cover Gasket	1
36002-133	Cover	1

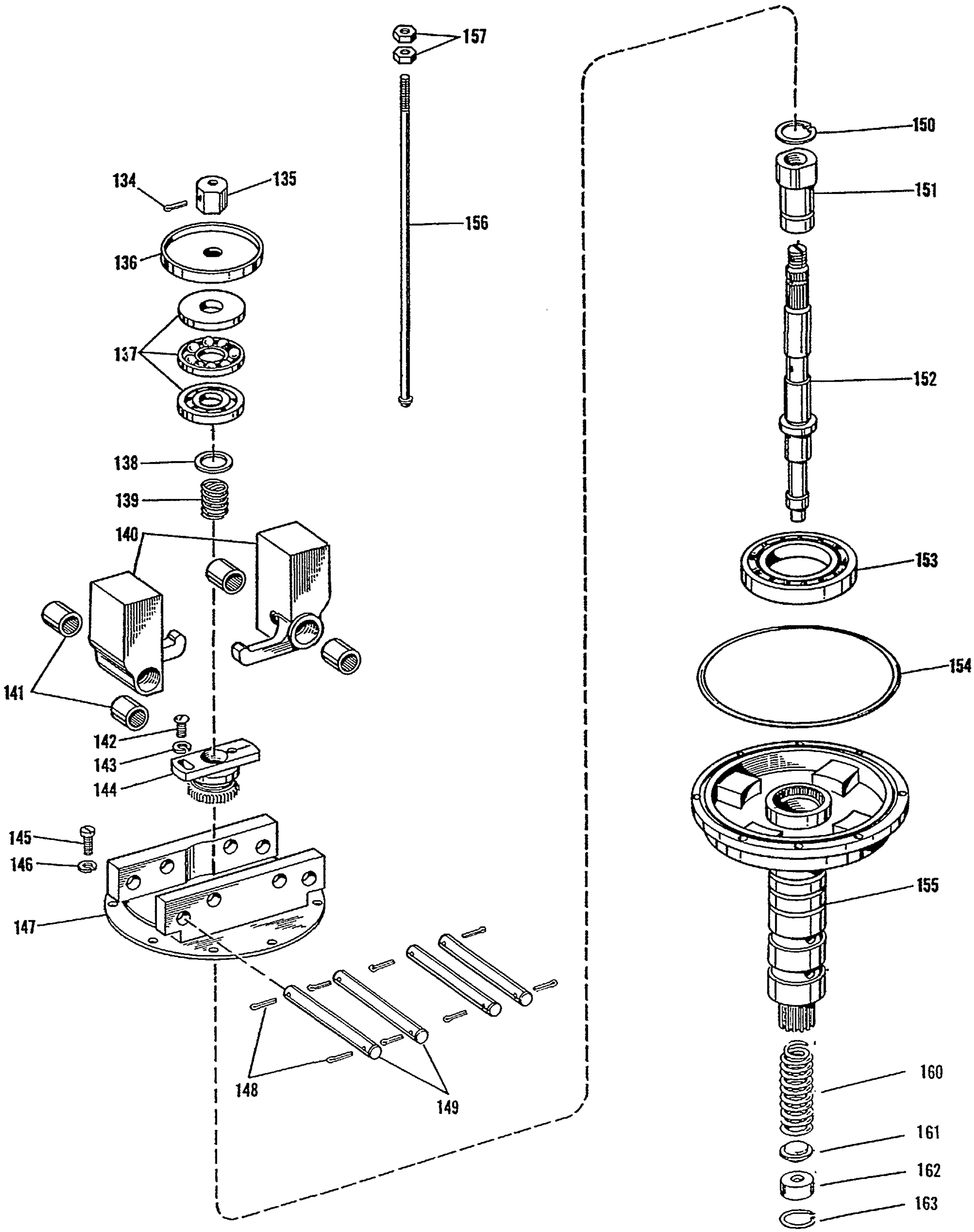


Figure 28, Spring Driven-Oil Damped Flyweight Head

INFORMATION AND PARTS REPLACEMENT: When requesting additional information concerning governor operation, or when ordering repair parts, it is very essential that the following information accompany the request.

1. Governor serial number (shown on name plate). The serial number is needed since the reference numbers shown in this bulletin do not identify the exact part number required for any one governor.
2. Bulletin number. (This is bulletin number 36002).
3. Part reference number, name of part, or description of part.

Parts List for Spring Driven-Oil Damped Flyweight Head

REF. NO.	PART NAME	NO. REQ'D.	REF. NO.	PART NAME	NO. REQ'D.
36002 - 134	Cotter Pin	1	36002 - 146	#5 Lockwasher	8
36002 - 135	Pilot Valve Plunger Nut	1	36002 - 147	Flyweight Head Sub-Assembly	1
36002 - 136	Speeder Spring Seat	1	36002 - 148	1/16" x 7/16" Cotter Pin	8
36002 - 137	Thrust Bearing	1	36002 - 149	Flyweight Pin	4
36002 - 138	Washer	1	36002 - 150	Snap Ring	1
36002 - 139	Adjusting Spring	1	36002 - 151	Compensating Bushing	1
36002 - 140	Flyweight	2	36002 - 152	Pilot Valve Plunger	1
36002 - 141	Flyweight Bearing	4	36002 - 153	Bearing	1
36002 - 142	8-32 Round Head Screw	1	36002 - 154	Oil Seal Ring	1
36002 - 143	#8 Lockwasher	1	36002 - 155	Flyweight Head Cup-Bushing Assembly	1
36002 - 144	Spring Coupling Assembly	1	36002 - 156	Shutdown Rod Assembly	1
36002 - 145	5-40 Round Head Screw	8	36002 - 157	Shutdown Nuts	2

Parts List for Special Low Speed Governor Operation

REF. NO.	PART NAME	NO. REQ'D	REF. NO.	PART NAME	NO. REQ'D
36002 - 160	Spring	1	36002 - 162	Plug	1
36002 - 161	Spring Seat	1	36002 - 163	Snap Ring	1

Parts and Parts List for Pre-Loaded Buffers

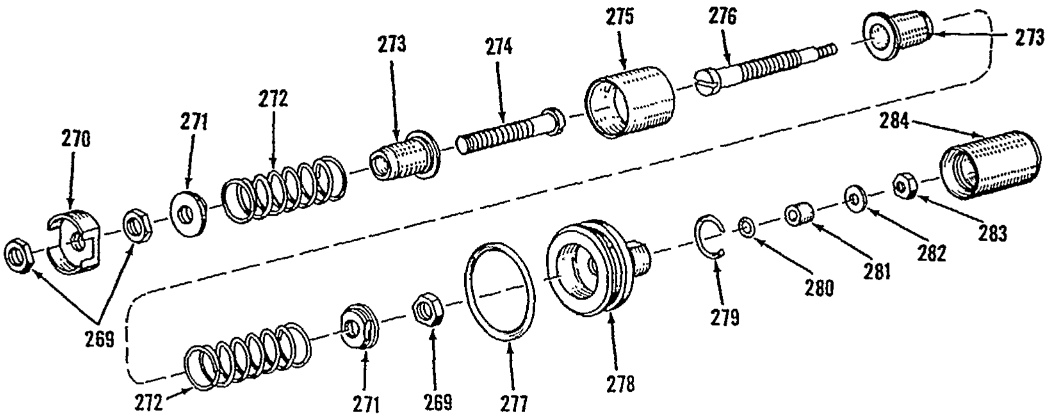


Figure 28-A

REF. NO.	PART NAME	NO. REQ'D	REF. NO.	PART NAME	NO. REQ'D
36002 - 269	5/16" — 24 Lock Nut	3	36002 - 277	"O" Ring	1
36002 - 270	Buffer Adjusting Cap	1	36002 - 278	Adjustable Buffer Plug	1
36002 - 271	Spring Seat	2	36002 - 279	Retaining Ring	1
36002 - 272	Buffer Spring	2	36002 - 280	"O" Ring	1
36002 - 273	Spring Retainer	2	36002 - 281	Spacer	1
36002 - 274	Inner Preload Adj. Screw	1	36002 - 282	.203" x .438" Washer	1
36002 - 275	Buffer Piston	1	36002 - 283	#10-32 Jam Nut	1
36002 - 276	Outer Preload Adj. Screw	1	36002 - 284	Buffer Preload Screw Cover	1

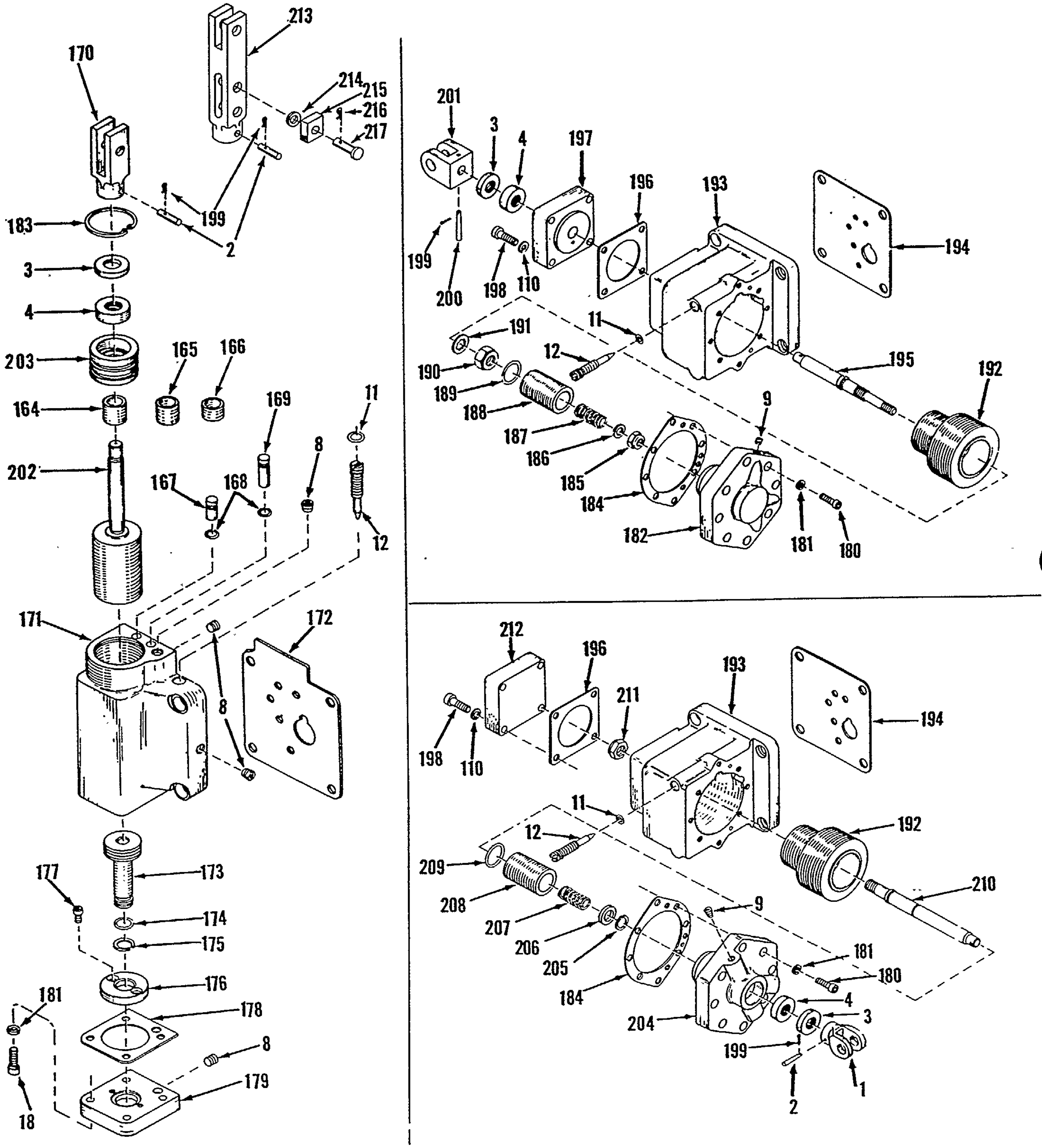


Figure 29, Alternate Power Cylinder Parts

INFORMATION AND PARTS REPLACEMENT: When requesting additional information concerning governor operation, or when ordering repair parts, it is essential that the following information accompany the request.

1. Governor serial number (shown on name plate). The serial number is needed since the reference numbers shown in this bulletin do not identify the exact part number required for any one governor.
2. Bulletin number. (This is bulletin number 36002).
3. Part reference number, name of part, or description of part.

Parts List for Alternate Power Cylinder Parts

REF. NO.	PART NAME	NO. REQ'D
36002 - 164	Stop Collar 1″	1
36002 - 165	Stop Collar ¾″	1
36002 - 166	Stop Collar ½″	1
36002 - 167	Plug	1
36002 - 168	"O" Ring	2
36002 - 169	Plug	1
36002 - 170	Rod End	1
36002 - 171	Power Cylinder	1
36002 - 172	Servo Gasket	1
36002 - 173	Piston	1
36002 - 174	"O" Ring	1
36002 - 175	Snap Ring	1
36002 - 176	Retainer	1
36002 - 177	10-32 x ⅜″ Socket Head Screw	2
36002 - 178	Cylinder Head Gasket	1
36002 - 179	Cylinder Head (Large)	1
36002 - 180	¼″-20 x ¾″ Socket Head Cap Screw	8
36002 - 181	¼″ Split Lockwasher	8
36002 - 182	Differential Servomotor Cover	1
36002 - 183	Snap Ring	1
36002 - 184	Cylinder Head Gasket (Large)	1
36002 - 185	⅜″-24 Elastic Stop Nut	1
36002 - 186	25/64″ Washer	1
36002 - 187	Spring	1
36002 - 188	Piston	1
36002 - 189	"O" Ring	1
36002 - 190	Power Piston Nut	1
36002 - 191	½″ Shakeproof Washer	1
36002 - 192	Power Piston	1
36002 - 193	Power Cylinder	1
36002 - 194	Servo Gasket	1
36002 - 195	Differential Piston Rod	1
36002 - 196	Cylinder Head Gasket (Small)	1
36002 - 197	Cylinder Head	1
36002 - 198	5/16″-18 x 1″ Socket Head Cap Screw	4
36002 - 199	Cotter Pin	1
36002 - 200	Taper Pin	1
36002 - 201	Rod End	1
36002 - 202	Power Piston	1
36002 - 203	Cylinder Head (Small)	1
36002 - 204	Differential Servomotor Cover	1
36002 - 205	Retaining Ring	1
36002 - 206	Washer	1
36002 - 207	Spring	1
36002 - 208	Piston	1
36002 - 209	"O" Ring	1
36002 - 210	Differential Piston Rod	1
36002 - 211	½″-20 Elastic Stop Nut	1
36002 - 212	Cylinder Head	1
36002 - 213	Rod End	1
36002 - 214	Washer	1
36002 - 215	Block	1
36002 - 216	Cotter Pin	1
36002 - 217	Pin	1

SPEED ADJUSTING MOTOR

PURPOSE:
The speed adjusting motor is used to provide remote speed adjustment. Its use enables the switchboard operator to match the frequency of an engine driven alternator with that of an engine or a system before synchronizing and to change load distribution after synchronizing.

INSTALLATION:
The motor used is of the split field, series wound, reversible type. Certain voltages can be supplied for use with either A.C. or D.C. It should be wired as shown in figure 31.

ADJUSTMENT:
A friction type slip coupling on the motor shaft permits manual adjustment of the speed setting by means of a knob on the panel. If the friction should require adjustment, the fibre washer may have to be replaced or a metal shim added between the spring and the slip coupling screw. Slippage should occur at 3 to 3½ lb. in. torque to permit speed adjustment by either the motor or the knob.

INFORMATION AND PARTS REPLACEMENT:
When requesting information concerning governor operation or ordering replacement parts, it is essential that the following information accompany the request:

1. Governor serial number (shown on the name plate). The serial number is needed since the reference numbers given in this bulletin do not identify the exact part numbers required for any one governor.
2. Bulletin number. (This is bulletin 36002)
3. Part reference number, name of part, or description of part.

The motor should not be replaced until it is known that the failure of the remote speed adjustment is not caused by defective wiring or low voltage to the motor, excessive friction in the speed adjusting gear train, or too little friction in the slip coupling.

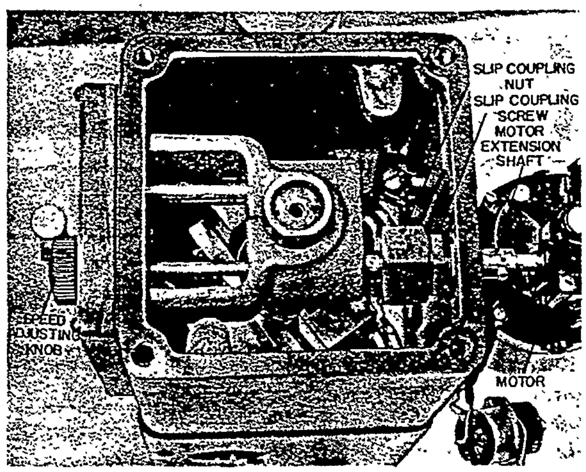
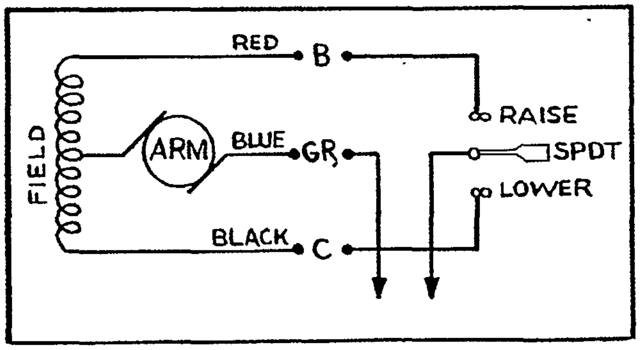


Figure 30



Wiring Diagram for Motor
Figure 31.

Parts List for Speed Adjusting Motor

REF. NO.	PART NAME	NO. REQ'D	REF. NO.	PART NAME	NO. REQ'D
36002 - 218	Shaft	1	36002 - 224	Nut	1
36002 - 219	Gear	1	36002 - 225	Screw	1
36002 - 220	Taper Pin (6/0 x ¾")	2	36002 - 226	Motor	1
36002 - 221	Bushing	2	36002 - 227	Cover	1
36002 - 222	Bushing	1	36002 - 228	Wire Marker "C"	1
36002 - 223	No. 10-32 x ¼" Set Screw	2	36002 - 229	Wire Marker "L"	1

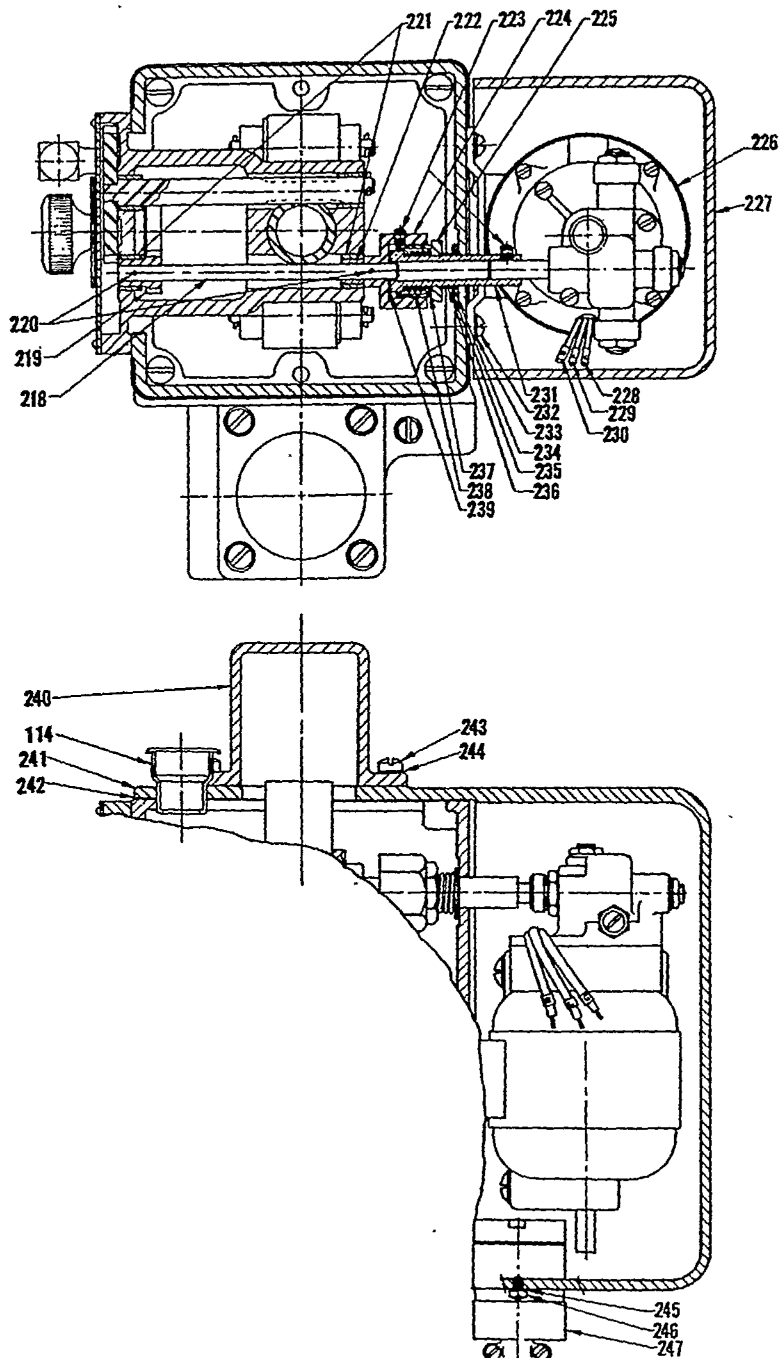


Figure 32

REF. NO.	PART NAME	NO. REQ'D
36002 - 230	Wire Marker "R"	1
36002 - 231	Plug	1
36002 - 232	No. 10-32 x ½" Screw	4
36002 - 233	No. 10 Shakeproof Washer	4
36002 - 234	Felt Washer	1
36002 - 235	Washer	1
36002 - 236	Spring	1
36002 - 237	Fibre Washer	1
36002 - 238	Spring	1
36002 - 239	Fibre Washer	1
36002 - 240	Cover	1
36002 - 241	Cover	1
36002 - 242	Gasket	1
36002 - 243	¼"-28 x ⅝" Screw	4
36002 - 244	¼" Shakeproof Washer	4
36002 - 245	Splitlock Washer	2
36002 - 246	No. 8-32 x ⅜" Screw	2
36002 - 247	Connector	1

SPEED DROOP

GENERAL: Speed droop is used to balance and divide load between engines (or turbines) running in parallel. Speed droop is defined as the decrease in governor speed as its output connection to the engine fuel racks (or valve) moves from minimum to maximum fuel positions. Speed regulation of an engine is defined as the decrease in engine speed as its load is increased from no load to full load (invariably accomplished by using less than the full governor stroke available), and is expressed in R.P.M. or as a percentage of normal speed. Since the normal speed of the governor is determined by the compression of the speeder spring, any change in compression of the speeder spring will change the normal speed of the governor.

OPERATION: The method of incorporating speed droop in a typical Woodward type PG governor is shown in figure 33. In those governors in which the rod end is below the governor power cylinder, a tail rod, connected to the governor power piston, is attached to the speed droop lever instead of the rod end shown.

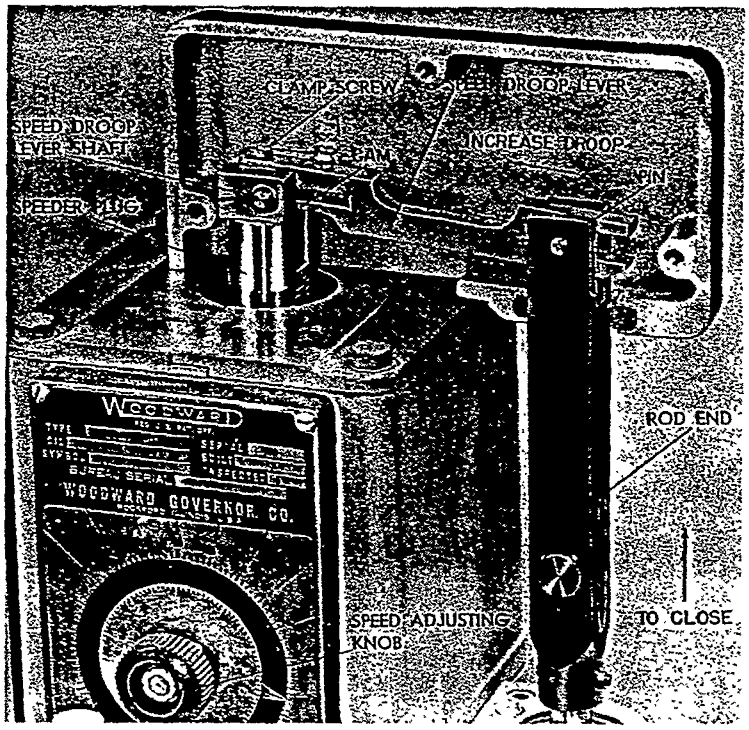


Figure 33

For any given speed adjustment setting, the speeder plug is stationary. The position of the speeder plunger within the speeder plug is determined by the position of the cam on the speed droop lever.

The rod end (or tail rod) moves up and down with the governor power piston as it changes the fuel setting. The rod end movement raises or lowers the speed droop lever which, pivoting about the speed droop lever shaft, raises or lowers the cam on the speed droop lever. The speed droop lever shaft is positioned so that the speeder plunger is moved upward as the rod end moves in the direction to increase fuel. The shaft is between the cam and rod end on governors in which the rod end moves up (as shown in figure 33) to decrease fuel. On governors arranged so that the rod end moves up to increase fuel, the cam is between the lever shaft and rod end.

The upward movement of the speeder plunger as the governor moves to increase fuel for increased loads thus decreases the compression on the speeder spring, and the governor — and engine — runs at a slower speed. Conversely, when the governor power piston moves to decrease fuel as load decreases, the speeder plunger increases the speeder spring compression, and the governor and engine run at a faster speed.

ADJUSTMENT: Adjustment of the speed droop setting is accomplished by loosening the clamp screw and changing the position of the speed droop lever cam with respect to the speed droop lever shaft. Moving the cam away from the lever shaft increases the droop; moving the cam towards the lever shaft decreases the droop. If the center of the cam coincides with the center of the lever shaft, "zero droop" results and the governor will give isochronous (constant speed) operation. When decreasing the droop setting, care must be taken not to move the cam beyond the zero droop point since "negative droop" (i.e., speed increasing with load increases) leads to an inherently unstable system.

INFORMATION AND PARTS REPLACEMENT: When requesting additional information concerning governor operation, or when ordering repair parts, it is essential that the following information accompany the request:

1. Governor serial number (shown on name plate). The serial number is needed since the reference numbers given in this bulletin do not identify the exact part number required for any one governor.
2. Bulletin number. (This is Bulletin number 36002)
3. Part reference number, name of part, or description of part.

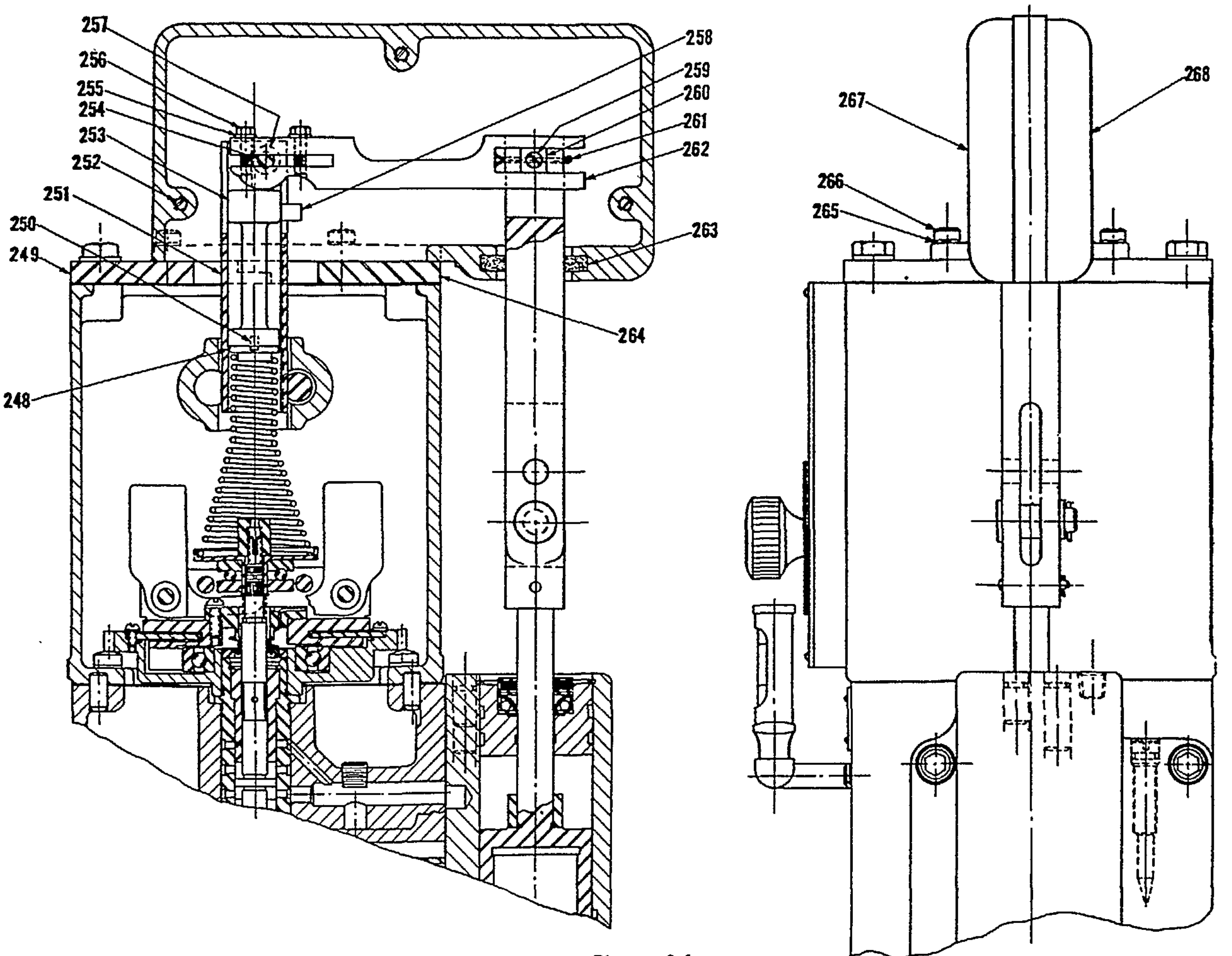


Figure 34

Parts List for Speed Droop Components

REF. NO.	PART NAME	NO. REQ'D
36002 - 248	Spring Check Plug	1
36002 - 249	Cover..........................	1
36002 - 250	Pin............................	1
36002 - 251	Speeder Plug Assembly	1
36002 - 252	Screw — ¼"-20 x 1½" Soc. Head..	3
36002 - 253	Speeder Plug Plunger	1
36002 - 254	Speed Droop Lever Shaft.........	1
36002 - 255	Washer..........................	2
36002 - 256	Screw — No. 8-32 x ⅝" Hex Head	2
36002 - 257	Needle Bearing	2
36002 - 258	Pin............................	1
36002 - 259	Pin............................	1
36002 - 260	Speed Droop Block...............	1
36002 - 261	Cotter Pin — 1/16" x 1⅛"........	1
36002 - 262	Speed Droop Lever	1
36002 - 263	Felt Wiper	1
36002 - 264	Cover..........................	1
36002 - 265	Washer.........................	4
36002 - 266	Screw — ⅜"-16 x 1" Soc. Head....	4
36002 - 267	Cover..........................	1
36002 - 268	Cover..........................	1

TROUBLE	CAUSE	CORRECTION
2. Fuel pump racks do not open quickly when cranking engine.	A. Low oil pressure in governor.	a. Check governor pump gears and gear pockets for excessive wear. No correction except to replace worn parts. b. Examine pump check valves. If not seating tight, install new ones.
	B. Cranking speed too low.	May be necessary to use a booster servomotor (consult governor manufacturer).
	C. Booster servomotor (if used) not functioning properly.	Check action of automatic air starting valve.
3. Jiggle at governor rod end or terminal shaft.	A. Rough engine drive.	Inspect drive mechanism: a. Check alignment of gears. b. Inspect for rough gear teeth, eccentric gears, or excessive backlash in gear train. c. Check gear keys and nuts or set screws holding drive gears to shafts. d. Tighten chain between crankshaft and camshaft (if used). e. Check engine vibration dampener (if used).
	B. Failure of flexible drive in flyweight head.	Remove, dis-assemble and clean flyweight head parts. a. If rubber drive, install new rubber coupling. If more parts than the coupling need replacement, exchange the entire rotating sleeve and flyweight head assembly for a new assembly with spring drive and oil-damping. (Consult governor manufacturer). b. If spring drive, check spring and install new spring coupling assembly if necessary. Center the coupling for equal travel in opposite directions.
	C. Speed droop (if used) at critical setting.	Reduce droop to eliminate critical. Load division will be affected if this is done. Readjust droop on units affected.
	D. Governor not bolted down evenly on engine mounting pad.	Loosen bolts, realign governor correctly and tighten bolts.
4. Load interchanges between connected units in parallel operation of an AC system. One unit on zero droop (to control system frequency) — all other units on droop.	Incorrect setting of the speed droop adjustment on one or more of the droop units. **NOTE:** If droop is not provided, the governor is isochronous only, and cannot be used for parallel operation in an AC system except as the lead engine.	Increase droop on affected units until load remains steady on each droop unit. System load variations will be taken by the lead unit with zero droop. The droop units will assist in correcting speed deviations on large disturbances, but will return to their original loads after the load change has been absorbed by the zero droop unit.
5. Load does not divide properly between connected units in parallel in a DC system — ship propulsion — or similar type installation. All units on droop.	Droop setting incorrect on one or more units. Speed droop — in the governor — is usually not essential in a DC system, the equivalent of speed droop being obtained electrically. However, governors with speed droop are commonly used for DC service since the droop adjustment may be used to correct for inequalities of generator compounding.	Adjust droop on each unit until desired division of load is obtained. Increasing droop will result in the unit taking a smaller share of load changes. Decreasing droop will result in the unit taking a larger share of load changes.

TROUBLE	CAUSE	CORRECTION
6. Engine is slow to respond to a fuel correction made by the governor as a result of a load change or speed setting change.	Incorrect adjustment of the compensating needle valve.	Open needle valve further (usually), if possible to do so without causing an objectionable amount of instability when running without load.
7. Engine is slow to recover from a speed deviation resulting from a change in load — or slow to respond to a change in speed setting.	A. Governor response is lagging, with resultant delay in correction of fuel setting.	See Section 1 - J.
	B. Governor oil pressure is low.	See Section 2 - A.
	C. Fuel supply restricted.	Clean fuel filters and fuel supply lines.
	D. Engine may be overloaded.	Reduce the load.
	E. Type PG governors with pneumatic-hydraulic speed control are designed to INCREASE speed setting slowly. If this is objectionable, special parts can be supplied to obtain faster action.	Consult governor manufacturer. Changes in field may require services of a governor engineering specialist.
	F. Supercharger does not come to new speed quickly to supply sufficient air to burn the added fuel.	No simple field correction. Consult engine and governor manufacturer, or overhaul the supercharger.
8. Engine will not pick up rated full load.	A. Fuel racks do not open far enough.	a. Check fuel pump stops and adjust as necessary. b. Check linkage between governor and fuel pumps and adjust if necessary. c. Certain special PG governors are equipped with a load limiting device, and the governor may be against the load limit. Adjustment may be made, if considered advisable. d. Oil pressure may be too low — see Section 2 - A. e. Oil in governor may be too light — change to next heavier grade (also see Bulletin 25007).
	B. Fuel supply restricted.	See Section 7 - C.
	C. Speed adjustment of the governor is restricted.	a. Check and adjust maximum speed limit on a dial type PG governor. b. Check and adjust speed setting linkage on a lever type PG governor.
	D. Engine misfiring.	See Section 1 - L.
	E. Gas pressure too low.	Adjust pressure regulator in gas supply line.
	F. Supercharger does not supply sufficient air.	Overhaul supercharger.
	G. Slipping clutch (if used) between engine and driven load.	See Clutch Instruction Manual.
	H. Voltage regulator (if used) not functioning properly.	Readjust or repair voltage regulator.

1-B-22 ACCUMULATOR ASSEMBLY

(a) An accumulator is connected in the H.P. oil supply line to the steam-valve operator. This accumulator provides a constant oil pressure to the valve operator during momentary pressure fluctuations caused by load change on the TG set.

(b) The accumulator shown in Figure T-35 consists of a cap diaphragm "14" enclosed in the air cylinder assembly "5" secured by retainer "15" and nuts "11". The cap diaphragm "14" presses against the head of a piston, preloaded by springs "9" and "10". When a sudden load is added to the turbine, the oil pressure in the oil supply line to the operator may drop. Should the momentary oil pressure drop activate the accumulator, the springs will expand against the reduced pressure in the cylinder and, through the action of the cylinder head on the diaphragm "14", increase the oil pressure in the lines until increased turbine speed returns the pressure to normal. A sudden decrease in turbine load will not actuate the accumulator. A two-way relief port, installed in the wall of the cylinder, will bleed off entrapped air when the springs are compressed and allow the air to enter the cylinder as the springs are expanded.

NOTE

Before starting any maintenance on the accumulator, read the CAUTION note in Figure T-35.

1-B-23 DUPLEX OIL FILTER

(a) The duplex oil filter shown in Figure T-36 is connected into a H.P. oil supply line. Foreign matter larger than 33 microns is removed from the oil passing through by either of two filter elements "17" contained in filter body "18". The filter assembly consists of a head "11" with inlet and outlet oil connections, two bodies "18", a tapered plug "8" with handle "3", springs, relief valves, preformed packings, air vent cocks, drain cocks and a valve lock.

(b) The filter provides continuous filtering at all times when transferring from one filter body to the other and while servicing one of the elements "17". Oil enters the body "18" through the inlet flange on head "11", flows down the inside circumference of the body and discharges up through the element to the outlet flange on the filter head. The handle "3" positions the tapered plug "8" so that the oil is directed to either filter body. A valve lock "7" which is spring loaded, locks the handle in place and should be shifted only for servicing. The handle can be locked in a position between positions 1 and 2. This will allow oil flow through both bodies simultaneously. Should an element become clogged with filtered matter, the relief valve poppet "13" will open when the pressure differential between the body inlet and discharge reaches 7-10 psi. This action prevents interruption of the H.P. oil flow. Each body has a drain cock at the bottom and an air vent cock at the top.

(c) The spiral bevel gear is mounted on the shaft "3" with the key "12" and secured in place by the coupling "4" which in turn is locked in position by the setscrew "17". The thrust washer "9" is installed between the bevel gear hub and the thrust surface of the bearing "6".

(d) The entire governor and oil pump drive assembly is mounted on the gear housing base, and the method of lubricating the bearings, meshing gears and pinions is shown in the Oil System and Control Diagram, Figure T-20.

(e) An oil spray nozzle, ("28", Figure T-13) provides the lubrication at the mesh of the governor driver and driven gears.

1-C-7 MAIN OIL PUMP

(a) The main oil pump, shown in the illustration Figure T-16 is manufactured by the Gimple Machine Works Inc., of Philadelphia, Pa. The pump is mounted in the oil reservoir and is driven by the oil pump and governor drive assembly which is shown in Figure T-15.

(b) As shown in the Figure T-16, the pump consists of two driven helical gears, "6" and "7", mounted on the shaft "11" and meshing with the two driving helical gears "4" and "5". The driving gears are mounted on and secured to the shaft "10" with the key "14". The gear shafts "10" and "11" are mounted in the bearings "8" and "9". The driving and driven gears, with their respective bearings are enclosed in the pump discharge and suction housing halves "2" and "3".

(c) The lower end of the drive shaft "3" of Figure T-15 is threaded into the coupling "15" of Figure T-16, and secured in place with the setscrew "16". The lower end of the coupling "15" engages splines machined on the upper end of the drive shaft "10".

(d) A nozzle pump suction is cast integral with the pump housing half "3" which is continuously submerged in oil in the reservoir. The rotation of the pump gears entrains the oil between the gear teeth and the housing wall, sweeping the oil from the suction to the discharge. Any oil return, except for the small amount of leakage, is prevented by the meshing teeth of the gears.

(e) As shown in the Oil System and Control Diagram, Figure T-20, the oil pump gear bearings are submerged in a constant oil bath, hence lubrication of the bearing surfaces is constant.

1-C-8 AUXILIARY OIL PUMP, MANUALLY OPERATED

(a) The manually operated, self-priming auxiliary oil pump, which is used to supply oil for the system when starting up from a cold unit condition is shown in Figure T-17. It is operated by turning the crank "5" in a clockwise direction and will deliver 9.0 gpm at 100 psi when operated at 100 rpm. The crank "5", turns the shaft "12" and the rotor "7" in the same direction. The packing "13" and packing nut "11" prevent leakage along the shaft where it extends through the cylinder head "2".

(b) The rotor, which is eccentric to the centerline of the pump cylinder, contains three spring positioned vanes "9", which operate with small axial clearance and follow the inner surface of the pump body being pressed radially outward by the springs "10". Oil entering from the suction side is imprisioned between consecutive vanes and is carried around to the discharge side. The small axial clearance between the vanes and the cylinder heads, prevents oil from returning to the suction side except for a very small amount of leakage.

(c) The auxiliary oil pump furnishes oil for lubrication and simultaneously provides oil with sufficient pressure to actuate the start-sequence valve to open the steam-chest valves. The oil necessary to furnish pressure to open the throttle valve and to operate the start-sequence valve is discussed in paragraph 1-B-20.

1-C-9 OIL COOLER, STRAINER AND BY-PASS VALVE

(a) The assembly shown in Figure T-18 consists of an oil cooler, duplex oil strainer, and a strainer by-pass valve. Two relief valves are installed in the oil inlet side of the assembly.

A study of the Oil System and Control Diagram Figure T-20 should be made which shows the diagrammatic location of this assembly.

(b) The L.P. relief valve, (adjustable orifice), installed adjacent to the strainer by-pass valve, is set to maintain an oil pressure of 10 psig in the strainer-cooler and bearing oil supply system. The H.P. relief valve, installed below the by-pass valve, is set to open at 75 psig, discharging into a drain line returning to the oil reservoir.

(c) The oil cooler is of the shell and tube type, with the oil circulating through the shell around the tubes, and the circulated cooling water making two passes through the tubes. The tubes are straight and are rolled into both tube sheets. The inlet-outlet tube sheet is secured between the shell and the inlet-outlet water chamber, but the reverse tube sheet is free to float endwise within the shell, it being sealed against leakage of oil to water or vice versa, by two rings of packing, clamped between the shell and the reverse chamber. Gaskets prevent joint leakage between the inlet-outlet water chamber, tube sheet and shell connections.

(d) Flanged oil and water connections are made to the shell, so that the water chambers can be removed without disturbing any piping. Vents are provided in the inlet-outlet water chamber cover. Both water chamber covers have been provided with zinc pencils, secured to pipe plugs. These zinc pencil electrodes should be examined at intervals of not less than thirty days and cleaned or replaced if their condition so warrants. Removal of the zinc pencil-plug from the reverse chamber cover permits full drainage from the tube side.

(e) Preferably the oil pressure in the shell should be higher than the water pressure in the tubes, so that a leaky tube will not cause contamination of the oil supply, although it will cause a loss of oil from the system. If the quantity of oil in the reservoir diminishes, the cooler should be examined at once for leaks.

(f) The oil strainer, also shown in Figure T-18 is of the duplex type and is equipped with magnets for removal of ferrous materials from the oil. The basket assembly, through which the oil must flow is of reinforced construction, the basket "44" of wire mesh being strengthened by an outer framework "36". Each basket is provided with a handle "38" of spring material, by means of which the basket can be lifted out for cleaning and which also holds the basket in place, the handle being compressed by the cover "5".

(g) The flow of oil to the individual strainers is controlled by the plug "3" which is so designed that when turned in its conical seat by the turning lever "20", it will change over the inlet and outlet connections from one strainer to the other, but will not completely cut off the oil flow during the change over period. The purpose of the jack lever "13" is to loosen the conical plug from its seat before the turning lever "20" is so applied. After the change over has been made, the jack lever may be tightened, securely seating the plug on the seat, preventing any oil bleeding around the plug.

1-C-10 OIL SYSTEM

(a) The arrangement of the oil system is shown diagrammatically in Figure T-20. This system consists essentially of a reservoir, formed by the reduction gear housing, a main oil pump, a cooler, a duplex strainer, a L.P. oil filter, a duplex H.P. oil filter, hand-operated auxiliary oil pump for use when starting or stopping the turbine and the connecting piping.

(b) The level of the oil in the reservoir is shown by the bayonet type oil gage, which is located on the generator end of the gear housing base. The oil level should be maintained so that it is between the maximum and minimum limit marks on the bayonet, with the unit in operation.

(c) During normal operation, the main pump discharges at pressures in excess of 75 psig. A part of this oil is led through machined passages and external piping to operate the governor and the steam chest and throttle valve operating mechanisms. The pressure in this part of the system is maintained at a maximum of 75 psig by a H.P. relief valve, built in as part of the oil strainer assembly which discharges the oil in excess of this value back into the reservoir. The remainder of the system oil is directed through a L.P. relief valve (adjustable orifice) to the strainer and cooler, to lubricate the bearings and the reduction gear teeth. This L.P. relief valve, functioning as a regulating orifice limits the pressure in this portion of the system to 10 psig. During operation, a portion of the H.P. oil is constantly being fed through a 7/32 inch diameter fixed orifice and an oil filter into the oil cooler-bearing oil supply system, by-passing the L.P. relief valve (adjustable orifice). Cut out valves are installed in the by-pass line, on each side of the oil filter as shown in Figure 20, which enable the line to be closed off during examination or replacement of an oil filter cartridge. The maximum permissible temperature of the oil leaving any bearing is 180° F. The temperature rise of oil passing through any bearing is not to exceed 50° F.

(d) As shown in the Oil System and Control Diagram, Figure T-20, a low-pressure-alarm contact maker is connected in the most remote part of the system so as to sound an alarm, if the pressure at the bearings drops to 4 psig. The alarm contact maker is illustrated in Figure T-19. A by-pass valve, around the cooler (Figure T-18) is provided so that the cooler can be taken out of service for cleaning or repair while the unit is operating. The cooler circulating water should preferably not be turned on, when starting the unit, until normal bearing operating temperatures have been established. When the unit is in service the oil cooler water circulation should be carefully adjusted so as to prevent under-cooling of the oil.

1-C-11 LUBRICATING OIL

(a) Oil, Navy Symbol 2190-T, having a viscosity of 185-205 S.S.U. at 130° F should be used in the oil system.

SECTION C—DESCRIPTION OF REDUCTION GEAR AND ACCESSORIES

1-C-1 GENERAL DESCRIPTION

(a) The illustration Figure T-2, shows a longitudinal section through both the high speed and slow speed rotating elements of the double reduction gear. The gear housing consists of a fabricated steel base and cover sections. The housing base is secured to the turbine exhaust end cylinder by stud bolts, mounted in a half flange. The half flange has been machined with a spigotted fit as shown in the illustration Figure T-2, by means of which the alignment of the turbine and gear are held to a common plane and base line. The gear housing base also serves as an oil reservoir, with the main oil pump and governor drive mechanism mounted at the horizontal flange. The cover, which is secured to the base at the horizontal flanged joint, is fitted with an inspection or access opening. The governor and speed changing mechanisms are mounted on the cover adjacent to the access opening.

(b) Lubricating oil, delivered by the main oil pump is supplied to the various gear bearings and meshing teeth of the rotating elements through internal and external passages fabricated to the housing. Drains are provided whereby the oil may be returned to the oil reservoir.

1-C-2 ROTATING ELEMENTS

(a) The rotating elements of the double reduction gear consist of one high speed pinion and high speed gear, together with one low speed pinion and low speed gear, all shown in Figure T-2. The pinions and gears are of the single helix type, carefully machined in order to produce a balanced tooth loading.

(b) The high speed pinion consists of a toothed rim, fitted with an internal flange. The exhaust end of the turbine rotor shaft is also machined with an integral flange as shown in Figure T-2 and the high speed pinion is shrunk on the turbine rotor shaft, the two flanges being secured together with fitted bolts.

Two journal bearings, one on each side of the high speed pinion are mounted in the gear housing base and support this end of the turbine rotor shaft.

(c) The high speed gear consists of a truncated cone forging fitted with an integral rim machined with single helix teeth. The truncated portion of the cone is secured to the hub of the low speed pinion with fitted bolts.

(d) The low speed pinion, machined from a forging of high grade alloy steel, consists of a shaft and pinion integrally forged and carefully machined. The high speed truncated gear is then shrunk on the pinion shaft and after the axial drilled holes in the pinion and gear hubs have been commonly reamed, the two pieces are secured together with fitted bolts. The pinion shaft is supported in two journal bearings as shown in Figure T-2.

(e) The low speed gear with its integral shaft has been machined from a forging of alloy steel. The shaft is supported in two journal bearings and is provided with a flange whereby it may be rigidly connected to the generator coupling flange.

1-C-3 PINION AND GEAR BEARINGS

(a) The two journal bearings which support the gear end of the turbine rotor upon which the high speed pinion is mounted are similar in design. The actual size of the bearing shells are different, but in both cases these bearings are of the segmental shoe type and are illustrated in Figure T-5. Each bearing consists of a bearing shell split at the horizontal plane, the two halves being doweled together and internally machined to accommodate four (4) babbitt lined pads, each pivoted on an axially disposed pin. The pins locate each pad and permit the small angular movement necessary for the formation of an oil film between the pads and the journal surface of the rotor. A pin, extending from the bearing shell lower half into the gear housing base, prevents any circumferential movement of the shell. Lubricating oil, under pressure from the main oil pump, is supplied through internal passages to the location of these two bearings. Both bearing shells have been machined with an annular groove on their outer circumference and four radial oil inlet passages 90° apart, through the shells. Hence, the oil under constant pressure is directed to the bearing shells, flowing through the radial inlets to the journals and hence to the ends of the bearing where it may flow to drain.

(b) The two bearings which support the shaft upon which the low speed pinion is machined and the high speed gear is mounted, are of the split shell type. Both of these bearings consist of a steel shell, split in the horizontal plane with the two halves doweled together. An annular groove has been machined on the outer circumference of each shell and oil inlet passages are provided on each side at the horizontal joint. The low speed pinion bearing shell is lined with genuine tin-based babbitt the entire length of the journal surface, the babbitt being relieved at the oil inlets, permitting the oil to cover the entire journal surface. The high speed gear bearing journal, as shown in the Figure T-2 is located in an annular groove machined in the shaft. Hence, for the high speed gear bearing in addition to the journal surface, the ends are also lined with genuine babbitt. The babbitted bearing ends are machined with radial grooves permitting the development of an oil film over the entire end surface. Any small amount of unbalanced end thrust that may be present is transferred to the stationary parts at this point, the high speed gear bearing serving as a combined journal and thrust bearing. Pins, located in the lower half of each bearing shell, extend into the gear housing base thus preventing any rotation of the shell. Lubricating oil is also supplied to these bearings by the main oil pump, through internal passages to the bearing locations, through the shell inlets, escaping from the bearing ends and flowing to drain.

(c) The two bearings which support the low speed gear shaft are also of the split shell type. The halves are doweled together at the horizontal joint. Both bearings are machined with an annular groove on the outer circumference which connects with two oil inlet passages, located at the horizontal joint. Pins in the lower bearing halves, extending into the gear housing base, prevent bearing rotation. Oil supplied by the main oil pump is directed by means of internal passages to the location of these bearings entering through the inlets to the journal surface, escaping at the ends and flowing to drain. The bearing at the turbine end of the low speed gear shaft is lined the entire length of the journal surface with a high grade of tin base babbitt. The journal surface for the bearing which supports the generator end of the low speed gear shaft is located in an annular groove machined on the shaft. Hence, for this low speed gear bearing in addition to the journal surface, a portion of the shell ends are also lined with babbitt. The babbitted bearing ends are machined with radial grooves, which permit the development of an oil film over this portion of the ends, for it is at this point that any small amount of unbalanced thrust that is present, will be transferred to the stationary parts of the gear. Thus, this bearing serves as a combined journal and thrust bearing.

1-C-4 OIL SEAL RINGS

The oil seal rings which are used to prevent the escape of oil where the rotating shafts extend through the gear housing consist of labyrinth rings made in halves and baffle plates also made in halves. These rings are shown in the illustration Figure T-2 and are mounted in an annular groove machined in the gear housing base and cover. The oil seal ring and baffle assembly is constructed and machined to form several annular chambers encircling the rotating shafts with a close clearance. Several of the chambers are interconnected by radial and axial drilled passages which permit any oil creeping along the shafts to be caught in the labyrinths. The oil then flows into a pocket formed in the lower half of the rings and thence through the axial passages to drain back to the reservoir. These axial passages are located at sufficient height to maintain an oil level in the pocket, thus preventing the escape of oil vapor from the reservoir.

1-C-5 PINION AND GEAR SPRAYS

(a) Oil spray nozzles have been fabricated into the gear housing base structure, by means of which the meshing teeth of each pinion and gear are under constant lubrication. The location of these nozzles is indicated in Figure T-2, one nozzle serving the H.S. elements and two nozzles serving the L.S. elements. Each nozzle consists of a button fitting machined with a slotted head that flattens the oil stream into a fan shaped sheet which is directed between the pinion and gear teeth.

1-C-6 GOVERNOR AND OIL PUMP DRIVE ASSEMBLY

(a) The driving element for the governor and main oil pump which is shown in the assembly Figure T-15 consists of a main gear "5" fitted with an integral stub shaft, upon which is mounted a bevel pinion, that in turn drives the bevel gear. The bevel gear is secured to the drive shaft "3", which rotates in the bearing "6" and is connected at its lower end to the main oil pump, and at the upper end to the spline shaft ("29", Figure T-13). The driver gear ("13", Figure T-13) which is secured to the spline shaft, motivates the governor-driven gear ("10", Figure T-13). The governor ("8", Figure T-13) contains its own oil pump which runs on the same drive assembly to pressurize the steam-valve operator hydraulic control line.

(b) The main gear "5", driven by the high speed pinion, rotates in the bearings "7" mounted in the pump support "2". The spacer "10" is located on the stub shaft which is integral with the main gear wheel "5". The pinion (of the bevel pinion and gear assembly "8") is mounted on the stub shaft with the key "13" and secured in place with the elastic stop nut "11".

SECTION D—SAFETY DEVICES

1-D-1 OVERSPEED TRIP AND MANUAL TRIP MECHANISM

(a) The overspeed trip mechanism shown in Figure T-21, provides a means of automatically releasing the operating oil pressure under the throttle valve operating piston which allows the piston spring to close the valve. The mechanism comprises a trip of the eccentric weight shaft type, and an oil-release valve, together with a resetting device and a manual trip mounted in a housing on the thrust bearing pedestal cover.

(b) The overspeed trip consists of an eccentrically loaded weight "26" held in a transverse hole in the rotor shaft by the retainer "23" and retainer nut "25". The centrifugal force acting on the weight is resisted by the compression of spring "24", which is adjustable by means of the liners "18" through "22" and "28".

(c) At the predetermined speed of 10,500 rpm, for which the device is set, the centrifugal force overcomes the spring resistance and the weight moves outward to the limit of its travel, striking the trip lever "10". This pushes up pilot valve "12" releasing to drain, the pressure above valve piston "6". The piston "6" in turn is moved upward by the compression of spring "15" and thereby opens to drain operating oil line leading to the throttle valve operating cylinder, shutting down the unit.

(d) When the speed of the turbine has dropped to approximately 7,300 rpm and the trip mechanism can be reset by pressing down on the reset knob "9" which is connected to the plunger "11". With the pilot valve "12" closed and the piston valve "6" returned to its closed position, full oil pressure will be restored above the valve and piston, and unbalance them in the closing direction thus holding them on their seats.

(e) By pressing on the manual trip plunger "13", the same effect can be obtained as though the overspeed trip had functioned.

1-D-2 BACK PRESSURE TRIP MECHANISM

(a) The back pressure trip, illustrated in Figure T-22 consists of a valve, seating against an opening and controlling the flow of oil from a lower chamber in the valve body to an upper chamber and thence to drain. The valve is normally held in the closed position by spring which presses against an adjustable spring seat secured to the valve stem.

(b) A bellows assembly mounted on the bonnet by means of spacer bolts extends into a housing or cap which is connected to the exhaust space of the turbine through a pipe connection. The bellows is normally held at its maximum extension by a spring. However, should the unit go non-condensing, and the exhaust pressure reach 5 psig, the pressure on the bellows will overcome the spring resistance and compress the bellows which in turn moves the valve stem, unseating the valve. The opening of this valve releases the oil pressure in the operating oil line to the throttle valve operating cylinder and causes the unit to shut down in like manner to the overspeed trip.

1-D-3 LOW OIL PRESSURE ALARM CONTACT MAKER

The contact maker which closes the alarm bell circuit to warn the operator of dangerously low oil pressure is shown in Figure T-19. It is adjusted to operate and close the alarm circuit if the bearing oil pressure falls to a predetermined minimum of 4 pounds. With an increase in the bearing oil pressure, the contact maker will break circuit at 5-1/2 pounds. The operation of this device is as follows:

The bellows element is actuated by direct oil pressure, which in turn operates the switch mechanism to make or break the circuit. The switch is a single pole, single throw type, designed for 115 volt, 60 cycle service. A permanent magnet at the contacts provides a quick make and break, and prevents excessive arcing. The control element causes the switch to cut-in and cut-out in accordance with the setting of the range adjusting screw and differential adjusting screw.

The method of setting the switch mechanism is as follows:

1. As the adjusting screws for setting the range and differential are located inside the case, the cover plate should be removed.

2. The differential adjusting screw should be turned clockwise to the wider position.

3. The bearing oil pressure should be brought to a point at which it is desired to have the switch close the circuit (4 pounds).

4. The range adjusting screw should be turned until the switch just "closes".

5. The bearing oil pressure should be increased to the point at which it is desired to have the switch open the circuit (5-1/2 pounds).

6. The differential adjusting screw should be turned counterclockwise until the circuit opens.

The changing of the range adjustment screw raises or lowers both the "closing" and "opening" points but will not alter the differential between the two points.

After the "closing" and "opening" adjustments have been checked from the gauge pressures the cover plate should be replaced.

1-D-4 ATMOSPHERE RELIEF VALVE

(a) The atmosphere relief valve shown in Figure T-27 is mounted on the cylinder cover at the exhaust end of the turbine, as shown in the Figures T-1 and T-2. This valve, when operating, permits excess pressures within the turbine cylinder to be discharged to the atmosphere. The valve is water sealed and spring loaded and is adjusted to start opening when a pressure of 10 psig exists within the turbine cylinder at the exhaust end.

(b) The spring loading of the valve cannot be adjusted, the spring being permanently set for the 10 pound loading.

(c) The atmosphere relief valve consists of a cast steel body "19" and cover "12" secured to each other by means of the studs "13" and hex nuts "11". A stainless steel seat ring "18" is threaded into the body. The cover is threaded to receive the stem bushing "14", the bore of which is also threaded to receive the valve stem "3". The valve disc "17" is fitted with four guide legs extending into the bore of the seat ring "18". The upper end of the valve disc has a milled slot to receive the valve stem, the lower end of which has been machined with an integral collar, by means of which the valve disc is raised whenever the handwheel "2" is turned in the counterclockwise opening direction. The handwheel "2" is secured on the valve stem "3" with the hex nut "1". A stop collar "6" is located on the valve stem with the taper pin "7". The valve stem bushing "14" is prevented from rotating by means of the socket head cap screw "8" through the bushing into the cover "12". An indicator "4" is also mounted on the valve stem and secured with the taper pin "5". The brass indicator plate "20" secured to the cover "12" will show by the referenced position of the indicator "4", the relative position of the valve stem. Connections are provided, as shown, for the sealing water inlet and overflow drain.

1-D-5 TESTING OF SAFETY DEVICES

(a) Overspeed Trip Mechanism

The overspeed trip was set at the factory, to operate at 10,500 rpm and no additional adjustment should be necessary. No change should be made in the thickness of the overspeed trip body weight adjustment liners without first having checked to make sure that all the parts are clean and in proper operating conditions as determined by several successive trials, and that the tripping speed is incorrect and does require adjustment.

The overspeed trip mechanism may be tested by pushing in on the manual trip plunger, "13" of Figure T-21. Since this releases the operating oil pressure from above the trip valve piston "6", it actuates the valve and trips the throttle. This, however, only insures that the trip valve operates properly and that the throttle mechanism responds to the resultant drop in oil pressure.

To test the overspeed trip itself it is necessary to overspeed the unit.

CAUTION: The utmost care should be used in making this test.

To make the test proceed as follows:

1 - Gradually reduce the load to zero.

2 - Trip the circuit breaker and take the unit off the line.

3 - Close down on the throttle valve until speed drops slightly, indicating that the unit is under manual control with the steam chest valves on the wide-open position.

4 - Block the steam chest valves in this position.

5 - Remove turbine front end cover upon which the rotor position indicator is mounted and apply a reliable hand tachometer to measure the speed. Do not trust portable vibrating reed type tachometers for this purpose.

6 - Station a man at the manual trip ready to trip the unit by hand if the tachometer reader signals to do so.

Very gradually inch open the throttle valve and raise the speed to the tripping point (10,500 rpm). If the unit exceeds this speed without tripping, do not in any case go beyond 10,800 rpm but shut down and check the trip for cleanliness. If the trip is perfectly clean start up and check speed again. If the trip still fails to function at 10,500 rpm remove one liner of minimum thickness from the overspeed trip assembly and try again.

(b) Back Pressure Trip

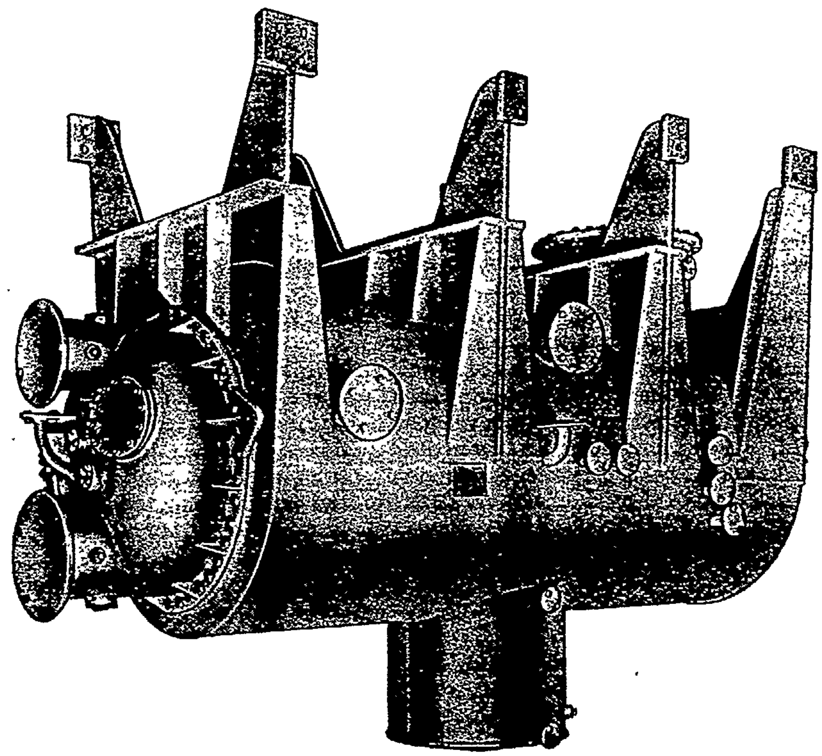
The back pressure trip can be tested with compressed air when the unit is shut down, but should also occasionally be tested by operating the unit at no-load and building up back pressure by shutting down the circulating pump and air ejector. This trip should function at 5 psig.

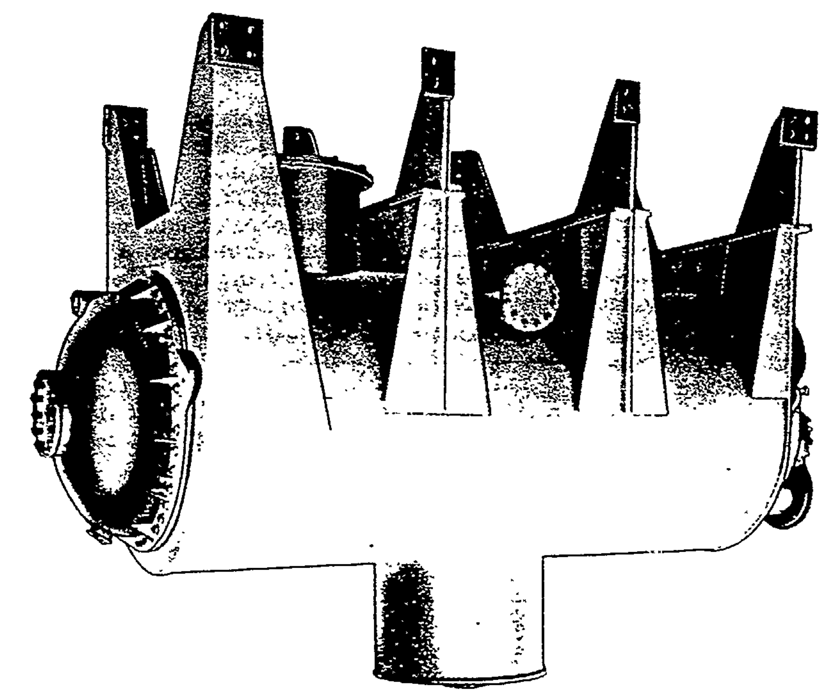
(c) Low Oil Pressure Alarm Contact Maker

This device may be checked when shutting down the unit by noting when the alarm sounds and observing the bearing oil pressure gage on the gage board. The alarm should ring when pressure falls to approximately 4 psig.

(d) Atmosphere Relief Valve

The spring loading of the atmosphere relief valve can be tested with compressed air, when the unit is shut down. However, this procedure requires that the valve be removed from the turbine cylinder. A more desirable arrangement is to test the valve with the unit operating at no load, and a built up back pressure. This test can be accomplished by first installing a blank metallic gasket in the flanged joint between the turbine exhaust and the back pressure trip mechanism. The unit can then be started without the condensing equipment being in operation and allowing the back pressure to build up. Watch the exhaust pressure gauge to see at what pressure the relief valve starts to open. In the ordinary sense, this valve is not susceptible of adjustment or regulation, the spring loading being fixed. However, shim material could be placed under the spring in an emergency, to increase the spring loading. Should the spring setting be too much out of the designed value, it is recommended that a spare be installed. After the valve has been satisfactorily tested, the unit should be temporarily shut down and the blank metallic gasket removed from the back pressure trip mechanism before endeavoring to restart the unit.





Auxiliary Condenser Assembly Ready for Shipping

SECTION E—CONDENSING EQUIPMENT

1-E-1 AUXILIARY CONDENSER

(a) General

The auxiliary condenser is of the radial flow, non-divided water box, two pass type with the steam inlet located at the conventional position at the top. There is one circulating water inlet and one circulating water outlet opening in the inlet-outlet water box. The circulating cooling water makes two passes back and forth through the condenser shell. A condensate well is provided and the necessary connections are made to the shell for the admission of various vents and drains. The condenser is connected to the turbine exhaust by a flexible expansion joint. An assembly of the condenser is illustrated in Figure T-30.

(b) Shell

The condenser shell is fabricated of plate material and stiffened against external pressure by the tube support plates which are welded to brackets which in turn are welded to the shell proper. The tube plates are mounted directly on the shell ends and secured as shown in the Figure T-30. Fabricated to the shell proper are hanger supports, which are in turn secured to the turbine foundation.

(c) Tube Fastening

In order to allow for the differential expansion that takes place between the shell and the tubes, only the inlet end of the tubes have been rolled into the tube sheet. The outlet end of the tubes are secured to the tube sheet with expansion packing rings which in turn are secured between metallic rings, as shown in the Figure T-30.

(d) Expansion Joints

The flexible expansion joint by means of which the turbine cylinder exhaust flange is connected to the condenser shell inlet flange, consists of a stainless steel corrugated tube or bellows secured to flanges at each end by welding. The flanges have been machined with bolt holes matching those of the turbine exhaust and condenser inlet. The expansion joint is bolted to the turbine and condenser. Any differential expansion between these two pieces of apparatus is absorbed by this flexible joint.

(e) Condensate Well

An opening is provided in the bottom of the condenser shell, through which the condensate drains into a cylindrical well which is welded to the shell. The condensate rains down through the steam flowing to the lower tubes and drains from the shell into the well.

(f) Water Boxes

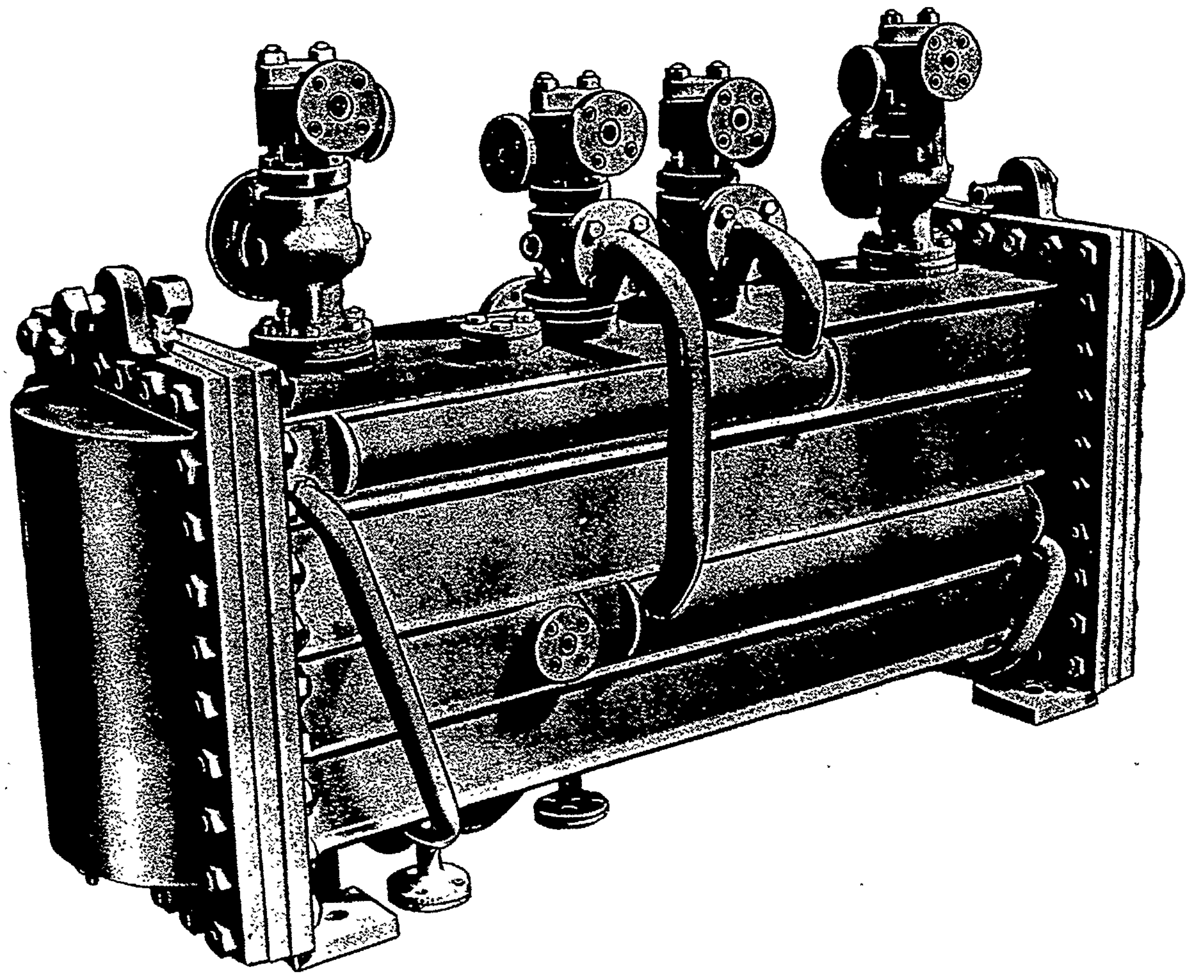
The water boxes are formed from copper-nickel alloy fabricated to a steel flange. Rib supports fabricated to the flange and the water boxes provide additional flange strength. The inlet-outlet water box has the inlet nozzle at the bottom and the outlet nozzle at the top and is partitioned horizontally through the mid-section so that the circulating water flows toward the reverse end of the shell through the lower bank of tubes and returns through the upper bank. The reverse water box is merely a domed cover of similar material which serves to direct the flow of water from the lower bank of tubes to the upper bank. Suitable access openings are provided at both ends to permit examination of the tube plates. Zinc plates are mounted on the inside of the access cover plates at each end.

(g) Air Baffles and Offtake

The steam entering the condenser shell has access to the full periphery of the tube bundle. A longitudinal "A" shaped baffle extends the full length of the shell and the apex of this "A" forms the air collecting space toward which the steam flows from all direction. The air is removed from the condenser at the inlet end where the air and vapors will last have contact with the coolest tubes. Before entering the internal offtake passage, the air and non-condensable vapors are forced to pass out among the tubes by means of a transverse baffle, thus insuring that they will receive the maximum degree of cooling before being withdrawn from the condenser.

(h) Accessories

As indicated in the illustration, Figure T-30, the inlet water box as well as the shell proper have been provided with relief valves. The relief valve mounted on the inlet water box is set at 20 psig while the relief valve mounted on the shell is set at 10 psig. On the steam inlet trunk provision has been made for the connection of a dial type vacuum gage. Thermometers



Auxiliary Air Ejectors Assembled on Inter-After and Gland Condenser Showing Reverse Water Box End

are mounted on the condenser shell, the condensate well and the circulating water inlet and outlet nozzles.

1-E-2 TWO STAGE AIR EJECTORS

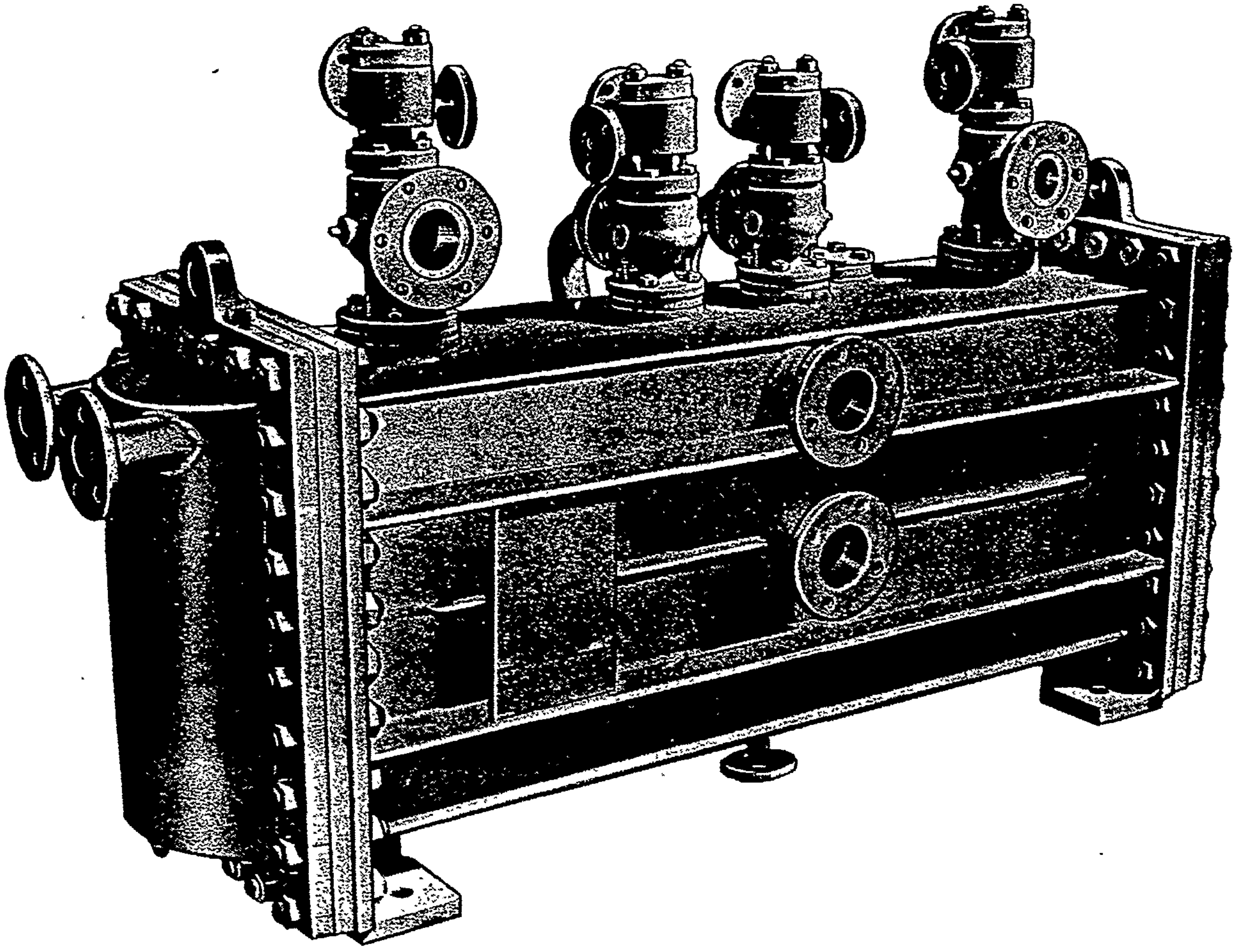
(a) General

The air and uncondensed vapors are removed from the auxiliary condenser by twin two stage air ejectors, mounted on an integral surface type inter-and-after and gland steam condenser. The arrangement and structural details are shown in Figure T-31.

The gases drawn into the first stage ejectors are entrained by the steam jets from the first stage nozzles and are carried through the diffusers into the inter-condenser. There the steam is condensed and the gases cooled. From the inter-condensers, the gases enter the second stage ejectors where they are again entrained by the motive steam and discharged through the diffusers into the after and gland condenser, where they are vented to the atmosphere, the steam being condensed.

(b) Construction

For the sake of compactness and simplicity the first stage and second stage diffusers are recessed into the inter and after condenser structure so that only the mixing chambers project above the condenser shell and no interstage piping is needed. The piping required is the steam supply piping to the ejectors and the cooling water piping and condensate drains. The



Auxiliary Air Ejectors Assembled on Inter-After and Gland Condenser Showing Water Box Connections

characteristics of the construction are shown in the Figure T-31, the path of the gases being indicated by arrows. The inter-and-after condenser shell is fabricated from plate by welding as are also the water chamber covers. In order to make it possible to cut out either ejector unit for examination or replacement without need for interstage valves, the inter-condenser is divided into two sections, each of which serves only one first stage ejector and is separately drained. Therefore, to work on either first-stage unit, it is only necessary to close the valve in the air line from the condenser and the steam stop valve for the ejector and the inter-condenser drain for that unit, then unbolt the connections from the ejector and remove it from the condenser. The after-condenser is also divided into two sections but both receive the vapors through a common opening. However, since the after-condenser is at atmospheric pressure, it is only necessary to be careful in removing the ejector to guard against any vagrant puffs of steam by using clean pieces of canvas which may also be used to cover the opening in the after-condenser while the ejector is removed.

(c) Tube Fastening

As shown in the illustration, the tube plates are mounted between the shell flange and the water box flanges and are commonly secured. In order to compensate for the differential expansion between the shell structure and the tubes, the later has been rolled and flared into the tube sheet at the inlet end only. At the outlet end of the tube, the tube sheet has been counter bored and threaded. This opening is then packed with copper foil packing which is held securely in place by ferrules threaded into the counter bore.

SECTION F - INSTALLATION OF THE UNIT

1-F-1. ALIGNMENT OF UNIT AND SETTING OF TURBINE ROTOR

(a) The bedplate of the unit is supported at three points on seating pads and is bolted down at these points only, as shown in Figure T-1. Each turbine generator unit was carefully aligned in the shop, the bedplate having first been set perfectly level. After the several parts had been set on the bedplate and correctly aligned, they were doweled to the bedplate. It is therefore evident that if the bedplate has been set upon a properly leveled foundation in the ship, the parts will be in alignment as established at the factory and the relationship of the parts should be unchanged.

(b) When the unit was first assembled, the turbine cylinder cover was inverted and the turbine rotor was placed in it and adjusted axially to obtain the proper clearance dimension between the nozzle block and the first rotating row of impulse blades, as shown in the Rotor Clearance Diagram Figure T-24. The distance from the low pressure end of the cylinder cover to the face of the turbine rotor at the exhaust end, was then measured. This dimension was recorded and is also stamped on the turbine cylinder base horizontal joint flange at the low pressure end.

(c) The rotor, (with the thrust bearing but without the thrust bearing liners) was then placed in the cylinder base, which had previously been doweled and bolted to the gear housing base, and the rotor was adjusted axially until the dimension from the rotor to exhaust housing agreed with the figure stamped on the flange. Next, the axial distance from the thrust bearing casing flange (Figure T-4 Item "5") to the housing was measured and the inner filler ring (Figure T-4, Item "16") of proper thickness was installed. Then, with the turbine rotor barred tight toward the exhaust end, the axial dimension from the outer surface of the end ring (Figure T-4 Item "18") to the housing was measured the nominal thrust clearance subtracted therefrom and the outer filler ring (Figure T-4, Item "17") was ground to this value and installed. The thrust clearance was then checked by barring the rotor first one way and then the other and comparing the positions in the housing.

(d) In the event that a new rotor should ever be installed in the unit, the process described above should be carried out to insure establishment of proper internal clearances in the turbine.

(e) With the rotor located as described above, the proper loading of the turbine and high speed pinion bearings were checked. If these three bearings were originally put in line with a mandrel, the two pinion bearings will be unequally loaded. To load them equally, the turbine inlet end bearing will actually have to be raised .016 inch by moving the support (Figure T-2, Item "21") the required amount. The high speed pinion bearing loading may then be checked by:

(1) Rolling out the high speed pinion generator end bearing #3 and noting the down spring of the shaft which should be .0015 inch, as measured on the shoulder just outside the journal.

(2) Rolling out the high speed pinion turbine end bearing #2 and noting the down spring of the shaft which should be .001 inch, as measured on the shoulder, adjacent to this journal, on the turbine side.

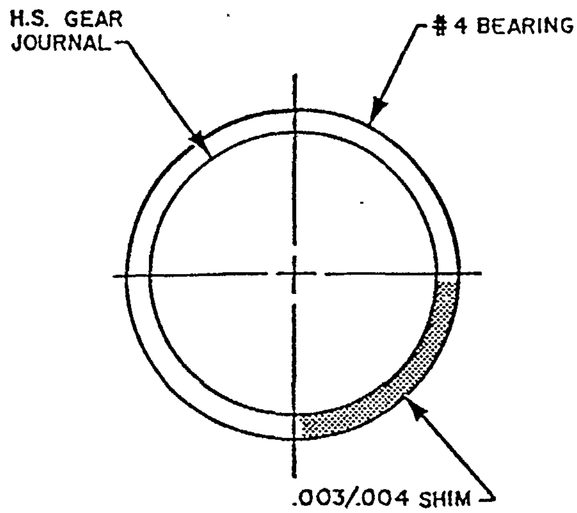
NOTE: IT IS MORE IMPORTANT TO OBTAIN THE CORRECT RATIO OF THESE DEFLECTIONS, THAN A SPECIFIC VALUE OF EITHER, FOR THE ABOVE VALUES ARE SUBJECT TO A TOLERANCE OF PLUS OR MINUS .001". THE DEFLECTION OF #2 BEARING SHOULD BE 70% OF THAT AT #3 BEARING.

(f) With the turbine rotor located to correctly load the turbine and high speed pinion bearings as specified above; install the high speed gear - low speed pinion assembly and the low speed gear and armature assembly. Check and correct the arthwartships alignment of the bull gear and generator rotor as necessary. Check the runout of the bull gear journal with the No. 6 bearing rolled out. Runout shall be within .0005".

NOTE: IN THE PREPARATION FOR THE FOLLOWING ALIGNMENT WORK, IT WILL BE NECESSARY TO MANUFACTURE TEMPORARY BEARING CAPS OR STRONG BACKS FOR THE FOUR BEARINGS WHICH HAVE CAPS INTEGRAL WITH THE UPPER GEAR CASE (TURBINE END PINION BEARING, BOTH BEARINGS ON HIGH SPEED GEAR - LOW SPEED PINION SHAFT, AND GENERATOR END LOW SPEED GEAR BEARING).

(g) Install temporary and permanent bearing caps to insure that all bearings will be held in place.

(h) In order to assist the moving of the high-speed gear journal to its normal running position, insert a .003" to .004" shim under the journal in such a position as to raise the journal and permit it to be pushed directly away from the high speed pinion. This journal runs with almost no vertical load and the bearing only restricts the gear from moving laterally out of mesh.



(i) Since the low speed gear journals run in the upper portion of the bearings at loads above 200 KW, it will be necessary to check the gear alignment with the gear in this position. Mount two 1/10,000 dial indicators adjacent to each bearing to detect vertical movement of the low speed gear shaft, and pass a padded sling over the low speed gear shaft adjacent to the coupling flange and vertically to a chainfall centered over the shaft. It will be necessary to incorporate a turnbuckle between the sling and the chainfall to facilitate minute adjustments.

(j) Raise the gear shaft while monitoring both indicators until a maximum reading of .008" is observed on one indicator. Adjust the vertical position of the generator bearing pedestal by means of shims until the indicator at the turbine end low speed gear journal reads .001" to .0015" higher than the generator end indicator.

(k) Raise the shaft until both low speed gear journals are located in the tops of their bearings (both indicators will stop moving). The gear is now in its running position.

(l) Coat both pinions with a thin layer of Prussian Blue and the mating teeth of both gears with a light coat of Williams Gear Marking Compound.

(m) Clamp a torque arm about the low speed gear coupling so as to resist rotation with an upward force.

(n) Using the rotor jacking wrench, roll the coated gear teeth into mesh, reverse the torque arm and roll the coated teeth out of mesh. In order to achieve maximum tooth contact, it may be necessary to replace the high speed pinion bearings and low speed gear bearings with centrically bored bearings to improve alignment. In the event the high speed pinion bearings are altered, check and reset the shaft droop at the bearings as required.

NOTE: JACKING IS TO BE DONE BY MEANS OF THE HEX MACHINED ON THE THRUST COLLAR NUT. THE NUT IS LOCKED IN PLACE WITH A SET SCREW; THEREFORE, DISCRETION MUST BE USED IN TORQUING THE GEARS TO OBTAIN THE TOOTH CONTACT.

(o) After achieving proper tooth contact, lower and raise the low speed gear and record the amount of lift at each bearing necessary to locate the journal in the top half of its bearing. In recording the movement, it is required that the dimension at the turbine end bearing be distinguished from the generator end bearing movement. Record with the letter "A" designating turbine end movement and the letter "B" for generator end movement. Repeat to insure accurate dimensions.

(p) Remove the high speed gear - low speed pinion assembly from the gear case, center a chainfall vertically over the low speed gear, and remove both bearing caps from the low speed gear bearings. Retain dial indicators located at same places on gear shaft.

(q) Lift the gear using a well-padded strap about the center of the gear, until the turbine-end indicator exceeds dimension "A" by one-half the amount that the generator-end indicator is less than dimension "B". Raise the generator rotor bearing by means of the shims until the indicator readings coincide with dimensions "A" and "B". Repeat this step to check the readings and adjust shims as required to achieve dimensions "A" and "B" on indicators.

(r) Check and bolt generator rotor bearing pedestal in place and repeat paragraph (q) above, shimming pedestal for fine adjustment if required.

(s) After position of generator rotor bearing pedestal has been established, raise pedestal .005" with shims to compensate for thermal growth of gear case.

(t) Check the air gap readings of the generator and exciter.

(u) Reassemble unit, coating sections of all gears with "Dykem Red" layout dye, and test.

1-F-2 PIPE CONNECTIONS

(a) The steam pipe connected to the turbine throttle valve steam strainer must not be rigid because, if it were, it could move the unit out of alignment. The steam inlet pipe connections should be made with long radius bends supported at a point close to the turbine. When making this connection, the pipe should never be sprung into place. It should be made so that the joints match properly.

(b) Before connecting the steam line to the turbine the line should be thoroughly blown out with high pressure steam to remove any foreign matter such as dirt, scale or joint compound, which if carried into the turbine could prevent the closing of the steam chest valves and cause-overspeeding or plug up part of a nozzle throat, thus reducing the capacity and efficiency of the unit.

(c) Wet steam is objectional as it causes much more rapid erosion of the blades and nozzles than does dry steam. It also reduces both the efficiency and capacity of the unit. Slugs of water whether from priming of the boilers or the picking up of condensation in the pipe line, if carried through the turbine cause serious shocks, vibrations and speed fluctuations or may trip the overspeed trip mechanism. If the pipe connections are such as to allow condensation to collect in the steam line, drains must be installed for use when starting up.

Step 9. Open drains to throttle valve, steam manifold and steam inlet piping. Vent glands.

Step 10. Operate the auxiliary oil pump where oil pressure falls to 4 pounds or less, until the turbine rotor comes to rest. With the decreasing oil pressure, the low oil pressure alarm contact maker should function when the value of 4 psig is reached and at this time the auxiliary oil pump should be started.

Step 11. Shut down circulating pump, close valves in cooling water supply to oil cooler.

Step 12. Clean machine and place in readiness for reoperation.

1-G-6 OPERATION PRECAUTIONS

(a) The following operation precautions should be carefully observed:

Point 1 - Avoid passing steam through the turbine with the rotor at rest. With the throttle and steam chest closed the throttle valve drain should be open.

Point 2 - Avoid air being drawn through the glands with the rotor at rest.

Point 3 - Periodically, at monthly intervals inspect the overspeed trip weight to see that it works freely in the body. Test all safety devices to see that each one functions properly.

Point 4 - Keep the throttle valve and steam chest valve lifting rods clean. Do not under any circumstances paint these parts.

Point 5 - Keep bearing oil pressures between 7 and 10 pounds gauge.

Point 6 - Keep the oil level in the reservoir between the limits indicated on the oil level gauge.

Point 7 - Keep oil strainer clean.

Point 8 - Keep oil cooler clean.

Point 9 - When the unit is not operating, keep all switches open.

Point 10 - At the least sign of trouble, stop the unit immediately. Investigate and correct the trouble before re-starting the unit.

Point 11 - Once each week, where practicable, test the overspeed trip by actually overspeeding the unit as described in paragraph 1-D-5(a).

SECTION H—MAINTENANCE

1-H-1 INSPECTION

(a) About once each year, depending on the nature of the service, the unit should be dismantled and thoroughly inspected and cleaned. Erosion of the blades, nozzles and valves, wear of bearings (including the Kingsbury thrust bearing) and changes in clearances, are the main points to be inspected. The gear-case cover should be removed to permit inspection of the gear teeth. If the gear tooth bearing is not well-distributed over the tooth surfaces, the parallelism of the pinion and gear bearings should be checked.

(b) The oil cooler, oil strainer, and steam strainer should be cleaned. All oil piping should be disconnected and thoroughly washed and cleaned. A light coat of shellac should be applied to the flange faces in making up the joints.

1-H-2 WEIGHTS

(a) The estimated, and for some items the actual weight of the principle parts of the unit which may require handling are given in the table below:

Name of Part	Pounds
Turbine Complete	4,736
Gear	3,626
Bedplate (actual weight)	2,160
Oil Cooler and Strainer (Dry)	320
Generator Complete	12,235
Exciter Complete (actual weight)	2,365
On Board Repair Parts (One Set)	1,433
Condenser (Dry) (actual weight)	9,255
Condenser (Operation)	10,952
Condenser (Flooded)	15,300
Air Ejector (Dry)	1,700
Air Ejector (Operating)	1,900
Air Ejector (Flooded)	2,200
Accessories	265
Oil Piping	327
Steam Gland and Drain Piping	66
Total Weight of Unit Dry (Actual Weight)	35,295
Total Weight of Unit (Operating)	37,792
Total Weight of Unit (Condenser Flooded)	42,140

1-H-3 ROTOR CLEARANCE DIAGRAM

(a) Figure T-24 shows the normal clearances and the clearance limits throughout the turbine. These clearances should be checked whenever an inspection of the turbine is being made.

1-H-4 ROTOR LIFTING DEVICE FOR REMOVING BEARINGS

(a) In order that the turbine and pinion bearings may be examined or removed without the necessity of lifting the turbine-cylinder cover, two rotor-lifting yokes are furnished as shown in Figure T-25. By slipping these yokes into place as indicated in the Figure and applying pressure on the jackscrews, the rotor may be raised sufficiently so that the lower halves of the bearings may be rolled out for examination or replacement, the auto stop cover, steam chest servomotor mechanism and rotor position indicator first having been removed. Care should be taken when using these yokes to make sure that the rotor is raised just enough to take its weight off the bearings, because by the use of the jackscrews, the rotor might be lifted sufficiently to damage the thin seal-strips around the blading and dummy seals.

1-H-5 ROTOR LIFTING GEAR AND GUIDES

(a) Figure T-26 shows the arrangement of the rotor lifting gear and guides. The guides are bolted to the turbine cylinder base, one pair at each end. The guides serve to hold the rotor central when lifting and thus lessen the danger of damaging the blading. The lifting gear is fabricated from plate steel and pipe. The slings fit around the rotor as shown and then over the collars. The hanger is welded to the pipe at a point which balances the two ends and thus keeps the rotor level while it is being lifted.

1-H-6 JOINT SEALING

(a) The horizontal and vertical joints of the turbine cylinder are grooved, for filling with a joint sealing compound, in the event that at some future date the flanged joint shows signs of leakage. Tapped holes located around the flanges as shown in Figure T-29 are on the outside of the casing and are accessible upon removal of the lagging.

(b) To fill the grooves, remove one end plug and the adjacent plug; start at one end and in-

SECTION G—OPERATION

1-G-1 GENERAL

(a) When turbines are started from a cold condition they are subject to expansion moments caused by the temperature of the incoming steam. Care, must therefore be exercised in warming-up the turbine to obtain uniform heating of the turbine parts. During the warm up period the turbine should be inspected for any unusual noise, for correct oil flow and bearing temperatures, for satisfactory gland sealing steam flows and for freedom of operation. Before proceeding with the warming up, a time schedule and check list should be prepared so that the steps listed below will be accomplished in sufficient time and in a satisfactory manner.

1-G-2 STARTING THE UNIT

(a) The starting procedure is as follows:

Step 1. See that the circuit breaker and main generator switch are open.

Step 2. Cut in all resistance in the field rheostat.

Step 3. See that the throttle valve is in the close position. Make sure that the overspeed trip mechanism is in operating condition.

Step 4. Check the oil level in the reservoir and the temperature of the oil.

SPECIAL CAUTION: Except in extreme emergency such as battle conditions, units should not be started up until the oil in the reservoir is at least 60°F. Oil below 60°F should be removed from the reservoir and preheated to that value before the unit is turned over.

When starting up with oil in the reservoir between 60°F and 100°F, the unit should be operated slowly until such time as the inlet oil to the bearings is 100°F or until such time as there is a free blow from the bearings, at which point full speed may be attained and load applied.

Due caution should be used when starting up with cold oil for lower oil temperatures require lower warming up speeds.

Step 5. Drain the Steam inlet piping.

Step 6. Open the drains from the throttle valve, steam seal manifold and vent the turbine glands.

Step 7. Start the circulating cooling water pump to auxiliary condenser.

Step 8. Start the condensate pump, recirculating condensate if necessary.

Step 9. Start the auxiliary condenser air ejector as outlined below, in the paragraph 1-G-3.

Step 10. Depress the reset handle knob on Overspeed Trip (Figure T-21). Prime the lubricating system thoroughly with the auxiliary oil pump, and continue operating this hand pump until the unit is operating at sufficient speed for the main oil pump to take over.

Step 11. Open the throttle valve handwheel one-half to one turn, sufficient to permit the turbine rolling immediately so that the turbine rotor will be heated evenly. Note: When the throttle valve handwheel has been turned in the opening direction the oil pressure in the system, as established by the operation of the auxiliary oil pump, will act upon the throttle valve operating piston opening this valve sufficiently to permit the initial flow of steam to the steam chest valves and hence the turbine. The steam chest valves will be in the partial open position being under the influence of the steam chest operating mechanism.

Step 12. As soon as the rotor has started turning, turn steam on the glands using not more than 2 pounds pressure.

Step 13. Operate the hand trip to check the operation of the tripping mechanism.

Step 14. Open the throttle valve handwheel one or two additional turns, permitting a greater steam flow. Bring the turbine speed up slowly, as the vacuum rises, coming up to normal speed in a period of not less than 5 minutes. Be sure that the unit is now under the influence of the governor which acts to control the speed.

Step 15. See that the bearing oil pressure is maintained between 7 and 10 pounds.

Step 16. Close all drains.

Step 17. Check lubricating oil temperature and if normal operating temperatures have been reached, start circulation of cooling water through oil cooler.

Step 18. Gradually open the throttle valve additional turns until the turbine is operating at normal full, noload speed.

Step 19. Adjust the voltage regulator for normal voltage of the generator. (Reference should be made to Chapters 3 and 4 for further study).

Step 20. Connect the generator to the line and put on load.

1-G-3 STARTING AUXILIARY AIR EJECTORS

(a) The operation of the auxiliary air ejectors is simple and should require very little attention, however, the designed steam conditions must be adhered to for satisfactory operation. An excess of a few percent in pressure may be tolerated although wasteful of steam and detrimental to the ejector capacity, but any reduction below the designed pressure would not only reduce the efficiency but involves danger of instability and breakdown. When trouble is experienced, it is very often due to either low steam pressure or wet steam or to an obstructed nozzle or steam strainer. Such a condition is indicated by unstable operation or failure to obtain or maintain full vacuum.

(b) To start either of the twin ejectors:

1. Be sure that the air vent at atmosphere is free.

2. The condensate drains from the inter-and-after condensers must be free.

3. Open the valves to allow the water to be circulated through the inter-and-after condensers.

4. Open the steam inlet valve on the second stage ejector.

5. Open the valve between the first stage ejector and the condenser.

6. After maximum vacuum obtainable with second stage alone is reached open the steam valve to the first stage.

The condensate from the inter-condensers is drained back to the main condenser, thus providing an opportunity for the liberation of entrained air from the ejector condensate. The condensate outlet from the after-condenser should be connected to drain system or returned by pump or trap into the make-up supply or into the condenser.

1-G-4 PARALLEL OPERATION

(a) When it is desired to place one unit in parallel operation with another unit which is already operating on the line, the recommended procedure is as follows:

Step 1. Bring the unit up to normal no-load speed as outlined above in paragraph 1-G-2.

Step 2. With the speed changer regulate the speed to the synchronous speed of the system.

Step 3. Observe the synchroscope and manipulate the speed changer until synchronism is indicated.

Step 4. Throw the unit on the line.

Step 5. Re-adjust the speed changer until each unit takes its share of the load at the proper speed.

(b) The proper voltage to obtain before throwing one generator in parallel with the other, can be found best by trial. It may vary slightly from the line voltage, depending upon local conditions.

1-G-5 SHUTTING DOWN THE UNIT

(a) The recommended procedure for shutting down the unit is as follows:

Step 1. Reduce the load to practically zero by manipulating the speed changer.

Step 2. Throw off the load by opening the circuit breaker, and then finally the main generator switch.

Step 3. Close the turbine throttle valve by the manual operation of the handwheel. Note: The manual closing of the throttle valve stops the flow of all steam to the turbine but at the same time permits the main oil pump to continue in operation supplying oil to the journal and thrust bearings.

Step 4. Break vacuum by means of vacuum breaker.

Step 5. Shut off steam to glands.

Step 6. Shut down auxiliary air ejector.

Step 7. Shut off circulating cooling water to condenser.

Step 8. Shut down condensate pump.

"24" and disconnect pilot valve from lever assembly. Remove lever assembly.

8. To lift out bellows assembly "5", remove screws "49".

WARNING

EXERCISE EXTREME CARE WHEN REMOVING COVER "66". SPRING "53" WHICH EXERTS PRESSURE ON POWER PISTON "3" PUSHES THE PISTON AGAINST THE COVER.

9. Replace two holddown screws "22" with longer screws (use 5/16-inch-18 by 1-3/4 inch long). Back out the other two screws "22" evenly, allowing the cover to rise. When these become free, replace them with two 2-1/2 inch long screws, and in turn replace the 1-1/2 inch long screws with 3-1/4 inch long screws. When the free length of the spring is reached (when the 2-1/2 inch screws have been removed) remove the cover, piston and spring.

10. To remove pilot valve sleeve "56" and pilot valve plunger "57", disconnect bracket "60".

11. To disconnect oil motor housing with the oil motor assembly, remove two screws "29". To disassemble the oil motor, remove two screws "74".

12. Reassemble the valve operator in the reverse order of disassembly.

SECTION I—REPAIR PARTS AND BASIC PLAN LIST

1-I-1 REPAIR PARTS

The various repair parts supplied for this unit, are listed in the Figures T-32 and T-33. All those parts which apply to the Turbine, Reduction Gear and associated mechanisms are shown in Figure T-32. All those parts which apply to the condensing equipment and associated mechanisms are shown in Figure T-33.

1-I-2 BASIC PLAN LISTS

The Basic Plan lists will be reproduced from the following drawings:

	Westinghouse Electric Corporation	BuShips
Plan List, Turbine	1-JH-3273	CVA60-S6102-H-1,475,770
Plan List, Condenser . . .	1-JD-5550	CVA60-S4600-D-1,475,931

1-I-3 TURBINE AND GEAR PLAN LIST

The basic plan List of Drawings, pages 135-136 shall remain in the manual. However, as a result of the modification to the governor assembly, a new plan list, drawing 849A618, comprising 21 pages, supersedes the Turbine and Gear Plan List drawing 1-JH-3273.

ject the sealing material with the gun provided until it overflows through the adjacent hole. The first hole should now be plugged and the process repeated at the other holes until the entire groove has been filled. With the gun in the next to the last hole and the sealing material flowing from the end hole, plug the end hole and put pressure on the gun to fill the groove solidly and then promptly plug the last hole.

(c) This operation must be carried on rapidly and continuously to finish before the sealing material hardens. Clean the gun thoroughly and oil it before putting it away.

(d) For joints, the temperature of which does not exceed 500° F, it is satisfactory to use a material such as "Furmanite" which may be obtained from the Furmanite Corporation, Newport News, Virginia, under the name of "Furmanite Standard Leak Sealing Cartridges", or an equivalent product. For joints exposed to temperatures above 500° F, it is expedient to use a material such as "Plasket #20", Turbine Grade; obtainable from the Scully Steel Products Company, Chicago, Illinois, or "Smooth-On No. 3" made by the Smooth-On Mfg. Company, Jersey City, New Jersey, or an equivalent substance.

1-H-7 AUXILIARY CONDENSER

(a) Unless the circulating water is badly contaminated, maintenance should be negligible. Most troubles arise from bad circulating water, over-treated or under-treated boiler water or both.

(b) Since the shell is a welded structure, air leaks, if any occur will probably be found at the valve stems or joint flanges. The preferred method of testing is to fill the condenser and turbine with water nearly to the turbine centerline and then check all doubtful points for water seepage, the water chamber access covers being removed so that all tube ends may be examined. Should any leaking tubes be found they may be plugged, rerolled or repacked depending upon the nature of the leak, until it is convenient to have the tube replaced.

1-H-8 AUXILIARY AIR EJECTORS

The design of these twin ejectors are such that should some difficulty arise, the standby unit may immediately be cut in service and the unit suffering the casualty cut out of service for examination.

Occasionally some foreign matter may become lodged in the nozzle, rendering it useless. Such a condition must, of course, be corrected by removing the foreign matter. The ejector nozzle is secured in the mixing chamber by being clamped down by the steam chest, into which is is screwed. A pipe plug in the steam chest provides access to the nozzle throat by the use of a piece of soft copper wire. If this will not serve, the steam chest and nozzle may be removed together and the obstruction backed out. If the nozzle gasket is damaged in the operation, it must be replaced with one of like thickness. Too much stress cannot be laid on the importance of maintaining the proper distance between the nozzle outlet and the inlet of the diffuser. The correctness of this dimension is vital to the operation of the ejector.

1-H-9 TOOLS AND WRENCHES

(a) Special tools and wrenches are provided to facilitate the disassembly and reassembly of the units in case of overhaul or repair. Figure T-28 illustrates these tools so that the personnel may more readily identify them and choose the proper tool for each operation.

1-H-10 REPAIR PARTS

(a) The lists which face the illustrated figures in this book have been compiled to facilitate ordering additional spare or repair parts by name and number. Whenever parts are ordered, it is of utmost importance to give the Serial Number of the turbine on which the parts are to be used.

(b) A complete list of the spare or repair parts as supplied with the original equipment are listed in Figures T-32 and T-33.

1-H-11 STEAM-VALVE OPERATOR AND GOVERNOR ADJUSTMENT

(a) The steam-valve operator was adjusted at the factory and, except for removing air from the oil control line between the governor and valve operator when the turbine is operating for the first time, or anytime this line has been loosened, no other adjustments should be necessary.

(b) Adjustment of the governor compensating needle valve and anticipation needle valve may be required after the TG set has been in operation. Proper adjustment is necessary to insure that both the governor and steam-valve operator respond properly to load change and oil pressure impulses.

(c) To make the proper adjustments due to either turbine hunting or excessive speed deviation recovery time, proceed as follows:

NOTE

Speed deviation recovery time can only be checked by using tracing instrumentation.

1. Screw the anticipation needle valve in until it is closed; then back the needle valve out one-half turn. Start the turbine and open the compensating needle valve three or four turns; this should cause the turbine to hunt. Using a key wrench, loosen the air vent plug—an instruction plate on the side of the governor case identifies this plug—far enough to establish a leak, and allow the turbine to hunt a sufficient period of time so that air trapped in the governor oil passages will escape at the vent plug. When air bubbles are no longer apparent, tighten the vent plug and, if necessary, add oil to the governor using the same oil used for the turbine. Verify correct oil level in the governor gage glass.

NOTE

It will also be necessary to purge air from the control line between the governor and the signal pressure receiving bellows in the operator, and the oil supply line to the operator.

2. Slightly loosen the oil line connections between the governor and operator, and also the oil supply line at the operator so that air will be removed as oil flows from the connections. Check oil level in governor gage glass and, if necessary, add oil to the governor.

3. If necessary, bleed air from the operator bellows by turning screw ("28", Figure T-14B).

4. Close governor compensating valve until hunting is just eliminated, or if not eliminated, minimized. Now, turn anticipatation valve—both in and out—from its original one-half turn position to find speed deviation recovery time.

NOTE

The speed deviation recovery time is approximately two seconds.

5. After finding the best setting for the anticipation valve, check to see whether or not the compensating valve can be opened further without causing instability. The objective is to have the compensating valve open as far as possible and the anticipation valve closed as far as possible.

NOTE

The operator restoring adjustment adjusts the position of the output piston of the operator with respect to the governor power piston position.

6. Adjust restoring spring ("54", Figure T-14B) so that output piston ("3", Figure T-14B) begins to move down from its uppermost position just as the governor power piston begins rising from its lowest position.

NOTE

For a given pressure in the bellows ("5", Figure T-14B) increasing the preload on the restoring spring will cause the operator output piston to move in the decrease steam direction.

1-H-12 STEAM-VALVE OPERATOR, DISASSEMBLY AND REASSEMBLY

To disassemble the steam-valve operator, proceed as follows:

1. Disconnect steam valve linkage from operator. See Figure T-14A.

NOTE

The following steps refer to Figure T-14B.

2. Remove holddown screws "20" from case "65". Remove cover "4" with boot seal "51" attached.

NOTE

To replace boot "51", perform step 3.

3. Remove screws "43" and lift clamping washers "55".

4. Remove snap ring "30" and lift off spring "54".

NOTE

Measure and record distance between stop clamp "78" and snap ring groove before proceeding with the next step. This distance can be reset on reassembly.

5. Loosen screw "78" and remove stop clamp "79".

NOTE

It is not necessary to remove spring seat "58" unless something is wrong with lever "68" or the spring seat. If either needs to be replaced, perform the next step.

6. Loosen screw "45".

7. Remove screw "28" and washer "31". Next, remove screws and clamp plate on pilot valve end of lever "68". Tilt lever "68" and remove screws on the other end of lever assembly. Remove nut

FOR REVISIONS SEE SHEET NO.2

BEFORE ORDERING MATERIAL CONSULT MFG. VARIATIONS DRAWINGS LISTED ABOVE

NAVY CONTRACT	SHIP NO.	SHIP NAME	BUILDING YARD	PURCHASE ORDER	MFG. VARIATIONS			
					DRAWING NO.	SHEET NO.	LINE NO.	FRAME NO.

DATE	INITIAL
STANDARD	
INACTIVE	
	ENGR. FILE 41
	MECH. M. I.
	MECH. RTG.
	R-5
	L-1
	J-4
	M-3A
	M-3B
	L-2

PHASE CODE

ISSUE DATE

REF DWG

S.O. 41 V 1989

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PLAN LIST

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849 A 618

SUB REV

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REVISIONS

REV	SUB	SHEET NO.	LINE NO.	DESCRIPTION	MFR APPD	MFR DATE	[illegible]N APPD	[illegible]N DATE

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	MANUFACTURER PC NO.	PORT OR STBD	INDEX NO.
1					
2	LONGITUDINAL ASSEMBLY-TURBINE AND GEAR	715 J 992			
3					
4					
5					
6					
7					
8	BACK PRESSURE TRIP	95 J 503	GR 2		
9	SPRING	1 JA 8923			
10					
11					
12					
13					
14					
15	BEARING COVER AND END COVER	1 JH 3254			
16	TAPER DOWEL	1 JA 1614			
17	BEARING COVER & CYLINDER END COVER	95 J 504			
18	SIGHT FLOW ASSEMBLY	1 JA 1630			
19	PIN - STRAIGHT	1 JA 1621			
20	COVER PLATE	1 JA 8937			
21	BEARING - DEPTH PLATE	1 JA 1627			
22					
23					
24					
25					
26					
27	BEARING - COMBINED THRUST & RADIAL (KINGSBURY)	463994			
28					
29					
30					
31					
32					
33	BEARING (HS PINION)	1 JH 3282	GR1&2		
34	PIN - STRAIGHT	1 JA 1634			
35	PIN - DOWEL	1 JA 1623			
36					
37					
38					
39					
40					
41	BEARING (LS GEAR)	1 JD 5510			
42	PIN - DOWEL	1 JA 1623			
43	PIN - STRAIGHT	1 JA 1634			
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3					
4					
5					
6	BEARING (LS GEAR)	1 JD 5511			
7	PIN - DOWEL	1 JA 1623			
8	PIN - STRAIGHT	1 JA 1634			
9					
10					
11					
12					
13					
14	BEARING (HS GEAR)	1 JD 5512			
15	PIN - DOWEL	1 JA 1623			
16	PIN - STRAIGHT	1 JA 1634			
17					
18					
19					
20					
21					
22	BEARING (LS PINION)	1 JD 5513			
23	PIN - DOWEL	1 JA 1623			
24	PIN - STRAIGHT	1 JA 1634			
25					
26					
27					
28					
29					
30	BEDPLATE	1 JH 3255			
31	BOLT - (SEMI-FITTED)	1 JB 6876			
32	BOLT - FITTED	1 JB 1105			
33					
34					
35					
36					
37					
38	BLADING LH 1ST STAGE 1ST ROTATING	1 JD 5531	GR 1		
39	BLADE	1 JC 6059			
40	SHROUD SEGMENT	1 JC 6069			
41					
42					
43					
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	MANUFACTURER PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3	BLADING LH 1ST STAGE 2ND ROTATING	1 JD 5532	GR 1		
4	BLADE	1 JC 6060			
5	SHROUD SEGMENT	1 JC 1418			
6					
7					
8					
9					
10					
11	BLADING LH 1ST STAGE STATIONARY	1 JC 6071	GR 1		
12	STATIONARY BLADE	1 JC 6061			
13	CAULKING PIECE	1 JC 5506			
14					
15					
16					
17					
18					
19	BLADING BAFFLE 1ST STAGE STATIONARY	1 JD 5535	GR 1		
20					
21					
22					
23					
24					
25	BLADING LH 2ND STAGE	1 JD 5531	GR 2		
26	BLADE	1 JC 6062			
27	SHROUD SEGMENT	1 JC 6069			
28					
29					
30					
31					
32					
33	BLADING LH 3RD STAGE	1 JD 5531	GR 3		
34	BLADE	1 JC 6063			
35	SHROUD SEGMENT	1 JC 6069			
36					
37					
38					
39					
40					
41	BLADING LH 4TH STAGE	1 JD 5531	GR 4		
42	BLADE	1 JC 6064			
43	SHROUD SEGMENT	1 JC 6069			
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	MANUFACTURER PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3					
4					
5					
6	BLADING LH 5TH STAGE	1 JD 5531	GR 5		
7	BLADE	1 JC 6062			
8	SHROUD SEGMENT	1 JC 6069			
9					
10					
11					
12					
13					
14	BLADING LH 6TH STAGE	1 JD 5533	GR 1		
15	BLADE	1 JC 6065			
16	BLADE - LAST	1 JC 6066			
17	CAULKING PIECE	1 JC 5507			
18	SHROUD SEGMENT	1 JC 6069			
19					
20					
21					
22					
23					
24	BLADING LH 7TH STAGE	1 JD 5534	GR 1		
25	BLADE	1 JC 6067			
26	BLADE LAST	1 JC 6068			
27	CAULKING PIECE	1 JC 5507			
28	SHROUD SEGMENT	1 JC 6069			
29					
30					
31					
32					
33					
34	BLADE SHROUD MACHINING	1 JD 1445			
35					
36					
37					
38					
39					
40	CYLINDER BASE (INLET END)	1 JH 3256			
41	FLANGE				
42	CYLINDER BASE DETAILS - INLET END	1 JH 1503			
43	TAPER DOWEL	1 JA 5628			
44	COVER PLATE	1 JA 8935			
45	CYLINDER BASE (INLET END) CONTINUED ON SHEET 7				

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1	CYLINDER BASE (INLET END) CONTINUED FROM SHEET 6				
2	ORIFICE PLUG	1 JA 1618			
3	SUPPORT	1 JB 6921			
4	PIN - STRAIGHT	1 JA 1634			
5	GROOVE	1 JA 8962			
6	GROOVE	1 JA 8963			
7	GROOVE	1 JA 8966			
8					
9					
10					
11					
12					
13	CYLINDER BASE FABRICATION (EXHAUST END)	1 JH 3257			
14	FLANGE				
15					
16					
17					
18					
19					
20	CYLINDER BASE MACHINING (EXHAUST END)	1 JH 3258			
21	GROOVE	1 JA 8962			
22	GROOVE	1 JA 8963			
23	EXPANSION JOINT	1 JD 5564			
24					
25					
26					
27					
28					
29	CYLINDER COVER (INLET END)	1 JH 3259			
30	STUD (SQ HD)	1 JC 6340			
31	PATCH PLUG	1 JA 1615			
32	BOLT - STUD	1 JA 1617			
33	EXTENSION NUT	1 JA 1619			
34	TAPER DOWEL	1 JA 5628			
35	TAPER DOWEL	1 JA 1614			
36	GLAND COVER	1 JC 5516			
37	GROOVE	1 JA 8963			
38	GROOVE	1 JA 8962			
39					
40	STUD - GUIDE	1 JA 5440			
41	GROOVE	1 JA 8966			
42	GROOVE	1 JA 8963			
43	EXTENSION NUT	2 JB 941			
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3					
4					
5					
6	CYLINDER COVER FABRICATION (EXHAUST END)	1 JH 3260			
7					
8					
9					
10					
11					
12	CYLINDER COVER MACHINING (EXHAUST END)	1 JH 3261			
13	STUD - GUIDE	1 JA 5440			
14	EXTENSION NUT	2 JB 941			
15	GLAND COVER	1 JC 5517			
16	GROOVE	1 JA 8963			
17	GROOVE	1 JA 8962			
18					
19	TAPER DOWEL	1 JA 1614			
20	STUD (SQ HD)	1 JC 6342			
21					
22					
23					
24					
25					
26	GAGE BOARD AND GAGES	1 JD 5548			
27					
28					
29					
30					
31					
32	GEARS AND PINIONS	1 JH 3262			
33	BOLT - FITTED	1 JB 1139			
34					
35					
36					
37					
38					
39	GEAR HOUSING BASE FABRICATION	1 JH 3263			
40	SIGHT FLOW	1 JC 1391			
41					
42					
43					
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3	GEAR HOUSING BASE MACHINING	1 JH 3264			
4	BOLT - (SEMI-FITTED)	1 JB 6876			
5	SIGHT FLOW	1 JC 1391			
6	OIL LEVEL INDICATOR	1 JB 6875			
7	COVER - CLEAN OUT	1 JB 6920			
8	GEARCASE BASE AND BEDPLATE MACHINING	95 J 531			
9	ORIFICE PLUG	1 JA 1620			
10	COVER - HAND HOLE	904 A 632			
11					
12					
13					
14					
15					
16	GEAR HOUSING COVER FABRICATION	1 JH 3265			
17	INSPECTION HOLE FLANGE	1 JC 1380			
18					
19					
20					
21					
22					
23	GEAR HOUSING COVER MACH & OIL SEAL RINGS	1 JH 3266			
24	OIL SEAL RINGS	1 JH 3287			
25	INSPECTION HOLE COVER	1 JD 1417			
26	OIL VAPOR CONDENSER	40 J 547			
27	BEARING CAP	1 JA 8956			
28	COUPLING GUARD	1 JB 6909			
29	STUD (SQ HD)	1 JC 6342			
30	END COVER	1 JA 8890			
31	COVER PLATE	1 JA 8887			
32	BEARING DEPTH PLATE	1 JA 1627			
33	COVER PLATE	1 JA 8937			
34	TAPER DOWEL	1 JA 1614			
35					
36					
37					
38					
39					
40	GOVERNOR ASSEMBLY MODIFICATION KIT	715 J 983	GR 1		
41	ADAPTER PLATE	524 C 071			
42	BRACKET FABRICATION & MACHINING	715 J 977			
43	SHAFT HOUSING COMPLETE	524 C 078			
44					
45	GOVERNOR ASSEMBLY MODIFICATION KIT CONTINUED ON SHEET 10				

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1	GOVERNOR ASSEMBLY MODIFICATION KIT CONTINUED FROM SHEET 9				
2					
3	GEAR, DRIVEN	379 D 732			
4	THRUST WASHER	1 JA 8955			
5	GEAR, DRIVER	521 C 113			
6	WASHER	1 JA 5459			
7	STUDS (CARBON STEEL)	924 B 757			
8	KEYS - SOLID (DIMENSIONAL STANDARD)	1 JA 1637			
9	HEX NUT (ELASTIC STOP)	10 H 847			
10	COVER	524 C 077			
11	GOVERNOR & SPEED CHANGER ASSEMBLY	1 JH 3267	REF		
12	GOVERNOR, PGD (WOODWARD)	8550 - 086			
13					
14					
15					
16					
17					
18	INSULATION, ATTACHMENTS & NAMEPLATES	1 JH 3269			
19	ATTACHMENT RAIL & HOOK	1 JA 5636			
20	IDENTIFICATION PLATE	1 JA 5634			
21	NAMEPLATE (COMBINED UNIT)	1 JA 5469			
22	NAMEPLATE (STEAM SEAL MANIFOLD)	1 JA 5633			
23	INSULATION ATTACHMENT & NAMEPLATES	1 JH 2183			
24	LACING DEVICES	1 JB 6883			
25					
26					
27					
28					
29					
30	NOZZLE BLOCK LH 1ST STAGE	1 JD 1446			
31	NOZZLE PASSAGE MACHINING	1 JC 6082			
32	NOZZLE PASSAGE MACHINING	1 JC 6083			
33	BOLT (SOCKET HEAD CAP)	1 JB 6932			
34	BOLT RETAINER SEGMENT	1 JB 1137			
35	SEAL STRIPS	1 JC 5508			
36	LOCK STRIPS	1 JC 5505			
37	CAULKING PIECE	1 JA 9151			
38					
39					
40					
41					
42					
43	NOZZLE DIAPHRAGM LH 2ND STAGE	1 JF 117			
44	DIAPHRAGM HALF SEGMENT	1 JC 6051			
45	NOZZLE DIAPHRAGM LH 2ND STAGE CONTINUED ON SHEET 11				

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1	NOZZLE DIAPHRAGM LH 2ND STAGE CONTINUED FROM SHEET 10				
2	DIAPHRAGM HALF BLANK SEGMENT	1 JB 6890			
3	NOZZLE VANE	1 JB 6937			
4	INNER AND OUTER SHROUD	1 JC 6057			
5	DIAPHRAGM KEY	1 JA 5642			
6	CRUSHING PIN	1 JA 5641			
7	SEAL STRIPS	1 JC 5508			
8	LOCK STRIPS	1 JC 5505			
9	SEAL RING	1 JB 6934			
10	SPRING	1 JA 8970			
11					
12					
13					
14					
15					
16	NOZZLE DIAPHRAGM LH 3RD STAGE	1 JF 118			
17	DIAPHRAGM HALF SEGMENT	1 JC 6052			
18	DIAPHRAGM BLANK HALF SEGMENT	1 JB 6890			
19	NOZZLE VANE	1 JB 6938			
20	OUTER SHROUD - TAPERED	1 JC 6058			
21	INNER AND OUTER SHROUD	1 JC 6057			
22	DIAPHRAGM KEY	1 JA 5642			
23	CRUSHING PIN	1 JA 5641			
24	SEAL STRIPS	1 JC 5508			
25	LOCK STRIPS	1 JC 5505			
26	SEAL RING	1 JB 6935			
27	SPRING	1 JA 8970			
28					
29					
30					
31					
32					
33	NOZZLE DIAPHRAGM LH 4TH STAGE	1 JF 119			
34	DIAPHRAGM HALF SEGMENT	1 JC 6053			
35	DIAPHRAGM BLANK HALF SEGMENT	1 JB 6890			
36	NOZZLE VANE	1 JB 6939			
37	OUTER SHROUD - TAPERED	1 JC 6058			
38	INNER AND OUTER SHROUD	1 JC 6057			
39	DIAPHRAGM KEY	1 JA 5642			
40	CRUSHING PIN	1 JA 5641			
41	SEAL STRIPS	1 JC 5508			
42	LOCK STRIPS	1 JC 5505			
43	SEAL RING	1 JB 6935			
44	SPRING	1 JA 8970			
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3					
4					
5					
6					
7	NOZZLE DIAPHRAGM LH 5TH STAGE	1 JF 120			
8	OUTER RING SEGMENT	1 JC 5513			
9	INNER RING SEGMENT	1 JC 5511			
10	NOZZLE VANE	1 JB 6937			
11	INNER AND OUTER SHROUD	1 JC 6057			
12	DIAPHRAGM KEY	1 JA 5642			
13	CRUSHING PIN	1 JA 5641			
14	SEAL STRIPS	1 JC 5508			
15	LOCK STRIPS	1 JC 5505			
16	SEAL RING	1 JB 6936			
17	SPRING	1 JA 8970			
18					
19					
20					
21					
22					
23	NOZZLE DIAPHRAGM LH 6TH STAGE	1 JF 121			
24	OUTER RING SEGMENT	1 JC 6054			
25	INNER RING SEGMENT	1 JC 6055			
26	NOZZLE VANE	1 JB 6940			
27	OUTER SHROUD - TAPERED	1 JC 6058			
28	INNER SHROUD - TAPERED	1 JC 6070			
29	DIAPHRAGM KEY	1 JA 5642			
30	CRUSHING PIN	1 JA 5641			
31	SEAL RING	1 JB 6935			
32	SPRING	1 JA 8970			
33	SEAL STRIPS	1 JC 5508			
34	LOCK STRIPS	1 JC 5505			
35					
36					
37					
38					
39					
40	NOZZLE DIAPHRAGM LH 7TH STAGE	1 JF 122			
41	OUTER RING SEGMENT	1 JC 6054			
42	INNER RING SEGMENT	1 JC 6056			
43	NOZZLE VANE	1 JB 6941			
44	OUTER SHROUD - TAPERED	1 JC 6058			
45	NOZZLE DIAPHRAGM LH 7TH STAGE CONTINUED ON SHEET 13				

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1	NOZZLE DIAPHRAGM LH 7TH STAGE CONTINUED FROM SHEET 12				
2	INNER AND OUTER SHROUD	1 JC 6057			
3	DIAPHRAGM KEY	1 JA 5642			
4	CRUSHING PIN	1 JA 5641			
5	SEAL RING	1 JB 6935			
6	SPRING	1 JA 8970			
7	SEAL STRIPS	1 JC 5508			
8	LOCK STRIPS	1 JC 5505			
9					
10					
11					
12					
13					
14	LOW OIL PRESSURE CONTACT MAKER(DETROIT LUBE)	TS - 1214			
15					
16					
17					
18					
19					
20	OIL PIPING ASSEMBLY	715 J 986	11&133		
21	FLANGE SOCKET WELDING RAISED FACE	1 JB 1124			
22	FLANGE SLIP-ON WELDING RAISED FACE	1 JA 1635			
23	STUDS (CARBON STEEL)	924 B 757			
24	ORIFICE PLATE	1 JA 1641			
25	SIGHT FLOW	1 JD 1420			
26	CONNECTOR	1 JA 1633			
27	ADAPTER - THREADED (MALE)	1 JA 5470			
28	ADAPTER - THREADED (FEMALE)	1 JA 5605			
29	PIPE PLUGS	16590			
30	SCREWS - FILLISTER HEAD - CAP	16469			
31	FILTER BRACKET DETAILS	1 JC 6270			
32	NUTS - AM STD HEX - FIN	751459			
33	BUSHING - PIPE	74902			
34	VALVE OPERATOR, STEAM (WOODWARD)	8902005	REF		
35	VALVE OPERATOR DIM, OUTLINE (WOODWARD)	9987067	REF		
36	FILTER, FLUID, DUPLEX (AIR-MAZE)	D3W181088			
37	SPIRAL-WOUND GASKETS TYPE CG	522 C 011			
38	SOCKOLETS SADDLE	363 B 405			
39	ADAPTER-WELDING TO STRAIGHT THREAD	379 D 445			
40	CLAMPS	2 JB 978			
41	CONNECTOR - STR THD	386 B 119			
42	FLANGE - SOCKET TYPE FLAT FACE	522 C 103			
43	FLANGE - SIDE OUTLET 150#	935 B 338			
44	SCREW - HEX CAP	522 C 504			
45	OIL PIPING ASSEMBLY CONTINUED ON SHEET 14				

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1	OIL PIPING ASSEMBLY CONTINUED FROM SHEET 13				
2	TEE SOCKET TYPE	522 C 225			
3	MOUNTING BRACKET, DUPLEX FILTER	524 C 619			
4	ACCUMULATOR ASSEMBLY	302 D 314			
5	COMPRESSION SPRING	387 B 037			
6	COMPRESSION SPRING	387 B 038			
7					
8	SCREW - HEX CAP	522 C 506			
9	ADAPTER SOCKET TYPE	522 C 228			
10	ELBOW - 45° SWIVEL NUT	386 B 124			
11	VALVE - BALL CHECK (SOCKET WELD)	362 B 087			
12					
13					
14					
15					
16					
17	OIL COOLER STRAINER UNIT ASSEMBLY (ANDALE)	N-5074			
18					
19					
20					
21					
22					
23	OIL COOLER STRAINER UNIT - LIST OF MATERIAL	(ANDALE) FN-5074			
24					
25					
26					
27					
28					
29	OIL COOLER STRAINER DETAILS (ANDALE)	N-5075			
30					
31					
32					
33					
34					
35	OIL COOLER DETAILS (ANDALE)	N-5076			
36					
37					
38					
39					
40					
41	OIL COOLER PRESSURE CONTROL VALVES (ANDALE)	N-5077			
42					
43					
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3					
4	OIL COOLER STRAINER UNIT DATA & REPAIR				
5	PARTS (ANDALE)	GN-5074			
6					
7					
8					
9					
10					
11	OIL COOLER STRAINER UNIT CERTIFICATION DATA	(ANDALE) CD-5074			
12					
13					
14					
15					
16					
17	OIL PUMP - MAIN (GIMPEL)	S-219			
18					
19					
20					
21					
22					
23	GOVERNOR AND OIL PUMP DRIVE ASSEMBLY	1 JH 3271			
24	PUMP SUPPORT COMPLETE	1 JH 1103			
25	DRIVE SHAFT	1 JC 1411			
26	COUPLING	1 JC 1412			
27	DRIVE GEAR - MAIN	1 JC 5538			
28	BEARING	1 JB 6901			
29	BEARING	1 JB 6896			
30	SPIRAL BEVEL GEAR AND PINION	1 JB 6903			
31	THRUST WASHER	1 JA 5443			
32	SPACER	1 JA 5442			
33	KEYS - SOLID	1 JA 8927			
34					
35					
36					
37					
38					
39	OIL SYSTEM AND CONTROL DIAGRAM	715 J 982	REF		
40					
41					
42					
43					
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	MANUFACTURER PC NO.	PORT OR STBD	INDEX NO.
1					
2	1500 KW TURBINE-GENERATOR SET (WITH NEW				
3	GOVERNOR) OUTLINE AND CERTIFICATION DATA	715 J 991	REF		
4					
5					
6					
7					
8					
9	OVERSPEED AND MANUAL TRIP	1 JH 3272			
10	BODY (UPPER) COMPLETE	1 JC 5514			
11	PIN - STRAIGHT	1 JA 1621			
12					
13	BODY (LOWER)	1 JC 5515			
14	BODY ROTATING	1 JC 5544			
15	VALVE SEAT	1 JA 8959			
16	OVERSPEED AND MANUAL TRIP	95 J 561			
17	PIN - LINKAGE	1 JA 5473			
18	PIN - STRAIGHT	1 JA 1621			
19	SPRING	1 JH 2154			
20					
21					
22					
23					
24					
25	OIL PUMP - HAND (GIMPEL)	S-368			
26	OIL PUMP - AUXILIARY HAND (GIMPEL)	S-240			
27	OIL PUMP - HAND (GIMPEL)	S-115			
28					
29					
30					
31					
32					
33	RELIEF VALVE (ATMOSPHERIC) (GIMPEL)	S-217			
34					
35					
36					
37					
38					
39	REPAIR PARTS AND TOOL LIST	1 JH 3274			
40					
41					
42					
43					
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1					
2	ROTOR	1 JH 3275			
3	CENTER PLUG	1 JB 6929			
4	KEY - SOLID	1 JA 1637			
5	ROTOR BLADE ROOT	1 JC 1413			
6	ROTOR BLADE ROOT	1 JB 6942			
7	ROTOR BLADE ROOT	1 JB 6943			
8					
9					
10					
11					
12					
13	ROTOR POSITION INDICATOR	95 J 565			
14	PLUG	1 JA 9221			
15					
16					
17					
18					
19					
20	ROTOR LIFTING GEAR AND GUIDES	1 JD 5515			
21	ROTOR LIFTING BAR	1 JD 1433			
22	SLING	1 JB 6897			
23	ROTOR GUIDES	1 JH 3288			
24	BUSHING	1 JA 8957			
25					
26	STRAIGHT DOWEL	1 JA 5450			
27	ROTOR LIFTING DEVICE	1 JC 5525			
28	ROTOR LIFTING DEVICE	1 JC 1410			
29					
30					
31					
32					
33					
34	ROTOR CLEARANCE	1 JH 1230			
35					
36					
37					
38					
39					
40	SEAL RING - DUMMY	1 JC 5518			
41	SEAL RING	1 JB 6926			
42	SPRING	1 JA 8965			
43					
44					
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	MANUFACTURER PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3					
4					
5	SEAL RING - GLAND	1 JD 1447			
6	SEAL RING	1 JB 6944			
7	SPRING	1 JA 8961			
8					
9					
10					
11					
12					
13	STEAM CHEST COVER VALVES AND LINKAGE	715 J 994	GR 1		
14	STEAM CHEST COVER	1 JD 2265			
15	VALVE SEAT	1 JB 1127			
16	VALVE 1/2 NOM	1 JB 6925			
17	STEM	1 JB 6928			
18	EXTENSION NUT	1 JA 8931			
19	TAPER DOWEL (DIMENSIONAL STDS)	1 JA 5628			
20	NUT - AM STD HEX - FIN	751459			
21	BOLT - STUD	9 H 176			
22	BUSHING	1 JB 1140			
23	WASHER (SPHERICAL) MALE	1 JA 5471			
24	WASHER (SPHERICAL) FEMALE	1 JA 5472			
25	SCREW	10 H 487			
26	SCREW (HEADLESS) HEX SOCKET	1 JA 8884			
27	BUSHING	1 JB 6899			
28	VALVE STEM BUSHING	1 JB 6882			
29	GUIDE PIN	1 JA 5621			
30	VALVE SEAT EXPANSION RING 1-JC-6155	~~1 JB 1142~~			
31	STUD	1 JB 6923			
32					
33					
34					
35					
36					
37	STEAM VALVE OPERATOR & LINKAGE ASSEMBLY	715 J 993	GR 1		
38	LEVER	524 C 092			
39	LINK	1 JA 5620			
40	NUT - AM STD HEX - FIN	751459			
41	COTTER PINS (PRONG - SQ CUT)	16500			
42	BUSHING	1 JA 5627			
43	TRUNNION	620 C 032			
44	SET SCREWS - AMERICAN STANDARD	16992			
45	STEAM VALVE OPERATOR & LINKAGE ASSEMBLY CONTINUED ON SHEET 19				

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	PC NO.	PORT OR STBD	INDEX NO.
1	STEAM VALVE OPERATOR & LINKAGE ASSEMBLY CONTINUED FROM SHEET 18				
2	TRUNNION	1 JB 6898			
3	PIN (DOUBLE END, SHOULDER)	1 JA 5624			
4	PIN (GROOVED)	1 JA 5625			
5	LOCK WASHER	1 JA 5626			
6	SUPPORT SERVO MECHANISM	302 D 293			
7	VALVE OPERATOR DIM. OUTLINE (WOODWARD)	9987067			
8	START SEQUENCE VALVE	715 J 450			
9	SCREWS - SOCKET HEAD	270 A 128			
10	NUT - AM STD HEX - FIN	751459			
11	PIN - STRAIGHT	1 JA 1634			
12	COMPRESSION SPRING	360 B 836			
13	START SEQUENCE VLV SETTING INSTR	385 B 040			
14					
15	VALVE - FLOW CONTROL (WOODWARD)	1326 - 002			
16	DOWEL STUD (COARSE & 8 THDS) NAVY	10 H 289			
17	WASHERS - FLAT	363 B 412			
18	STUDS (COARSE THD'S) NAVY	10 H 291			
19	NUT (AMERICAN STD) FINE THDS - FIN	9 H 117			
20	PIN - TAPER	16503			
21					
22					
23					
24					
25					
26	STEAM, GLAND AND DRAIN PIPING	1 JH 3286			
27					
28					
29					
30					
31					
32	STEAM SEAL MANIFOLD (GIMPEL)	S-218			
33	STEAM SEAL MANIFOLD DETAILS (GIMPEL)	S-203			
34	STEAM SEAL MANIFOLD DETAILS (GIMPEL)	S-238			
35					
36					
37					
38					
39					
40	STEAM STRAINER	1 JH 3280			
41	STUD	1 JB 6924			
42	HEX NUT	1 JB 6922			
43	WASHER (SPHERICAL) MALE	1 JA 5471			
44	WASHER (SPHERICAL) FEMALE	1 JA 5472			
45					

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	MANUFACTURER PC NO.	PORT OR STBD	INDEX NO.
1					
2					
3					
4					
5					
6					
7	THROTTLE VALVE	1 JH 3281			
8	VALVE SEAT	1 JB 1127			
9	EXPANSION RING	1 JB 1142			
10	BUSHING	1 JB 1140			
11	COMPRESSION SPRING	1 JA 8932			
12	PISTON RING - COMPRESSION	2 JB 1115			
13	STUD	1 JB 6924			
14	HEX NUT	1 JB 6922			
15	WASHER (SPHERICAL) MALE	1 JA 5471			
16	WASHER (SPHERICAL) FEMALE	1 JA 5472			
17					
18					
19					
20					
21					
22	WRENCHES AND TOOLS	1 JH 3289	GR1&2		
23	VALVE SETTING FIXTURE	1 JB 6950			
24	PIN - STRAIGHT	1 JA 1621			
25	DIAL INDICATOR POST	1 JA 8969			
26	BOLT STRETCH MEASURING SLEEVE	1 JA 8920			
27	BOLT STRETCH MEASURING ROD	1 JA 8921			
28	WRENCH (SPANNER)	1 JA 1659			
29	MICROMETER DEPTH GAGE	1 JA 1651			
30	BUSHING EXTRACTOR COLLAR	1 JA 8925			
31	BUSHING EXTRACTOR SUPPORT	1 JA 8926			
32	DISMANTLING JIG (OVERSPEED TRIP)	1 JA 8998			
33	WRENCH THERMOCOUPLE FITTING	1 JA 9380			
34	WRENCH (TACHOMETER)	924 B 553			
35	WRENCH ADAPTER	924 B 694			
36					
37					
38					
39					
40					
41	TACHOMETER MOUNTING ARRANGEMENT	909 D 002			
42	SHAFT	924 B 554			
43	OIL BAFFLE	904 A 533			
44	ADAPTER	924 B 555			
45	TACHOMETER MOUNTING ARRANGEMENT CONTINUED ON SHEET 21				

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LINE NO	TITLE	MANUFACTURER DRAWING NO.	MANUFACTURER PC NO.	PORT OR STBD	INDEX NO.
1	TACHOMETER MOUNTING ARRANGEMENT CONTINUED FROM SHEET 20				
2	TACHOMETER EQUIPMENT	1 JH 7378			
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
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OVERBLOWN DOCUMENTS

WITHIN THE CONTENT OF THIS EXHIBIT
ARE NOT IMAGED

TURBINE EQUIPMENT

General Index

CHAPTER 2—A-C GENERATOR

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

CHAPTER 2
SHIPS SERVICE A-C GENERATOR

SECTION 1—DESCRIPTION OF GENERATOR

GENERAL INFORMATION

Purpose

These instructions are intended to describe the construction and to guide in the installation, operation and maintenance of the ship's service generators.

Machine Identification and Data

Rating (Fig. G-10)

These generators are rated 1500 KW (1875 Kv-a) 80% power factor, 450 volts, 2400 amperes, 3 Phase, 60 cycles, 1200 RPM, excitation 125 volts, 149 amperes d-c; temperature rise for rated continuous load per Table I.

Generator Classification (Fig. G-10)

(a) Reference Ambient Temperature: $50^{\circ}C$

(b) Table and Method of Measuring Temperature Rise: Table I

(c) Class of Insulation: Class B

(d) Degree of Enclosure: Totally enclosed with heat exchanger.

(e) Method of Cooling: Self-Ventilated

(f) Manufacturer's Type Designation: Special 6 - 44 1/2 - 19-1/2 S.O. 52-P-514

(g) Means of Excitation: 125 volt, 1200 RPM, direct current, ROTOTROL type, Ship's Service Generator-Exciter, which is direct connected to main shaft.

(h) Prime Mover: Steam turbine via speed decreasing gear.

Generator Test Data

Factory test data are furnished at the close of these instructions.

TABLE I

Item	TEMPERATURE RISE-DEGREES CENTIGRADE		
	By Thermometer	By Resistance	By Detector
Armature Windings	60	70	70
Insulated Field Windings	60	70	--
Collector Rings	75	--	--
Bearings	30	--	--
Cores and Mechanical Parts in Contact with or Adjacent to Insulation	60	--	--

The caluclated performance table from drawing 1-JH-2802 is given in Table II.

TABLE II

Load	KW	P.F.	Kv-A	Amps	D-C EXCITATION		
					Amps	Volts	KW
50% cont.	750	.80	937.5	1200	108.5	58.1	6.3
75% cont.	1125	.80	1406	1800	126.3	60.9	7.7
100% cont.	1500	.80	1875	2400	144	69.4	9.99
150% 5 min.	1406	.50	2810	3600	201	96.9	19.48

The photo listed below is not available at this time and will be issued later.

Fig. G-1 — Generator and Exciter Completely Assembled

Nameplate Data

1500 Kw (1875 Kv-a)	1200 RPM	
450 Volts	125 Exciting Volts	
80% power factor	149 Exciting Amperes	
3 phase	Stator Serial	1-S-52-P-514 to 9-S-52-P-514
60 Cycles	Rotor Serial	1-R-52-P-514 to 9-R-52-P-514

It is recommended that the nameplate readings of the new equipment be reviewed and office copies of these readings be made available. This information will be found useful in subsequent correspondence on the equipment.

Always refer to the serial number stamped on the nameplate of the machine when corresponding with the manufacturer for this is the number which identifies the machine.

DESCRIPTION OF APPARATUS

Illustrations

Reference to the drawings, Figures G-9 to G-16 will be found useful in supplementing the following description.

General Arrangement
(Fig. G-9)

The generator unit consists of the steam turbine, speed decreasing gear, a-c generator, and the direct connected d-c ROTOTROL (exciter). Separate instructions are furnished for the ROTOTROL exciter. See Chapter 3.

The a-c generator is coupled to the speed decreasing gear by a forged flange coupling at the rear end. The shaft is supported at the other end of the a-c machine by a pedestal type bearing. The stator frame is mounted on the sub-base. The exciter rotor is overhung on the shaft. The exciter stator is mounted on the sub-base.

Frame
(Fig. G-9)

The enclosed box-type frame in fabricated from hot rolled steel members. Heavy steel-slab feet, welded to the lower portion of the frame rings, insure rigid attachment of the generator to the sub-base. These feet are situated parallel to the shaft and are drilled for holding down bolts and jackscrews. Lifting bars, welded inside the frame cover, facilitate lifting of the frame.

The stator-core laminations are stamped from special silicon steel. They are stacked on transverse bolts and are clamped between the steel frame rings. Ventilating spaces are provided by fingerplate spacers permitting air to circulate through the core. Terminals of the armature are brought out to straps at the side of the frame.

End Bells and Enclosing Covers
(Fig. G-9)

Covers and air shields which are bolted and welded to the frame parts enclose and direct the ventilating air and protect the armature windings. The rear cover is split on the horizontal centerline. The air cooler housing directs the air from the cooler into each end of the frame for re-entrance to the machine.

Removable covers at each end of the machine provide access for air gap measurement and inspection. Elongated holes are located in the air shield portion of the end bells in line with these cover plates. Three drains with plugs are located at the lowest part of the frame.

Air Cooler
(Fig. G-15)

The air cooler for the a-c generator is located at the top of the generator frame. It is a double-tube type of cooler furnished by the Harrison Radiator Division of the General Motors Corporation.

The purpose of the double-tube construction is to enable leaks in the water tubes to be detected before serious failure of a tube occurs. Each double tube consists of water-carrying tube surrounded by a close-fitting outer tube. Axial grooves in the inside surface of the outer tube extend the full length of the cooler.

The grooves in the outer tubes all open into "tell-tale" chambers at each end of the cooler. When a leak occurs in the main water-carrying tube, the leakage runs into the grooves in the surrounding tube, and from there it runs into one of the chambers mentioned. This arrangement is designed to prevent water leakage into the air ducts and generator. Leakage can be detected only if the lower-most drain is open permanently to permit the leakage from the "tell-tale" chamber to be observed.

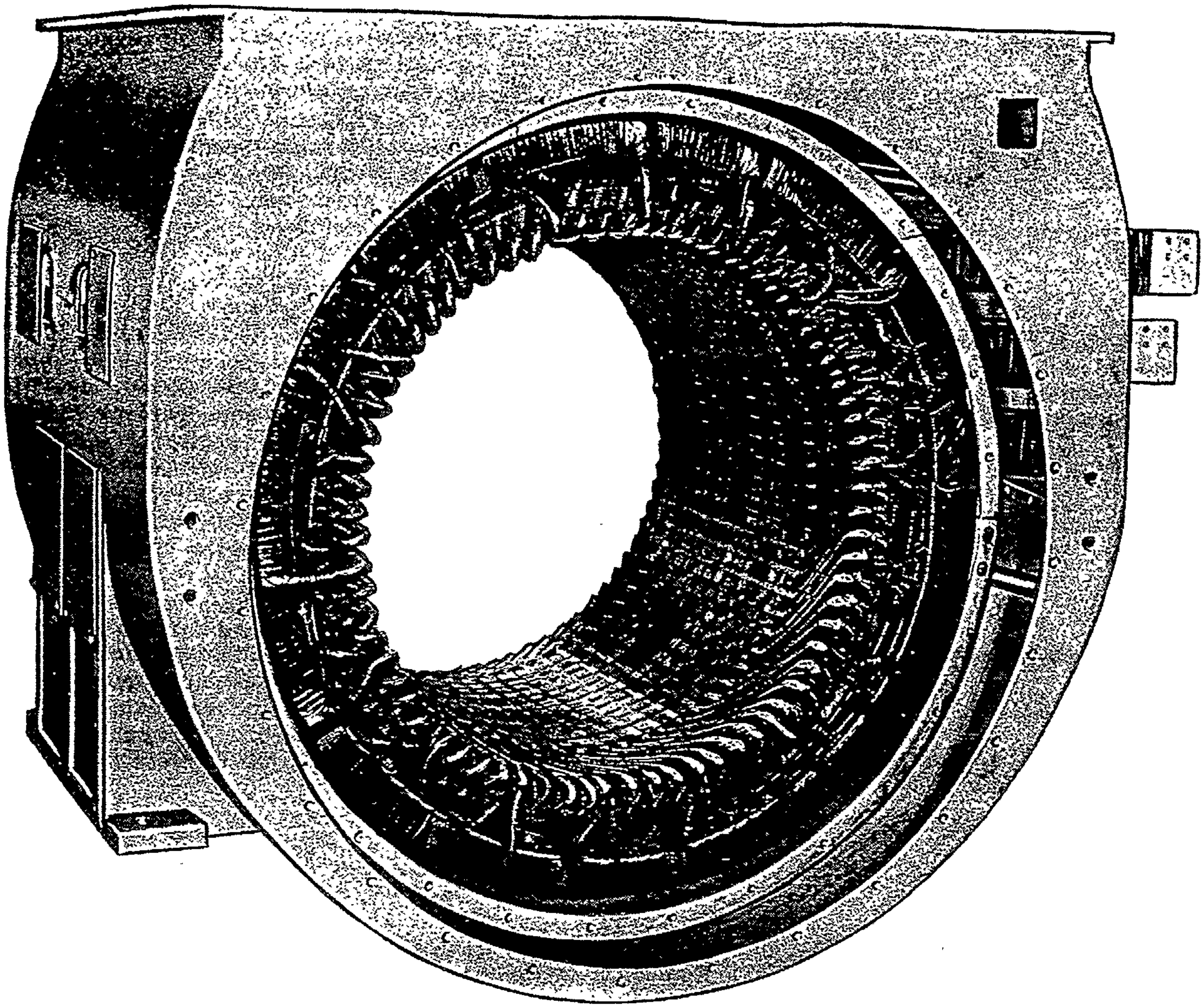


Fig. G-2 — Generator Stator

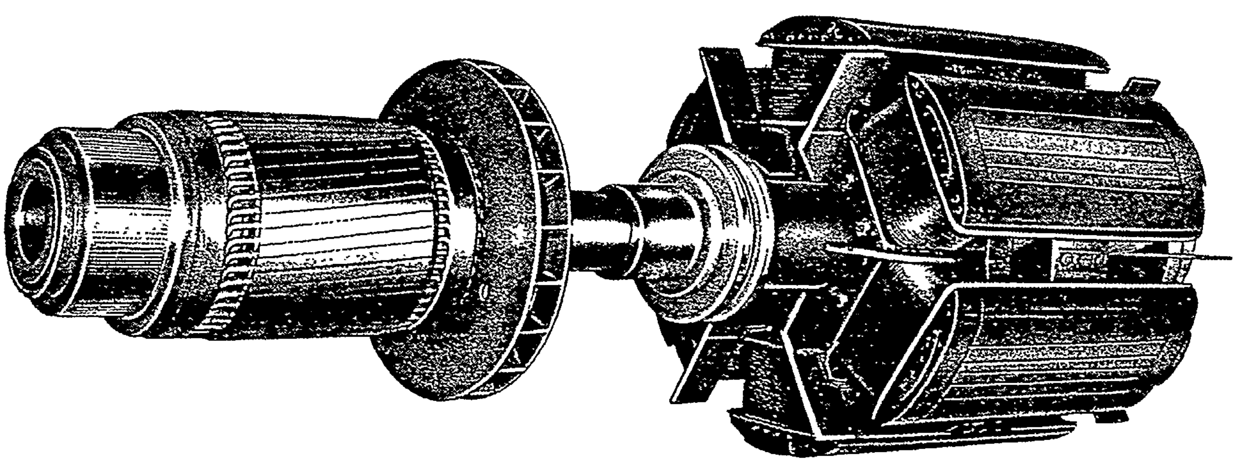


Fig. G-3 — Generator Rotor

The air cooler requires 60 gpm of cooling water at a temperature not exceeding 85°F.

Bearing
(Fig. G-9 and G-10)

The shaft is supported by a pedestal type split-sleeve insulated bearing at the collector end. The other end is supported by the speed reduction gear. The bearing insulation provides protection against bearing currents. The bearing is split horizontally and consists of an upper and lower cast steel shell lined with babbitt. Lubrication is provided by the forced feed system of the prime mover. A fixed orifice at the bearing inlet supplied with the generator by the generator builder limits the oil flow through the bearing to 1-1/2 gallon per minute at a pressure of approximately 5 psi.

In addition to oil throwers machined on the shaft, front and rear oil seals are provided to prevent leakage of oil along the shaft, and to prevent entrance of dust and dirt into the bearing. Each seal consists of two semi-circular steel rings having copper seal and look strips on their inner periphery, bolted to the bracket. The small clearance between the shaft and the inner periphery of the seal prevents leakage of oil along the shaft away from the bearing. Standard Navy type flanges are provided for the oil inlet and drain connections.

Core
(Fig. G-9)

The core of the machine is built up of circular, segmental laminations of silicon steel stacked on twelve transverse studs. Each circular lamination consists of six segments. Ventilating spaces are formed between the frame rings and the ends of the core by finger plate spacers, and between the packages of punchings by vent plate spacers at all positions along the length of the core. This arrangement furnishes a means for dissipating heat from the core by permitting cooling air to enter the inner portion of the core. The laminations are insulated from one another with a surface coating of sodium silicate (water glass). Finger plates at each end of the core prevent loosening of the teeth. After the punchings are stacked in the machine, they are compressed to the proper core length, and the frame rings are welded in place to hold the armature core firmly in the frame. The stator punchings have 82 slots each having a finished size, after stacking, of 0.525" wide by 2.325" deep.

Armature (Stator) Winding
(Figs. G-10 and G-12)

Tabulation of Winding

Coil Grouping: 4 Coils per Group
1 Group per Pole per Phase - 3 Groups
per Pole - 18 Groups Total 72 Coils
Throw of Coils: Slots 1 to 10 -
6 Poles - 3 Phase - 6 Parallels - Delta

The stationary armature has a bore of 31.5" and has 72 slots, each of which has a finished size of 0.525" wide by 2.325" deep. The armature coil is of the diamond type and consists of 4 conductors, each of which is two strands wide by two strands deep of double-glass-covered copper wire. The strands are .102" thick; and .204" wide. The weight of one coil is approximately 9.5 pounds.

Each of the straight sides of the coil is insulated with one and one-half turns of a .010 inch thick Glasweve and mica wrapper. The end portions of the coil are insulated by hand taping with one layer of half-overlapped .007 inch thick glass-backed mica tape. The coil is finished all over with one half-overlapped layer of .005 inch thick, Glasweve tape. The finished coil is impregnated with a heat-reactive varnish by the vacuum-and-pressure method.

The coils are placed directly in the slots without slot calls. Glass-Melamine-Micarta wedges are used to hold the coils in place in the slots. The coils are roped to an insulated steel ring at each end of the winding to prevent distortion of the end turns in case of short-circuit.

The assembled stator is treated twice in a moisture-and-oil resistant varnish.

Shaft and Spider
(Fig. G-9)

The rotor shaft is machined from a solid steel forging. An integral flange is provided on the rear end for coupling to the speed reduction gear. The front end of the shaft is machined to receive the quill of the exciter rotor. The spider which carries the field poles is built up of steel laminations riveted together, the assembly being pressed on and keyed to the shaft. The spider laminations are punched with dovetail slots for mounting the field poles.

Field Poles
(Fig. G-9)

The six poles are constructed of laminated steel punchings which are securely bound together by through rivets. Each field pole is fastened to the spider by a dovetail, which is held in place by two tapered keys. The dovetails are prevented from buckling by a weld extending the full length of each dovetail.

The brass upper coil support is held to the pole by studs.

Lower Coil Support, Balance Weights and Blowers
(Fig. G-9)

The lower coil supports and blowers are made of steel angle and sheet and are bolted to the spider assembly at the centerline between the poles. Elongated bolt holes in the lower coil supports permit the position of the supports to be adjusted. Balance weights are placed under the heads of the bolts which hold the lower coil support to the spider.

Field (Rotor) Winding
(Figs. G-9 and G-11)

Each open field coil consists of 82 turns of .032 x 2" and 29 turns of .047 x 2" edgewound bare copper strap. The dimensions of the uninsulated coil are 6.845" in width by 20-1/2" in length with a radius of 1-1/8" at the corners. Starting with the 4th turn from the top, the end section has every 4th turn extended 1/2" beyond the normal position. After the bare copper is formed, the coil is insulated as described on Figure G-11. The lower part of the side section of the coil is machined to the dimensions shown on Figure G-10, and the center section of the lower portion of the side of the coil is machined to give clearance for the coil brace bolts.

The coil is assembled on the pole with glass-melamine washers, and after assembly it is treated four times in moisture and oil-resisting varnish.

Each coil is secured in its position on the pole by the upper and lower coil supports. The upper coil supports are made from brass, and they are held to the pole by studs. The lower coil supports are made from steel angle and are bolted to the spider. The holes for the bolts are elongated to allow for adjustment of the lower coil support. It is pressed against the coil as tightly as possible during assembly.

Collector
(Fig. G-9)

The collector assembly is pressed on the shaft between the spider and the journal. It consists of two helically grooved bronze collector rings shrunk onto a length of steel bushing around which a sleeve of mica has been built up with the entire bushing used as a mandrel. Two copper studs, one threaded into each ring pass through glass melamine insulating tubes connecting the rings to their respective field leads. The surface of each collector ring is machined with a helical groove to improve brush performance.

The collector assembly is held in place on the shaft by a light press fit and three set screws inserted into a groove in the shaft so as to prevent both rotational and axial movement.

Brush Rigging and Brushes
(Figs. G-9 and G-10)

The four brushholders are supported on two insulated steel studs mounted from the pedestal. The part of the stud which screws into the pedestal is eccentric from the part which the brushholders mount from so that the distance of the brushholders from the collector ring may be adjusted by turning the stud. A lock nut secures the stud in position. Each brushholder contains two brushes 3/4" wide by 1-1/2" thick by 2" long. Each generator requires eight brushes. The brushes are grade WH4 - Navy grade H per 17B8. For replacement brushes, order Style #1593190.

Mechanical Rotation
(Fig. G-9)

The rotation of the generator is clockwise as viewed from the collector end.

Phase Rotation
(Fig. G-10)

When the mechanical rotation of the generator is clockwise as viewed from the collector end, the emf's induced in the phases will reach positive maximum values in the following manner:

$$T_1 \ - \ T_2 \ - \ T_3$$

Short Circuit Currents
(Fig. G-10)

The sustained short circuit current per phase is calculated to be approximately as follows:

(1) With the regulator in operation 10770 amperes
(2) Without the regulator in operation 4780 amperes and full load field excitation.

The symmetrical RMS short-circuit current is calculated to be approximately 26,500 amperes for the first half cycle.

The windings are designed to withstand the stresses incident to short-circuits when the machine is operated at full load and at rated voltage and power factor.

Air Seal
(Fig. G-9)

At the rear end of the generator a brass seal ring having a small clearance between it and the shaft coupling prevents mingling of the outside air with the cooling air of the machine's recirculating ventilation system.

Armature and Field Leads
(Figs. G-9 and G 13)

The armature leads are made of copper strap and are brought out at the side of the generator frame. Solderless terminals are provided as indicated on the certification data dwg.

The field leads consist of jumper cables which connect the brushholders to the exciter terminals. Except for metering leads brought out at the exciter terminal box. There are no external connections to the generator field and no terminals are required, since the generator field leads M_1 and M_2 connect directly to the exciter armature leads A_1 and A_2.

Space Heaters
(Figs. G-9, G-10 and G-13)

Eight, 250c, tubular-type, space heaters are located on the lower part of the frame inside the machine. The heaters are all connected in parallel for operation from a 115-volt power supply. The leads are brought out to the terminal board located on the right-hand side of the generator frame as viewed from the collector end. A removable cover plate provides access to the space heater terminal board. From there the space heater leads leave the generator through a conduit. See the Certification Data drawing for the size of the conduit.

Stator Temperature Detectors
(Figs. G-9, G-10 and G-13)

The temperature detectors consist of ten-ohm resistance coils embedded between the upper and lower coil sides in the stator slots. The six detectors are equally spaced around the circumference of the generator. The connections are shown on Figure G-10. The leads are brought out to the terminal board with conduit connection at the right hand side of generator frame as viewed from the collector end. Refer to the Certification Data drawing for the size of the conduit.

Air Temperature Relay
(Figs. G-9 and G-13)

An air temperature alarm contact maker is located in the discharge air stream at the side of the frame. The relay is set to close on rising temperature at 85°C (185°F). Conduit may be connected to the box of the relay. Refer to the Certification Data drawing for the size of the conduit.

Ventilation and Cooling
(Fig. G-9)

The generator is ventilated with air circulated through the machine by the combined blowing action of the field poles and blower blades. The blades are located at each end of the rotor and are shrouded by the inner end bells.

Air from the outer end bells is drawn axially into each end of the machine near the shaft. Part of the air ventilates the end turns of the stator coils and passes,through openings through the finger plates, into the space between the stator core and the frame cover. The remainder of the air enters the space between the field poles, crosses the air gap, and flows radially through the stator vent ducts into this same space behind the stator core. From there, all the air is directed into the air cooler through an opening at the top of the generator frame. After passing through the cooler, the air is returned to the generator through ducts which are integral parts of the frame.

The air cooler requires approximately 60 gpm at full load.

Spare Parts
(Fig. G 13)

The spare parts furnished for the a-c generators are given on the Lists of Spare Parts and Tools, Figure G-13. These lists are included at the close of these instructions, and they indicate whether the items are to be stored on shipboard or ashore.

SECTION 2—INSTALLATION OF GENERATOR

STORAGE

The generator is shipped with the windings well protected from moisture. At the destination, the rotor and stator should be placed in locations protected from the weather and from mechanical injury. Rain, snow, water or steam from leaking pipes, or condensation from the atmosphere should be excluded. It is particularly important to keep the windings dry for moisture lowers the insulation resistance and increases the likelihood of a breakdown. If the machine is brought from cold surroundings into a warm room, it should be kept covered until its temperature has risen to room temperature in order to prevent the condensation of moisture on the windings and other parts.

When storage over a period of time is anticipated, the machine should be completely enclosed by a tarpaulin or a covering of wood, metal or roofing paper unless the machine is in a protected location.

HANDLING AND PACKING

It is easily possible, by rough handling or careless use of bars or hooks, to do more damage to a machine before or during erection than would be done in years of regular service.

Care should be taken in transporting and handling the machines to see that the windings are not damaged. A blow upon any part of the windings is likely to injure the insulation and result in the burning out of a coil.

Lifting the parts of the generator set should be done with the greatest possible care. The a-c-generator is provided with lifting holes at the sides of the frame, and the bearing caps are equipped with eyes for lifting. The bottom of the air gap of the a-c machine should be shimmed in order to hold the rotor in position when both the stator and rotor of the machine are lifted together.

In lifting the rotor, it is preferable to use rope slings looped around the shaft. If chains are used, they should not be looped around the journals unless the latter are properly protected. In no case should the ropes or chains be allowed to exert pressure on the windings or collector rings.

INSTALLATION AND ERECTION

The instructions included for assembly and disassembly of the generator unit are intended to supplement the erection instructions furnished with the turbine and speed reduction gear. Satisfactory performance of the generator unit cannot be obtained when the unit is improperly aligned with the speed reduction gear.

GENERAL

The principal external dimensions of the generator set and the provisions for mounting it on the engine sub-base are shown on the Outline and Section Drawing 1-JH-2801 which appears as Figure G-9 of these instructions.

EXAMINATION OF BEARING AND JOURNAL

Before the machine is installed, the surface of the bearing and journal should be examined for injuries accidentally sustained during or after shipment. Scratches on the surface of the babbitt should be smoothed out, and scratches or rust on the journal should be polished off before the machine is assembled.

CLEANING COLLECTOR RINGS

Remove the protective compound covering the collector rings. A cloth dipped in benzine (or other solvent) will be useful in removing this compound.

ALIGNMENT OF EQUIPMENT

When the a-c generator and exciter have been approximately located on the engine sub-base, with the rotor in the machine and the coupling loosely fitted, the final alignment should be undertaken.

Care must be taken in locating the position of the generator frame axially on the sub-base so as to be sure that the journal is centered axially in the bearing. This may be checked when the top half of the bracket and top half of the bearing shell is removed.

The fit at the face of the coupling is the guide for alignment of the rotating parts with the reduction gear. The bearing cap should be removed so that the bearing can align itself properly in the pedestal. Liners should be inserted under the pedestal feet as needed to cause the faces of the coupling to fit together as specified in the instructions for the turbine and gear. The coupling bolts should then be tightened.

The position of the generator stator should be adjusted so that the following conditions are met after the frame feet bolts are pulled tight.

1. The proper axial clearance exists at the journal between the journal oil throwers and the bearing. The clearances at the ends of the bearing should be such that they will be approximately equal after the coupling bolts are tightened.

2. The air gaps are equal around the bore within 1/64". It is particularly important that the air gap between the armature core and the pole faces be uniform, for any inequality in the gap will cause unnecessary friction and heating in the bearings as well as unequal heating of the iron in the armature core.

During these adjustments, the air gap should be gaged from both ends of the machine at different points around the rotor. Gages for the purpose should extend to the center of the core.

The feeler gage should be inserted along the core between poles and then moved over into the space between the pole face and the stator core. This procedure reduces the likelihood of reading too small a value for the air gap at a point near the end of the machine where a high punching is most likely to exist.

If accurate readings of the air gap are required, the varnish should be removed from both the rotor and stator punchings at the air gap surface.

3. The coupling outage is less than .001" as measured at the flange with a dial indicator after the coupling bolts have been tightened. The presence of burrs, nicks, or other results of poor handling will be noticed in this check.

4. Refer to the Rototrol instructions for description of special electrical adjustment of the Rototrol exciter air gap.

When the proper alignment of all parts is obtained, ream holding down bolt holes and install bolts.

SECTION 3—OPERATION OF GENERATOR

STARTING

Brush Adjustment

Brushes and brushholders should be examined before the machine is started up to make sure that the brushes are in the proper position, that there is a proper fit between the collector and the brushes, and that the brushes are free in the holder. If the faces of the brushes do not conform to the curvature of the collector, it is necessary to grind them to shape. This operation is always required when new brushes are installed.

When fitting new brushes or damaged brushes, the operator should use sandpaper "Grade 1-1/2" for the roughing out and "Grade O" for the final fitting. The sandpaper should be drawn in the direction of rotation under the brushes. Rounding of the brush edges can be avoided by releasing pressure as the paper is drawn back and by being careful to keep the ends of the paper as close to the collector as possible. Each brush should be treated in turn, and it will be found that by this means a satisfactory contact is quickly secured.

The brushholders should be adjusted so that they are 1/8" from the collector rings.

An initial brush pressure of 2-1/2 psi or 2 pounds-5 ounces is recommended. Once the machine is in service, the pressure may be altered as necessary.

Initial Check on Insulation Resistance

The insulation resistance of an electrical machine gives an indication of whether the machine is in a suitable condition for operation or potential tests. If the insulation resistance of a winding is below the minimum acceptable value for a new machine, the winding should be dried out.

Once the windings are in a satisfactory condition for operation, it is recommended that initial readings be taken for both the armature and field windings so as to provide a basis for later comparison.

Further information on insulation resistance is given under the general heading "Maintenance", following.

Drying-Out Windings

If the insulation resistance indicates that the windings have absorbed moisture during shipment, the generator should be dried out before any high potential test is made or before the generator is initially run. Once the windings have been dried out, the space heaters should be placed in operation whenever the machine is not running. The windings may be dried either by the use of external heat or by the circulation of current through the windings themselves.

When external heat is to be applied, it is advisable to use resistance heaters or steam coils as sources of heat. The space heaters located inside of the generator are not of sufficient capacity for use in drying out the machine; so additional heaters are required. The space heaters may be used as supplementary sources of heat. The machine should be covered, and the heaters should be placed near the bottom of the enclosure. Care should be taken to protect the machine against direct radiation from the heaters. Effective drying cannot be accomplished unless means are provided to circulate the air so as to remove the moisture. The circulation of heated air can be improved by the following:

1. Forcing air into the bottom of the enclosure with small fans.

2. Having the enclosure sufficiently close-fitting to cause most of the heated air to pass through the ventilating spaces in the machine.

3. Providing an opening at the top of the enclosure for the escape of moisture-laden air.

When the heating is to be accomplished by the circulation of current, a d-c welding set may be used to provide the current. The current in any part of the winding should not exceed the rated value. Refer to Fig. G-4.

Another method of circulating current through the armature windings of the generator without subjecting them to full voltage is to drive the machine at a convenient speed with the armature windings short-circuited and with the proper value of excitation applied to the field to give somewhat less than rated armature current.

Regardless of the method of heating used, it is essential that the heat be brought up grad-

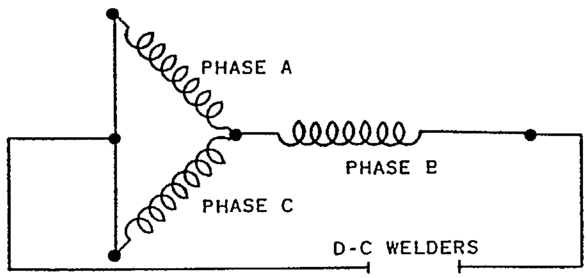


FIG. G-4 — Connections for Drying-out Windings with DC Welder

ually at first, the aim being to allow the water vapor to find its way out naturally through the insulation. Too rapid heating is likely to develop such steam pressure in local portions that escape passages are forced through the insulation, injuring it permanently. It is generally desirable to consume 15 to 20 hours in bringing the temperature up to the value required.

The total temperature of any part of the machine should not exceed 75°C during the early part of the drying out period. Later, after the insulation resistance has passed its minimum value and has become nearly stable, the temperature may be raised to 125°C or slightly higher. If the windings are heated by passing current through them, the temperature of the armature coils should be determined by the embedded detectors, and the temperature of the field windings may be determined by comparison of the winding resistance with its resistance at a known temperature. Refer to the section on "Temperature" for the method of measuring temperature by change of resistance.

During the drying-out process, measurements of insulation resistance should be taken at regular intervals, and it is recommended that the results be plotted in the form of a curve of insulation resistance vs. time. A typical curve of this kind is shown as Figure G-5. The initial drop in insulation resistance can be attributed to the effect of rising temperature, and the subsequent rise in resistance is caused by the removal of moisture. The drying-out process should be continued until the insulation resistance becomes approximately constant at a high value.

Final Check before First Start

Before the unit is started, the following check should be made:

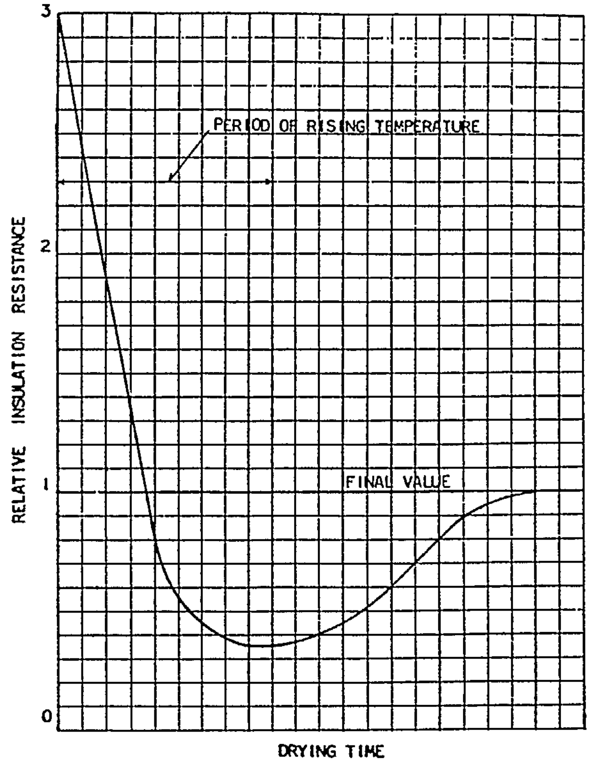


FIG. G-5 — Typical Behavior of Insulation Resistance During Dry-out Run

a. Be sure that all necessary work of installation and erection has been completed.

b. Carefully examine the interior of the generator for loose objects such as bolts, nuts and tools. Such items should be removed from the machine, and care should be taken to prevent their being drawn into it by magnetic attraction.

c. Check to be sure that the brushes are free in their holders and that the brush pressure is about 2-1/2 psi (roughly 2 lb. 5 oz. per brush for this machine).

d. Be sure that the voltage and frequency marked on the nameplate of the generator correspond with that of the power line.

e. Check the wiring and piping to be sure that all connections have been made properly.

f. Check to see that the proper electrical clearances exist between conductors. Do not allow brush shunts to touch each other.

g. Check the drain holes at the bottom of the frame to be sure that they are not clogged.

h. Be sure that all moving parts have sufficient clearance with respect to adjacent stationary parts.

i. Check to see that the windings are free from dirt and moisture.

j. Measure the insulation resistance of the windings, and dry-out the windings if the test shows this to be necessary.

k. Be sure that the coverplates have been installed over the openings in the frame and end bells.

STARTING GENERATOR

Check During First Start

When the unit is first started, the following observations should be made.

a. Check sight-flow indicators in the oil piping to be sure that an adequate supply of oil is being furnished to the bearing.

b. Be sure that the air cooler is adequately supplied with cooling water of the proper temperature.

c. Watch temperatures wherever possible to be sure that none is excessive.

d. Check the brush rigging to be sure that the brushes ride properly on the collector rings.

Starting Single Generator Unit

a) Before the generator is started from rest, make certain that a-c line breakers are open and no load is connected to the generator.

b) For generating systems equipped with sandby regulators, check to determine if the desired regulator is connected for operation. For adjustment and operation of the WRN-11 Static Voltage Regulator see the manual for the Voltage Regulating Equipment.

c) After the regulator has been adjusted for starting:

1. Jumper between D and C_3 of the POTENTIAL UNIT terminal block removed when generators are not to be operated in parallel.

2. Regulator transfer switch (VA) turned to NORMAL unless a standby regulator is used.

3. Regulator control switch (CA) turned to MANUAL.

4. VOLTAGE ADJUSTING UNIT set for the desired generator voltage (normally 450 volts).

5. MANUAL CONTROL UNIT handle turned to extreme LOWER.

d) Start the prime mover and bring it up to the desired speed as indicated by a tachometer. The frequency is indicated by the frequency meter on the a-c generator panel.

e) Adjust regulator to bring generator voltage up to the desired value = (normally 450 volts).

1. MANUAL CONTROL UNIT handle turned to extreme RAISE position until the generator voltage starts to rise.

2. MANUAL CONTROL UNIT handle turned back toward the LOWER position to obtain the desired voltage.

f) Set regulator for automatic operation and readjust generator voltage to the desired value.

1. Regulator Control Switch (CA) turned to AUTOMATIC.

2. VOLTAGE ADJUSTING UNIT reset for desired generator voltage.

g) Close the a-c line circuit breaker. The generator is ready to be loaded.

h) If it is desired to operate using MANUAL control, it will be necessary to adjust the generator voltage as the load changes. For a discussion of the effects of a change in excitation see the section on "Operation" which follows.

Paralleled Generators

When the a-c generator units are to be paralleled; the starting of subsequent units is similar to that described for a single generator, but additional care is required in order to synchronize the units.

In order that synchronous generators may be connected to a system already in operation, the voltage of the incoming machine and that of the system must be approximately the same at each instant. This requires that the two voltages be of the same frequency, have the same magnitude and phase rotation, and be in phase with each other. Voltmeters indicate whether the magnitudes of the voltages are the same, and frequency meters of tachometers indicate whether the frequencies, are approximately the same. Whether the voltages are exactly in phase and of exactly the same frequency is indicated either by a synchroscope or by a synchronizing lamp circuit.

Explanation of Synchronizing Lamp Circuits

Although the indication of synchronism given by a synchronizing lamp circuit is less precise than the indication given by a synchroscope, the frequent use of the lamp circuit justifies an explanation of its operation.

Lamps should be connected between the leads which will be joined together when the generators are synchronized. The lamps should be adapted for the highest voltage which they will receive. This voltage will be twice the normal value and will occur when the machine voltages are in phase opposition. When the voltage of the system is too high for the synchronizing apparatus, it is usual to place voltage transformers between the main circuits and the synchronizing circuits so as to reduce the voltage at the switchboard to a safe value. Fig. G-6 show such connections between two of the same phases of the two three-phase generators. One generator may be considered as representing a system which is already in operation. A recommended check on the transformer connections is given in a later paragraph.

As the voltage of the incoming generator and the voltage of the system change from a condition of phase-coincidence to one of phase-opposition, the flow of current through the lamps changes from a minimum to a maximum. When the voltages are exactly equal and in phase, the current through the lamps is zero. A phase difference between the voltages causes current to flow through the lamp circuit and illuminate the lamps.

If there is a small difference between the frequency of the incoming generator and that of the system, the lamps increase in brilliancy until the voltage of the machine and that of the system are in exact opposition. From this condition, the lamps decrease in brilliancy until they are completely dark (if the voltages are equal in magnitude), indicating that the voltages are again in phase. The frequency with which the lamps alternate between the bright and the dim condition is proportional to the difference between the generator and system frequencies.

When the frequencies of the incoming generator and the system are equal and the voltages are equal but out of phase, the lamps glow with a steady brilliancy. The degree of brilliancy depends upon the amount of phase displacement between the two voltages.

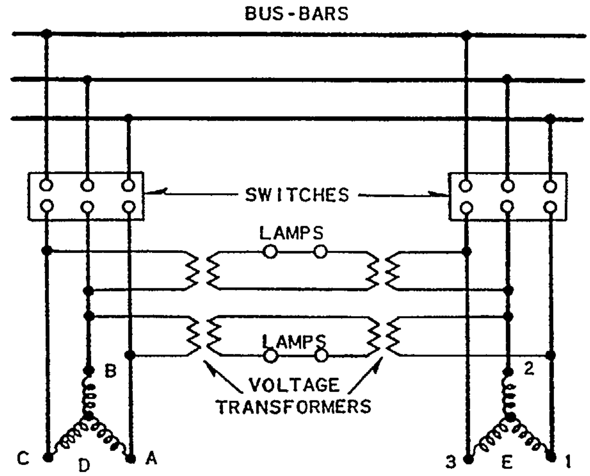


Fig. G-6 — Connections for Synchronizing 3 Phase Generators

When the voltage transformers are required in the lamp circuit because of high line voltages, it is possible for the transformer connections to be made in such a manner that the lamps burn with maximum brilliancy when the two voltages in question are IN PHASE rather than OUT OF PHASE. It is preferable to USE DARK LAMPS TO INDICATE SYNCHRONISM instead.

The following check can be used to make certain that the lamps will be dark when the voltages are in phase. Disconnect the main leads of the incoming generator at the generator, and throw it in the main switch of this generator so that its bus work will be energized from the system. Both voltage transformers will then be energized from the same voltage source, and the lamps will be dark if the transformer connections are correct. If the lamps burn brightly under these conditions, the two connections to one of the primaries or to one of the secondaries of the voltage transformers should be reversed.

Determining Proper Phase Sequence

When a generator is to be synchronized with a system already in operation, the phase sequence of the generator must be the same as that of the system. To check the phase sequence, the following procedure is recommended: Refer to Fig. G-6, and assume that generator "D" is to be synchronized with the system represented by generator "E" Note that synchronizing equipment is required, in two phases when the phase sequence is to be checked. Check the two lamp circuits separately, as described in the preceding section, to be sure that the lamps in each circuit are dark when the voltages being compared are equal and in phase. Once the circuits have been checked, the proper phase sequence for the incoming generator may be determined.

To check the phase sequence, observe both sets of lamps when the voltage, and frequency of the incoming generator have been made approximately equal to those of the system. If both sets of lamps become bright and dark in unison when the frequency or the incoming generator is slightly different from that of the system, the phase rotation of the generator is the same as that of the system.

If one set of lamps is bright while the other is dark, the phase sequence of the incoming generator is opposite to that of the system. To make the phase sequence of the generator agree with that of the system, interchange any two of the three line connectors between the generator and the bus. It is well to make a confirming check on the phase sequence after changing the connections, but first the lamps should again be checked to be sure that they will be dark when the corresponding voltages are equal and in phase.

Synchronizing Generators With Lamps

Synchronizing lamps are recommended for use as a check on the operation of the synchroscope and for emergency use in case the synchroscope is inoperative. Separate voltage transformers should be used for the synchroscope and lamps. If the phase sequence of the incoming machine is known to be correct, lamps need to be connected between only one phase of the generator and one phase of the system. The lamps should be connected so as to be dark at synchronism and to be at maximum brilliancy when the generator and system voltages are 180 degrees out of phase. Zero potential is applied to the lamps at synchronism. However, an incandescent lamp appears dark even though a considerable potential is applied. For this reason, lamps do not give as definite and accurate an indication of synchronism as is obtained with a synchroscope. Nevertheless they may be used satisfactorily if proper care is exercised.

With the generator frequency slightly greater than that of the system, adjust the speed of the generator so that the bright and dim sequence of the lamps becomes slow and constant. Anticipate the time required for the breaker to close its contacts, and throw the breaker so that its contacts will close at the middle of the dark period.

Fig. G-7 — Synchroscope

Synchronizing Generators With A Synchroscope

A synchroscope is an instrument which is used to indicate the instantaneous difference in phase between the voltage of the incoming generator and the voltage of the system with which the generator is to be synchronized. Refer to Figure G-7. The voltage of the system is used as a reference, and its voltage vector can be represented as a stationary pointer in the "twelve o'clock" position on the dial of the instrument. The voltage vector of the incoming generator is represented by the movable pointer. The number of mechanical degrees between these "vectors" on the synchroscope dial is the number of electrical degrees by which the generator and system voltages are out of phase.

When the pointer is in the left-hand portion of the dial, the voltage of the incoming generator is considered to be lagging the voltage of the system. When the pointer is in the right-hand portion of the dial, the voltage of the incoming generator is considered to be leading the voltage of the system.

The speed of rotation of the pointer is proportional to the difference between the frequency of the generator and that of the system. If the generator frequency is higher than the system frequency, the pointer will rotate in the "FAST" (clockwise) direction, indicating that the generator is running too fast. If the generator frequency is less than the system frequency, the pointer will rotate in the "SLOW" (Counterclockwise) direction, indicating that the generator is running too slowly.

Before the incoming generator is connected to the system, a check should be made on the synchroscope to be sure that the pointer of the instrument rotates when the generator frequency is known to be somewhat different from the system frequency.

When the incoming generator and the system are in exact synchronism, the following conditions exist:

a. The voltage of the generator is equal to the voltage of the system. When this condition exists, the generator and system voltmeter readings are equal.

b. The frequency of the generator is equal to the frequency of the system. When this condition exists, the pointer of the synchroscope remains stationary.

c. The voltage of the generator is in phase with the voltage of the system. When this condition exists, the pointer of the synchroscope is in the "Twelve o'clock" position.

In practice, the best results in synchronizing a generator with a system are obtained by closing the line breaker when the pointer is rotating slowly in the "FAST" direction and approaching the "twelve o'clock" position. By observing the synchroscope carefully and timing the closing operation properly, the circuit may be completed at the exact point of synchronism, or at least within a very few degrees of it. Faulty synchronizing will cause a disturbance on the power system and may result in automatic tripping of the circuit breakers.

OPERATION OF A-C GENERATORS

Single Generator

When a synchronous generator operates alone, and is not paralleled with other generators, the field current must be adjusted for each change in load in order to maintain rated voltage. This adjustment can be made through manual control of the regulator, but it is preferable for this to be done with the regulator set for automatic operation to keep the voltage constant even though the load varies rapidly. No change in the power factor of the generator can be affected by changing the field current of the generator, as the power factor for a single generator is determined entirely by the characteristics of the load.

Parallel Generators

a) REQUIREMENTS FOR SUCCESSFUL PARALLEL OPERATION

1. The following paragraphs give the general requirements for successful parallel operation of synchronous generators:

2. The speed regulation of the prime movers should be alike. That is, the percent drop in speed for a given percent increase in load should be the same for all units. The drop in speed from no-load to full-load may be only two percent or less, but if it is the same for all of the generators which are in parallel, the total load will be divided between them in proportion to their ratings.

3. The speed governors of the prime movers should be free from "hunting" and should bring the machines quickly to a steady speed. Any oscillation of the governors will result in a transfer of load back and forth between machines and a fluctuation of the voltage.

b) LOAD DIVISION AND POWER FACTOR CONTROL

1. When synchronous generators are operating in parallel, the power factor of each depends upon their relative excitation and upon the division of the total kilowatt-load among the machines. It is preferable for all the generators to operate at the same power factors.

2. In the following discussion, let it be assumed that the load is to be divided between two generators of equal rating. In addition, it will be assumed that the WRN-11 regulator is set for MANUAL operation. The kilowatt-load may be divided equally between the generators by adjusting the governor settings of the two prime movers. When the two generators are carrying equal loads, their watt-meter readings will be equal. This redivision of load may be affected without any appreciable change in the frequency of the power system (normally 60 cycles) by making each governor adjustment very slight and by making the adjustments alternately on the two machines.

3. After the load is balanced, the power factor and line current of the two generators may be equalized by properly adjusting the manual control unit of the WRN-11 regulator. This may be accomplished without appreciable change in the ship's service voltage (normally 450 volts) by slight and alternate adjustments of the MANUAL CONTROL UNIT handles of the two regulators. Refer to Chapter on Voltage Regulating Equipment.

4. With the Kilowatt-load divided equally between the two generators, the machine operating at the lower lagging power factor has the higher line-current ammeter reading. If the MANUAL CONTROL UNIT handle for the generator having the higher line current is turned slightly toward the LOWER position (in order to decrease excitation), the power factor of this machine will increase and the line-current ammeter reading for this machine will decrease.

5. In an extreme condition of improper MANUAL CONTROL UNIT setting, one generator may be operating at a low lagging power factor while the other generator is operating at unity power factor. Under this condition, the ammeter reading of the lagging power factor machine will be considerably higher than that of the other machine. This is due to the fact that the one generator is carrying all of the reactive-load whereas the other machine is carrying only its share of the kilowatt load.

6. When the WRN-11 voltage regulator is set for automatic control, during the power factor adjustments, the same equalization of current may be obtained. In this case it is necessary to vary from the VOLTAGE ADJUSTING UNIT INSTEAD of the MANUAL CONTROL UNIT. The regulators will continue to maintain the proper division of reactive-load by means of cross-current compensators, regardless of changes in load. Refer to Chapter on Voltage Regulator for instructions regarding the jumper required between D and C3 of the POTENTIAL UNIT terminal block for parallel operation.

SHUTTING DOWN OF A-C GENERATOR

Removing Generator From Service

When an a-c generator is operating in parallel with other generators of a system, and it is desired to remove the generator from service, the operator should reduce the load on the generator by adjusting the governor of the generator's prime mover. When all the load has been shifted to the other machines, disconnect the generator from the line. The MANUAL CONTROL UNIT handle of the regulator should then be turned to the extreme LOWER position. Turn the regulator control switch (CA) to MANUAL AND the voltage will drop to zero.

Routine Shutdown

a) The following procedure is recommended for a routine shutdown.

1. Open all line switches to isolate the machine from the external circuits.

2. Shut off the cooling water.

3. Turn on the space heaters.

4. Keep the generator warm and dry.

Extended Shutdown

a) During an extended shutdown, the following protective measures should be taken unless the generator unit can be started periodically and run for a few minutes:

1. Apply slushing compound to the shaft journals and bearing housing to prevent rusting.

2. Remove the brushes from the rings and wipe the rings with paraffin as the machine is coming to a stop with the rings still warm. Be sure that the generator has first been disconnected from the line and that the excitation has been removed before the brushes are raised.

3. Turn on the space heaters.

SECTION 4—MAINTENANCE OF GENERATOR

GENERAL MAINTENANCE

Temperature

The appearance of excessive temperature in any part of the machine is an indication of trouble. The situation should be investigated immediately and the cause of the trouble removed. Routine checks on temperature are recommended so that such conditions may be discovered before serious damage is done.

The bearing thermostat warns of excessive bearing temperature. If the alarm sounds, the oil supply should be checked. Shut down the unit if the temperature cannot be reduced immediately.

The temperature of the stator windings is determined by the resistance-coil type of temperature detectors. The temperature indicating meter which is used with the detectors acts upon the change in the resistance of the detector coils with temperature.

The temperature of the field windings is measured by the change in resistance of the field winding itself.

When the change of resistance of a copper winding is used to measure the average total temperature of the winding, the following equation can be used:

$$t_2 = \frac{R_2(234.5 + t_1)}{R_1} - 234.5$$

in which the resistance values (R) are both in the same units, and the total temperatures (t) are in degrees Centigrade. Subscript "1" refers to the known condition. Subscript "2" refers to the condition at which the resistance is known but the temperature is to be calculated. This equation is satisfactory for the range of temperatures normally obtained in electrical machines.

Possible Sources of Collector and Brush Trouble

One of the principal indications of improper brush and collector performance is sparking. The following list presents possible causes of brush and collector trouble. USE THIS INFORMATION TO PREVENT TROUBLE as well as to remedy it.

IMPROPER BRUSHHOLDER SPRING TENSION

The spring tension should be sufficient to maintain contact between the brush and the collector ring in spite of small vibrations of the brush rigging and collector rings. However, the pressure should not be such as to cause undue mechanical wear. It has been found that a brush pressure of 2-1/2 psi of brush area gives the best brush performance. This is equivalent to approximately 2 lbs. 5 oz. for this machine.

BRUSHES REQUIRING REPLACEMENT

As the brushes become shorter from wear, the springs should be tightened so as to maintain the proper brush pressure. Brushes should be replaced before they reach the limit of their travel.

UNEQUAL CURRENT DISTRIBUTION AMONG BRUSHES

Sparking may result from an unequal distribution of current among the brushes on any one ring. The spring tension should be relieved temporarily on the brush carrying the excessive current. Readjustment of the spring tension may be necessary for all the brushes on the ring to cause each brush to carry its proper share of the current.

DIRTY OR OILY COLLECTOR RINGS OR BRUSH RIGGING

Imperfect contact results when dirt, oil, or particles broken from the brush are present between the brush and the ring. Furthermore, dust between the brush and the holder may conduct sufficient current to fuse the brush to the holder.

The collector rings, brushes, and brushholders should be kept clean and free from dirt, carbon dust, and oil. A piece of canvas dipped in a grease solvent is recommended for cleaning these parts.

IMPROPER BRUSHES

Brushes of the proper grade are furnished with the machine. Other types may give unsatisfactory performance. See "Brush Rigging and Brushes", Page 204.

Brushes of the proper size must be used, If the brushes are too small, they may become wedged at an angle in the holders. If they are too large they will stick in the holders, but this can be remedied by rubbing the sides of the brush with fine sandpaper.

IMPROPER ALIGNMENT OF BRUSHHOLDERS

The alignment of the brushes on the ring should be checked occasionally to be sure that a brush does not overhang the edge of the ring. If the brush is allowed to overhang, the overhanging part develops a thin edge which chips and breaks off.

VIBRATION OF THE BRUSH RIGGING

Any loose parts of the brush rigging should be tightened.

UNBALANCE IN THE ROTOR OR ECCENTRICITY OF THE COLLECTOR RINGS

Either of these conditions can cause the brushes to leave the rings and draw an arc once every revolution. This repeated arcing at the same place on the ring in time burns the imprint of the brush on the ring.

The truth of the rings can be checked with a dial indicator on the back of a brush while the unit is running at low speed. If the rings are eccentric on the shaft, they should be turned, or ground, and polished. These operations must be done when the rotor is turning, for if they are done at standstill or by hand,the eccentricity of the rings may actually be increased.

ROUGH OR MARKED RINGS

Any black spots that appear on the surface of the collector should be removed by polishing lightly with fine sandpaper. It is very important that this be done; for while these spots are not serious in themselves, they will lead to pitting of the rings and the necessity for regrinding. However, no harm is done to the rings if the condition is corrected at once. If the rings are very rough, they should be ground and polished with the rotor turning. This should not be done at standstill or by hand, for under these circumstances, the rings may be made eccentric and uneven.

CORRODED RINGS

Brush imprints may be burned on the surface of the rings as a result of causes other than unbalance and eccentricity. This burning also occurs when the rings have been left unprotected during an extended shutdown. This usually occurs on a machine which is subjected to corrosive fumes. When the machine is shut down, the fumes act upon the surface of the rings except where they are covered by the brushes. The difference in surface caused by this action produces a slight burning as the rings rotate after the machine has been returned to service. Brush imprints due to corrosive fumes can appear at any point on the rings, depending upon the position in which the rotor happens to stop. Refer to the instructions on "Routine Shutdown" for protective measures.

Corroded rings may require grinding and should always be polished before being returned to service.

UNEVEN HARDNESS OF RING

If a ring is not of uniform hardness around the periphery, uneven wear results, and the performance becomes unsatisfactory.

ELECTROLYTIC ACTION

Because there is an electrolytic action at the surface of the rings, their performance is improved by reversing their polarity occasionally. In some cases, it has been found useful to do this as often as once a week.

UNUSUAL OPERATING CONDITIONS

Excessive current densities due to overloads.

The mechanical contact between the brush and the ring is never absolutely perfect, and high current density at the contact surface ca cause sparking with brush fits that would b sufficiently accurate for normal densities.

Extended operation with a low value of brush current.

Brush "chatter", accompanied by sparking, has been found to result from this practice, as when machines are run without load in a standby capacity.

CORRECTIVE MAINTENANCE

Insulation Resistance

GENERAL

The insulation resistance of a winding is the resistance of the insulation to a d-c voltage tending to produce leakage current through the insulation and over its creepage surfaces. Although it is not a measure of the dielectric strength of the insulation, the insulation resistance indicates whether the machine is in a suitable condition for operation or for high-potential tests.

Insulation resistance is affected by a number of conditions, and often an apparent inconsistency in a group of readings can be attributed to variations in one or more of the test conditions which have been incorrectly assumed constant.

The actual insulation resistance is lowered by the following conditions:

1. Aging of the insulation.

2. Mechanical damage to the insulation.

3. Presence of dirt in the machine.

4. Increased moisture content of the insulation.

5. Increased temperature of the insulation. (The effect of temperature on insulation resistance is great, the resistance at 25°C, being six to fourteen times that at 75°C, depending upon the type of machine.)

Measurements of insulation resistance are lowered by the following factors:

1. Increased magnitude of the test voltage used. (Variations of test voltage as small as two or three to one make no appreciable difference).

2. Increased time of application of test voltage.

SIGNIFICANCE OF TESTS

Insulation resistance varies widely among machines of different sizes and voltages. Therefore, measurements of this quantity are useful chiefly for comparison with those made at other times on the same machine. MONTHLY TESTS OF INSULATION RESISTANCE are recommended for detecting changes in the insulation material or creepage surfaces. In order for these tests to be correlated properly, each test should be made under the same conditions.

A trend toward lower insulation resistance is a warning that failure of the insulation is possible. For this reason, the readings obtained at any particular time should be compared with the previous readings in order to be of maximum significance.

The behavior of insulation resistance while the windings of a machine are being dried out is discussed in the section on "Drying Out Windings".

CONDITIONS FOR TESTS

In order for all the tests to be made under approximately equal conditions of temperature and moisture, it is suggested that the insulation resistance be measured immediately after shutdown while the machine is still hot. It is preferable to use the same method and the same circuit for all tests. In any case, the records of insulation resistance will be more valuable for future reference if the conditions of temperature, moisture, etc., and the test circuit and voltage are noted along with the insulation resistance.

METHOD OF TEST

The insulation resistance of a winding may be measured by using either an instrument called a megger or a d-c test circuit. In either case, one connection is made to the frame (for stator windings) or to the shaft (for rotor windings), and the other connection is made to a common terminal to which all leads of the winding in question are attached.

When the d-c circuit is used, readings are taken with a high-resistance d-c voltmeter, first with the meter connected directly across a 500 or 600 volt d-c power supply, and next with the unknown insulation resistance in series with the meter and power supply. A recommended test consists of 500 volts d-c applied for 60 seconds. Refer to Figure G-8.

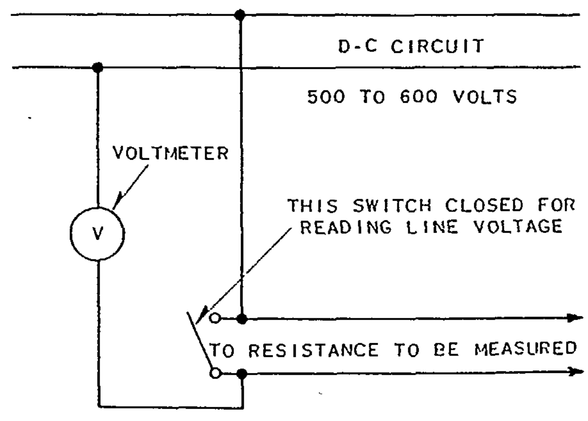


FIG. G-8 — Diagram of Connections for Measuring Insulation Resistance

The insulation resistance may be calculated from the following formula when the d-c test circuit has been used:

$$R = \frac{R' \ (E-E')}{1{,}000{,}000 \ E'}, \text{ where}$$

R = Insulation resistance in megohms.

R' = Resistance of voltmeter in ohms.

E = Voltage of d-c power supply.

E' = Voltage read on meter when insulation resistance is in series with the voltmeter.

If the readings of insulation resistance are low, the leads should be disconnected and the measurement repeated separately on the winding and on the leads in order to determine whether the trouble is in the winding or in the leads.

MINIMUM ACCEPTABLE VALUES FOR NEW MACHINES

For values of insulation resistance below which the machine is unsafe for operation, refer to chapter 60, Bureau of Ships Manual.

Annual Inspection

It is recommended that after one year of operation, and once a year thereafter, the generator be thoroughly inspected.

Remove the end bells and the bearings.

Examine the stator core and armature coils for loose wedges, coils, or coil bracing or any other unusual condition. Check the appearance of the coil insulation.

Check the rotor for loose damper bars and loose connections. Check the condition of the turn-to-turn insulation of the field coils and the condition of the ground insulation between the coil and the pole. Be sure that the lower coil supports press the field coils firmly against the upper coil supports. If a field coil is not tight, loosen the lower coil support, push the coil and lower coil support tightly against the pole head and upper coil support, and secure the lower coil support tightly in position. This procedure is done most successfully when the coil in question is located at the bottom of the machine where the weight of the coil can rest upon the head of the pole.

Inspect the collector rings, being sure that they are tight. If the rings are rough, marked, or corroded, polish them as described in the section on "Possible Sources of Collector And Brush Troubles".

Inspect the bearings and smooth out any rough places in the babbitt.

Bring to the attention of a Westinghouse Service representative any condition which cannot be repaired by the maintenance crew.

Clean the generator thoroughly, and clean the air cooler if necessary. These procedures are covered in separate sections.

Cleaning Generator

At the annual shutdown period, the generator should be cleaned. It is advisable to remove the dirt from all accessible parts of the generator, but particularly from the windings, collector, brush rigging, ventilating spaces, and parts adjacent to the electrical windings and connections. Follow the procedures outlined in Chapter 60, Section IV, of the Bureau of Ships Manual.

Ordering Renewal Parts

When ordering renewal parts, give the name of the parts, the drawing and item numbers which apply, and the nameplate reading of the machine, including the serial number. The stator serial number will be found stamped on the nameplate and on the metal under the nameplate. The rotor serial is stamped on the end of the shaft.

Communications

Should communication be desirable or necessary regarding the installation covered by this instruction book, or an individual device included in the installation, replies will be greatly facilitated by citing the General Order (G.O.) number for the complete equipment and the nameplate readings of the detail apparatus involved.

Do not fail to give the stator and/or rotor serial number and the COMPLETE nameplate reading when the information is desired for rotating machines. The stator serial number is stamped on the machine nameplate and the metal under the nameplate and on the machine foot. The rotor serial number is stamped on the end of the shaft.

Should any particular information be desired, please be very careful to state clearly and fully the question for consideration, and the associated conditions.

Communications should be addressed to the nearest Westinghouse Electric Corporation Sales Office. Local sales, engineering or service representatives are usually available for quick consultation.

DISMANTLING THE GENERATOR

Step I. To Remove Rototrol-Exciter Stator and Rotor

See the detailed instructions in the chapter on the Rototrol Exciter.

1. Remove covers from front bracket and raise brushes from the commutator. Remove rear end bell and drip cover.

2. Disconnect all external leads to the exciter stator. Tag leads to facilitate correct replacement.

3. Check air gaps under each pole of exciter carefully and record. Very careful setting of the exciter air gap is necessary for proper operation, and records of the air gap will be very helpful for realignment.

4. Remove the four fitted holding-down bolts from the exciter feet, and slide the exciter stator out axially. Lift the exciter stator by lifting eye at top of frame. The weight of the exciter stator is approximately 1800 pounds. Keep all shims in place to reduce work of realignment.

5. Remove 1"-8 bolt in end of shaft holding exciter rotor. Thread 1-1/2"-6 pulling-off bolt furnished with shipboard spares into the tapped hole provided in the exciter quill nut, and pull off the exciter rotor by tightening this bolt against the end of the shaft. When quill is free from fit on the shaft, place a sling around the body of the rotor and slide off the shaft taking care not to damage the exciter coils or commutator by bumping. The weight of the exciter rotor is approximately 515 pounds.

Step II. To Remove Bearing and Pedestal (Fig. G-9)

1. Remove front outer cover, Item 26, Fig. G-9, from end bell. Shut off oil supply line and disconnect it from pedestal. Drain oil from drain line and disconnect it from pedestal.

2. Unbolt top half of bearing seals, Item 44, Fig. G-9, from bearing cap. Remove the seal closest to the exciter.

3. Unbolt bearing cap, Item 36, Fig. G-9, from pedestal and remove. The bearing cap weighs approximately 50 lbs. Unbolt top bearing seal half nearest to collector from bottom seal half and remove.

4. Lift brushes from collector rings. Disconnect leads at brush holders. Unbolt semicircular piece which holds the brush holder studs, items 52, Fig. G-9, from pedestal and remove brush rigging without disassembly.

5. Lift off top half of bearing, Item 39, Fig. G-9.

6. Remove bulb of bearing alarm contact maker, Item 37, Fig. G-9, from bearing, Item 40, Fig. G-9. Disconnect leads and conduit.

7. Remove rear air seal, Item 88 and rear outer cover, Item 31, Fig. G-9. Remove rear air shield, Item 30, Fig. G-9. Do not damage stator coils by bumping. Place a sheet of steel or fibre board approximately 1/16" thick in lower part of air gap to protect stator punchings when rotor is rested in the stator bore.

8. Disconnect coupling bolts at speed reduction gear. Note or apply match marks on coupling halves before disassembling.

9. Relieve weight of rotor on bearing by lifting slightly with a jack under the shaft placed near the pedestal, and roll lower half of bearing, Item 40, out of pedestal.

10. Disengage pilot fit of shaft at speed reduction gear, and allow rotor to rest on shim in bore of stator.

11. Slide pedestal, Item 35, out axially. The pedestal without cap or bearing seals weighs approximately 220 pounds.

Step III. To Remove Enclosing Covers and Cooler (Fig. G-9)

1. Disconnect leads and conduit at field lead box on front end cover. Free leads from cleat. Remove front end cover, Item 27, Fig. G-9.

2. Remove front air shield, Item 25, Fig. G-9. Do not damage stator coil end turns by bumping.

3. Remove cooler housing, Item 33, Fig. G-9, in sections.

4. Drain water from cooler, Item 34, Fig. G-9, by opening lower (.540 outside diameter) drain.

5. Disconnect piping and remove bolts holding cooler to generator frame.

6. Remove cooler from generator frame, taking care not to spill any water left in the cooler into the machine. The weight of the cooler is approximately 750 pounds.

7. Remove front end cover, Item 27, Fig. G-9, and front air shield, Item 25, Fig. G-9.

Step IV. To Remove Rotor (Fig. G-9)

1. Disconnect main leads, air-temperature alarm contact maker leads, space-heater leads, and temperature detector leads, and free conduit attachments to frame. Tag all leads to facilitate easy replacement.

2. Remove air-temperature alarm contact-maker, Item 92, Fig. G-9, from frame to prevent its being damaged when moving the stator.

3. Remove the four fitted bolts in each generator frame foot.

4. Lift the stator and rotor together, blocking up and skewing stator on prime mover sub-base, so that a jack shaft can be assembled on the generator coupling flange. Keep shims under the frame feet in place to make re-assembly easier.

5. Assemble a jack shaft on the generator coupling flange. Place a sling on both ends of the shaft, and slide rotor out until centerline of rotor clears the stator frame.

6. Block both ends of the shaft to support rotor and release slings.

7. Place sling around center of rotor body and move straight out or by skewing. Great care should be used to prevent damage to the stator coil end turns by bumping.

Step V. To Remove Stator (Fig. G-9)

1. With hooks placed in the four lifting holes at the sides of the frame, exposed by removing covers, Item 2, Fig. G-9, lift the stator from the prime mover sub-base.

REASSEMBLING GENERATOR AND ROTOTROL-EXCITER

Step I. To Re-assemble Stator and Rotor (Fig. G-9)

1. Place the generator stator on the prime mover sub base in an elevated skewed position so that the rotor can be handled with its jack shaft in place.

2. Place a sheet of steel on fibre board approximately 1/16" thick in lower part of stator bore to protect stator punchings. Place slings around the center of the rotor and insert rotor into stator as far as possible and rest on blocking. Do not bump stator coil end turns.

3. Place a sling on both ends of the shaft and slide rotor into stator bore and rest on shim in bottom of stator bore. Remove temporary jack shaft.

4. Lower end straighten stator and rotor together on the prime-mover sub-base, placing shims from previous alignment under feet.

5. Replace air-temperature alarm contact-maker, Item 92, Fig. G-9, on frame.

6. Replace cooler, Item 34, Fig. G-9, on frame, and connect water and drain piping.

7. Connect main leads, air-temperature alarm contact-maker leads, space heater leads, and temperature-detector leads. Replace conduit and fittings associated with this wiring.

Step II. To Replace Pedestal and Bearing and Couple to Speed Reduction Gear (Fig. G-9)

1. Place pedestal, Item 35, Fig. G-9, in position on the sub-base with liners under feet from previous alignment.

2. Raise rotor on blocking, and roll lower half of bearing, Item 40, Fig. G-9, into place, applying a layer of oil to the babbitt surface of the bearing. The bearing and journal must be free from grit and dirt.

3. Align the equipment as described under Installation and Erection, Page 206, and in the manual for prime mover. Place all coupling bolts in position, tighten and secure. Replace holding-down bolts in frame and pedestal feet.

4. Replace bulb of bearing-alarm contact maker, Item 37.

5. Replace top bearing half, Item 39, Fig. G-9. Replace bearing cap, Item 36, Fig. G-9.

6. Replace oil seal rings, Items 44 and 45, Fig. G-9 on the pedestal, checking clearance to shaft with a feeler gauge to make sure it is uniform around the circumference.

7. Replace oil supply and drain lines, taking every possible care to avoid introduction of dirt into the oiling system.

8. Assemble brush rigging, Items 50 to 54, Fig. G-9, on pedestal and adjust brush holders and fit of brushes on ring as described on Page 208.

Step III. To Replace End Bells and Enclosing Covers (Fig. G-9)

1. Assemble rear airshield, Item 30, Fig. G-9.

2. Assemble rear outer cover, Item 31, and adjust air seal, Item 88, for equal clearance at shaft flange by means of a feeler gauge.

3. Assemble front airshield, Item 25, Fig. G-9.

4. Connect brush holder leads.

5. Assemble front end cover, Item 27, Fig. G-9, bringing brush holder leads out through opening to conduit box. Tighten brush holder leads in conduit box.

6. Assemble front outer cover, Item 26, Fig. G-9.

7. Assemble cooler housing, Item 33.

Step IV. To Replace Exciter Stator and Rotor (Fig. G-9)

1. Coat the fits on the exciter shaft with white lead in oil. Place a sling around the body of the exciter rotor and slide on shaft as far as possible. Thread the 1" eight-holding-on bolt into the threaded hole in the end of the shaft, with the plain washer under the head of the bolt, and draw the rotor into the proper position by tightening this bolt. Remove bolt, place plain and lock washers in position and tighten the bolt in place. Do not damage coils or commutator by bumping.

2. Lift the exciter stator into position, first making sure that all brushes are in the raised position.

3. Connect all external leads to the exciter stator. Connect the two field lead jumpers from the generator after the air gap or the exciter has been set electrically as described in the Rototrol exciter instructions. Install conduit associated with this wiring.

4. Lower brushes on commutator and adjust brush holders; check brush tension and fit of brushes on commutator.

5. Set air-gap of exciter as close as possible to the previous alignment (not necessarily equal). Check electrical operation of the exciter and tuning of the exciter as directed in the instructions for the Rototrol exciter, before inserting the fitted holding down bolts and securing the exciter stator to the engine sub base permanently.

6. Replace covers and end bells on exciter, both front and rear.

REMOVAL AND REPLACEMENT OF GENERATOR COILS

Removal of Stator Coils
(Figs. G-12, G-10 and G-9)

1. Remove generator end bells and rotor to obtain access to the stator coils.

2. Remove insulation at coil-lead connections.

3. Remove twine with which coils are lashed to the brace rings, and the twine binding the spacers between the end turns.

4. Using brazing tongs, disconnect coil leads from each other and from wiring-around-frame.

5. Drive out the stator-slot wedges, Item 101, Fig. G-9.

6. Raise the top-layer coil sides of nine coils and tie in the raised position.

7. Remove the stator coils from the slots, starting with the coil adjacent to the raised coil sides.

8. File the wiring around frame connections clean.

9. Clean any excess varnish from stator slots by scraping.

Replacement of Stator Coils
(Figs. G-12, G-10 and G-9)

1. Before rewinding, check spare coils for possible damage in storage, also, check the coils disturbed in the machine, by visual inspection, and check the insulation resistance with a 500 volt hand megger.

2. Place the coils in the slots with the leads toward the connection end. Place temperature detectors in slots between the coil sides as shown on Fig. G-10 and place glass malamine

strips in remainder of the slots. The coils must fit tightly in the slots. If necessary, drive strips of mica at the sides of the coils to tighten them width-wise in the slots, and use filler underneath the wedges to tighten the coils depth-wise in the slot. Note that the connections between the groups of coils are made with the coil ends. Therefore, care should be used when replacing coils, that coils with long leads are placed at the ends of groups of 4 coils, to avoid the necessity of patching in pieces of copper. The coils must be centered in the slot, with an equal amount of straight portion extending beyond the core at each end. All coils are to be drifted into the slots as carefully as possible by placing a board over the entire length of the coil. Light blows from a mallet are to be distributed over the length of the board in such a manner as to force the coils in evenly.

3. The coils must be lashed to each other with the spacers, Item 17, Fig. G-9, between them, and to the support ring, Item 13, Fig. G-9 as they are placed in the slots. That is, when the second bottom coil side is placed in the slot, the end turns are lashed immediately, and each succeeding coil is lashed as it is put in. Lashing is done with glass twine, Westinghouse No. 8211-2, Navy Spec. 17-I-31.

4. To complete the winding, the top-layer coil sides of the first throw of coils should be tied in the raised position with twine. When all bottom-layer coil sides and the strips between coils are in place, remove the twine and force the top layer coil sides of the first throw of coils into the slots.

5. Drive the stator slot wedges, Item 101, Fig. G-9, into the wedge grooves. Care must be taken not to damage the coils when driving the wedge. Use filler strips of insulating material to make coils tight in slots if necessary.

6. Wire the coil ends together temporarily by wrapping with light, bare-copper wire and check the insulation resistance with a 500 volt hand megger. Remove all of the temporary connection wire.

7. Cut and bend coil leads to form coil groups per tabulation of Fig. G-10, and to connect groups per schematic wiring diagram, Fig. G-10. Assemble lead connections, braze connections and apply insulation per Fig. No. 4 of Fig. G-12.

8. After the stator is wound, preheat 5 to 10 hours at 130°C. Cool to 60°C. Dip the stator in varnish Westinghouse No. 2227, Navy Spec JAN-V-1137, Type M grade BB at a temperature of 30°C and viscosity of 20 to 55 seconds, Saybolt. Soak 10 to 20 minutes or until bubbling ceases. Drain 30 minutes and bake 15 hours at 130°C.

9. Cool stator to 60°C and repeat the treatment given in paragraph 8 above to give a total of two dip and bake treatments. (When stator cannot be dipped, apply varnish with hose and pump. Continue flow until windings are saturated. Drain as above. Be sure to ground metal nozzle of hose.)

10. Make insulation resistance check with 500 volt hand megger.

Removal of Rotor Coils (Fig. G-9)

1. Remove generator rotor from stator to obtain access to the field coils. Remove exciter rotor.

2. Unbolt and remove the blowers, Item 63, Fig. G-9.

3. Unbolt and remove the coil braces, Items 81 and 82, Fig. G-9.

4. Heat joints between field coils to soften solder, remove bolts and disconnect. Also disconnect collector leads.

5. Remove locking screws, Item 87, Fig. G-9 from the collector bushing and pull collector from shaft by pulling on bushing, Item 84, Fig. G-9. Do not pull on rings, Item 83, Fig. G-9. Do not damage collector by bumping the rings.

6. Drive out dovetail keys, Item 62, Fig. G-9. Note that the dovetail key assembly consists of three pieces; a thick, drive-out tapered wedge; a thinner, drive-in tapered wedge; and a thin shim placed between the drive-out key and the punchings of the spider. To drive the keys out, strike the thin end of the thick, drive-out key sharply.

7. Remove poles and coils from the spider, and remove coils, coil washers, and wedge washers from the poles. See Items 64 to 78, Fig. G-9.

Replacement of Rotor Coils (Fig. G-9)

1. Assemble top washers, field coils with insulating cell, and bottom washers on the poles with leads located on the collector end. For diagram of leads on open and crossed coils and of assembly of open and crossed coils on the machine, See Fig. G-10. The poles and coils should be weighed at the time of assembly and distributed around the rotor so that it will be

as well balanced as possible. The coils must fit tightly on the poles. Use mica or glass melamine sheet material at sides and ends of coil to make the coil fit snugly on the pole if necessary. Center the poles and wedge washers with the center of the spider. Coat the dovetail keys with white lead and oil. Place the dovetail keys in the dovetail slot, with the thin shim next to the spider punchings, the thick drive-out key next, and the thin drive-in key next to the pole punchings. Drive the thin drive-in key tight, pounding pole down tight on spider. Do not cut off keys until after rotor is run and the keys are re-driven.

2. Coat collector fit on shaft with white lead and oil. Heat collector to 185°C (do not overheat), place the collector in position on the shaft, and cool with an air blast.

3. Tin field coil connections, connect the coils, insert bolts in connections, and solder connections, covering bolt head and nut with solder. Replace connections to collector and solder the connections at field coil.

4. Measure the resistance of the rotor winding and check the insulation resistance with a hand megger. Also, pass a small amount of direct current through the field winding and check the polarity of the field poles with a compass or with a nail supported at the center by a string. Poles must be alternately of north and south polarity.

5. Assemble the coil braces, Items 81 and 82, Fig. G-9 and lock the bolts securely by bending up corners of locking plate.

6. Run the rotor at 1380 RPM, bringing the speed up gradually, and noting the vibration. Make temporary balance corrections if necessary to run without dangerous vibration at 1380 RPM. Drive the dovetail keys tight and cut them off at the spider.

7. Assemble the blowers, Item 63, Fig. G-9, pressing them up under the field coils as tightly as possible.

8. Preheat the assembled rotor 5 to 10 hours at 130°C. Cool to 60°C. Dip the rotor in varnish-Westinghouse P.D.S. #2370, Navy Spec. JAN-V-1137 type M, grade CB at 30°C and viscosity of 20 to 55 seconds, Saybolt. Soak 10 to 20 minutes or until bubbling ceases. Drain 30 minutes and bake 15 hours at 130°C.

9. Cool rotor to 60°C and repeat the treatment described in paragraph 8 above three times to give a total of four dip and bake treatments. (When the rotor cannot be dipped, apply varnish with hose and pump. Continue flow until windings are saturated. Drain as above. Be sure to ground metal nozzle of hose.)

10. Install rotor and check mechanical balance at rated speed. Attach balance weights under heads of bolts holding blowers to spider.

EMERGENCY REPAIR MEASURES

Rebabbitting Bearings

In case it is necessary to rebabbitt an old bearing on a ship, it is necessary to melt out the old babbitt and prepare a suitable mandrel. Since the bearing is split, each half should be babbitted individually. The mandrel should consist of a half cylinder with shoulders running along its length so that the sides of the bearing may rest on them and form a close fit. Pieces of felt should be placed around the ends of the bearing shell to prevent the babbitt from running out at the ends. Remove bearing insulation and replace after bearing is rebabbitted.

Only a good tin-base babbitt such as Navy Spec. No. 46M2, Grade 2, or an approved lead-base babbitt (Westinghouse Alloy No. 25) should be used for such work. The melted babbitt should be poured into the gate until it begins to overflow. Sufficient time should elapse after the pouring and before the mandrel is removed from the bearing to allow the babbitt to harden.

The bearing should then be bored or reamed to the proper size. Holes for the introduction and draining of oil from the bearing should be drilled and the proper machining done to provide grooves at the splits and eccentric chambers for the oil in the center of the bearing. The finishing operations may be done with a suitable scraper.

Repair of Air Cooler

"Approximately 5% of the tubes may be blocked off and the generator air cooler will still operate efficiently. Thus a leaking tube may be blocked off by inserting plugs into each end".

These plugs are furnished with the spare parts - See list of Certification Data Sheets 47-A-6351, Fig. G-13.

SECTION 5—GENERATOR AIR COOLER

INSTALLATION OF AIR COOLER
HARRISON RADIATOR DWG. H-99006
BUSHIPS DWG. NO. S6101-H-3159718

Flanged connections are provided on the inlet and outlet cover for connection to the sea water line. Either connection may be used as the water inlet.

Strainers or filters, if used to exclude foreign matter or solids must be installed on the inlet side. The cooling water must be free of foreign matter larger than .250 inch screen openings. Strainers or filters are essential if liquids circulated through the cooler may contain foreign matter larger than specified.

Utilize the vent and drain connections on the inlet and outlet cover in conformity with applicable shipbuilder plans. The lower .405 outside diameter "tell tale" tube connection must serve as an open drain warning of tube leakage. The drain line from this connection should be piped to an openly visible funnel and then to a sump. The upper .405 outside diameter tube should be left open to serve as a vent for the double tube leakage detection system. Handle the .540" tube connections as conventional vents and drains. Care must be used to install the piping in such a way that the cooler will be full of water at all times during operation. The cooler will not operate properly if all of the tubes do not contain flowing water.

OPERATION OF AIR COOLER

Open the water valves to give the rated flow (at 85°F) 60 gallons of water per minute. No other operating instructions are necessary.

MAINTENANCE OF AIR COOLER

Clean strainers in sea-water inlet line as frequently as required to provide unrestricted flow.

The inside of the tubes should be cleaned as frequently as necessary to provide unrestricted flow of seal water. The unit should be inspected at long intervals to see if the fins on the outside of the tubes require cleanings from deposits of oil and grease from leaky bearings or carbon from brush wear.

Coolers are provided with zinc electrodes to centralize electrolysis. The electrodes should be examined 30 days after installation, and checked 30 days thereafter.

CLEANING OF AIR COOLER

Step I. Close valves in pipe connections to and from cooler; disconnect air ducts, drain water, and remove the unit from the piping.

Step II. Disconnect inlet and rear covers to expose inside of tubes.

Step III. Clean inside of tubes by use of air or water lance. A rubber plug may be pushed through if needed. Never use a metal plug, brush or rod end which might scratch the tube wall.

Step IV. Clean outside of tubes by use of steam jet, drying with compressed air.

Step V. Clean any foreign matter from inside of inlet and rear covers.

Step VI. Reassemble, using new gaskets when necessary.

Step VII. Reassemble on generator, replace piping, and air housing, and place cooler in operation as described above under Operation of Air Cooler.

CHAPTER 3—D-C ROTOTROL EXCITER

TABLE OF CONTENTS

CHAPTER 3
D-C ROTOTROL EXCITER

GENERAL DATA

1. IDENTIFICATION

Submitted by: Westinghouse Electric Corp.
Application: Ship's Service. Pilot Exciter for AC Generator
Initial Navy Contract: NOBS 61436
Westinghouse G.O. WG-70070 - I.B. S.O. 49-P-593 for Roto Exciter S.O. 49-P-587

2. REFERENCED SPECIFICATIONS

The Rototrol described hereunder will confrom strictly with Navy Dept. Specifications MIL-G-3111 (Ships) dated 30 Dec., 1949, unless exceptions are specifically enumerated on the Master Plan Drawing.

3. REFERENCE DRAWING

The following plans show the various construction details which cannot be suitably covered in these manufacturer's specifications:

Title of Drawing	Manufacturer's Number	Bureau Number
Master Plan	1-JH-1815	S6101-H-3198187
Certification Data	CD-4546	S6101-1456363

4. ROTOTROL RATING

Kilowatts	- 10	Duty - Continuous
Volts	- 69.4	Temperature Rise $60^{o}C$
Amperes	- 144	Overload Rating - 125% for 5 Seconds
RPM	- 1200	

5. EXCITER CLASSIFICATION

Prime Mover - Overhung on AC Generator Shaft
Degree of Enclosure - Drip-Proof - Protected
Class of Insulation - Class B
Method of Cooling - Self Ventilated

Service Application - Ship's Service
Ambient Temperature of Reference - $50^{o}C$
Type of Winding - Special
Speed Class - Constant

Manufacturer's Type and Class - Frame 123.11E Type SK
Service - Navy Service A
Shockproofness - Hi Shock

6. TEST DATA

For test data see master plan Drawing 1-JH-1815.

7. WEIGHTS (CALCULATED)

Rototrol Exciter (Complete) - 2550 lbs.
Spare Armature (Complete) - 650 lbs.
Field Coils, Each (Approximate)
Shunt - 25 lbs. Commutating - 15 lbs.

8. EFFICIENCY (GUARANTEED)

Included as part of Generator efficiency.

SECTION 1—INTRODUCTION

The Rototrol is quill type with laminated frame and is overhung on the AC generator shaft with the frame rigidly mounted on the engine bedplate.

The Rototrol is equipped with dripproof covers and all openings are covered with No. 4 mesh screen for suppression of radio noise.

The design of the front bracket cover is such as to provide ready access to all brushes and brushholders, making adjustment or replacement of the brushes easy.

The entire construction of the generator is such as to provide a compact and rugged unit combined with maximum accessibility for service and maintenance.

SECTION 2—DETAILED DESCRIPTION

MAGNET FRAME

The frame is made of laminated sheet steel held together by heavy steel plates on each end welded to a steel plate which completely encircles the laminations.

FRONT BRACKET (COMMUTATOR END)

The front bracket or rocker ring is made of steel. It mounts on the commutator end of the frame and provides the mounting for the brushholders and rods. A canopy is provided which completely covers the brush rig and makes it dripproof. The bottom openings are covered with No. 4 mesh screen for radio noise suppression.

MAIN POLE

The four main poles are made of laminated steel punchings securely held together by rivets. Two bolts are used to fasten the pole piece to the frame. The air gap is detailed on the Master Plan Drawing.

COMMUTATING POLE

The four commutating poles are made of laminated steel punchings securely held together by rivets. Two bolts are used to fasten the poles to the frame. The commutating pole air gap is detailed on the Master Plan Drawing.

MAIN FIELD WINDING, "X" and "Y" AXIS

See Master Plan Drawing for conductor, turns per coil, wire space and lead data. Coils are wound in a shell consisting of a 1/16 inch thick glass melamine tube with 1/8 inch thick glass melamine end washers. L-shaped pieces of .010 inch glass and mica are placed along sides of coil to protect it from frame and pole tips. The coil is taped with a half-lapped layer of .007 inch glass tape and then impregnated by vacuum-and-pressure method with Westinghouse No. 8826-4 varnish. It is then given two dipping and baking treatments with Westinghouse No. 8826-4 varnish. The center block or mould is 4-3/8 inches wide by 11-1/2 inches long with 1/8 inch radii at the corners.

COMMUTATING FIELD WINDINGS

See Master Plan Drawing for conductor, turns per coil, wire space and lead data. Coils are wound in a shell consisting of a 1/16 inch thick glass melamine tube with 1/8 inch thick glass melamine washers. The finished coil is dipped and baked the same as for main field coils. The center block is 6-15/16 inches long by 1-9/32 inches wide with 25/32 inch radii at the corners.

ARMATURE CORE

The armature core consists of circular laminations of silicon steel with steel end plates on each end, all riveted together with the slots skewed 15/16 inch in a counter-clockwise direction from the commutator end. The keyway is then cut and the assembly pressed on the quill. The core length is 10-3/4 inches, and the diameter is 13 inches. There are 49 slots.

ARMATURE WINDING

See Master Plan for details.

COMMUTATOR

The commutator is of the V-ring bound type. The bars are of hard drawn copper with a slotted neck portion for receiving the armature coil ends. The bars are held between steel V-ring insulated with formed 1/16 inch mica V-plates. The 147 copper bars are insulated from each other by .025 inch thick mica plates and the mica is undercut 3/64 of an inch. A commutator ring nut located on the threaded front end of the commutator bushing is used to secure the front V-ring in place.

The armature conductors are soldered into the slotted commutator bar necks.

BRUSH RIGGING

The brush rigging is supported on a steel rocker ring which is bolted in place to the frame. The rocker ring carries four round brushholder rods which carry the brushholders.

The rocker ring can be shifted in position. This has been determined at the factory and is doweled in place.

There are eight brass radial type brushholders, two on each rod. The brushholders clamp tightly to the rod by means of clamping screws. Each brushholder has two fingers which press down against the top of the brush in its holder. The pressure at which this finger presses down on the brush is adjusted by the position of the spring which can be placed in one of several notches on the brushholder body. The pressure applied by the finger should be 2 to 2-1/2 pounds per square inch measured parallel to the direction of brush travel in the holder.

BRUSHES

Brushes are 3/8 inch by 3/4 inch by 1-1/2 inches long, grade SA-35, which meet the requirements of Navy Specification 17-B-8, Grade A. These carbon brushes are manufactured by the National Carbon Company for Westinghouse Electric Corporation. The brushes are supplied with flexible copper shunts to carry the current from the brush to its holder. The terminal clip is of a special design to prevent the brushes being thrown out of its holder during shock.

SHUNT FIELD TUNING AND CONTROL FIELD RESISTORS

Mounted on either side of frame, directly above feet, are three shunt field tuning resistors and one control field resistor (see Master Plan Drawing for exact location and connections). These are HI-shock test resistors bought from the Ward Leonard Electric Company. The three shunt field turning resistors are 150 ohms, 75 watts, with taps and are connected at installation in whatever series parallel combination is necessary in order to tune Rototrol with the generator field. The control field resistor is 400 ohms, 75 watts, adjustable, with a slider, and is adjusted at installation in conjunction with regulator.

ROTATION

1. The rotation of the Rototrol exciter is clockwise as viewed from the commutator end.

COMMUTATION

1. In a d-c machine it is necessary that the current in the armature coil reverse from a maximum in one direction to a maximum in the opposite direction, each time the commutator bar to which the coil is connected passes under a brush. If this reversal of current is not accomplished before the commutator bar emerges from under the brush there may be sparking and damage to the brushes and commutator. In order that this reversal of current may be accomplished during the period the commutator bar is under the brush, interpoles are added to help the current in the armature coil reverse by producing a flux that generates a voltage in the coil being commutated to aid this reversal of current. In a normal generator the load current flows through the commutating coil and produces a flux proportional to the current being commutated.

2. It is necessary to the normal operation of the Rototrol exciter for the current distribution in two brush arms of the same polarity to be varied by means of a current flowing in the control field (F1-F2).

3. As the current distribution in the brush arms is varied the armature coil currents will likewise vary. If only one interpole coil per pole were used the flux from the interpole would not vary correctly with the armature current. In order to obtain a commutating pole flux that varies with the current in each brush arm, four commutating coils are used on each interpole. One coil on each pole is arranged in series with each brush arm and the combined effect gives the required compensating flux for good commutation. Refer to the wiring-around-frame drawing on Master Plan for the proper connections.

SPARES

See CD4546 sheet 2.

SECTION 3—INSTALLATION INSTRUCTIONS

INSTALLATION OF D-C ROTOTROL EXCITER

Unpacking

When unpacking, be sure and protect any exposed windings from damage. Coil insulation is easily damaged. Never pry against a winding, nor strike it a blow with a hammer. Do not allow sharp instruments to come in contact with the coils. Avoid damage to the shaft.

Inspection

As soon as the machine is unpacked, give it a thorough inspection. Look especially for any loose field connections, bolts, covers, broken brushes, or brushholders, and any noticeable damage to coil insulation. Repair immediately any damage found. If the machine has been in storage some time, or has been exposed to dampness, the insulation resistance should be checked. (See instructions under "Maintenance"-Insulation.)

Handling

Electrical equipment is easily damaged when dismantled. If the machine is dismantled and the windings are exposed, care is necessary to protect these windings from damage. In handling the armature, do not allow the commutator or coil ends to be bumped as this will damage them. Support the armature by rope slings about the shaft. Use a spreader to keep the ropes from pressing against the coil ends or commutator. Never support the armature by pressure on the coil ends or on the commutator, either when using a rope sling or when resting on blocks. Never use any sharp instrument or any coils, as the insulation can easily be punctured.

Connections

Connect the Rototrol exciter in accordance with the diagrams supplied with the regulating equipment and Master Plan Drawing.

SECTION 4—OPERATING INSTRUCTIONS

OPERATION OF D-C ROTOTROL EXCITER

Before Starting

Check to see that all connections are made and all joints are tight. Examine the brushes and brushholders. The brushes should be free to slide in the holders and should be bearing against the surface of the commutator. If any broken brushes are found, they should be replaced. (See instructions under "Maintenance"-Brushes.) The holders should provide approximately 2-1/2 p.s.i. pressure and should be located 1/16" to 1/8" from commutator surface.

If brush rig has been disturbed during installation, it should be returned to the correct position as set at the factory and which is marked by means of a dowel bolt. Always keep the rig in this position. Examine air gaps and remove any foreign material found therein.

Starting

Consult Regulator portion of Instruction Book before starting prime mover.

On initial starting, proceed slowly and note especially any evidence of rubbing.

SECTION 5—MAINTENANCE

DIRECT CURRENT ROTOTROL EXCITER

General

To obtain long, satisfactory service from direct-current generating equipment, it is necessary to install, operate and maintain such equipment properly. The following gives the simple precautions and instructions for such care. Properly maintained generators and exciters will require very little care other than periodic inspection. The most important factor is to keep the apparatus clean and free of oil, water and other foreign particles.

Insulation

Keep machine free of dirt, oil and water at all times. The greatest enemy to coil insulation is dirt and, if the equipment is kept clean, little trouble will result. The best way to check for excessive dampness in the windings is to make an insulation resistance measurement. This can be done directly by a "megger". If a megger is not available, the measurement can be made using a 100 to 500 volt direct current (the higher voltage available, the more accurate the results) and a direct-current voltmeter, of which the resistance in ohms is known (generally marked on label inside the instrument cover).

The method of making a resistance measurement with a voltmeter is to read the voltage of the line first, then connect the resistance to be measured in series with the voltmeter and take a second reading.

The measured resistance is calculated from the formula:

$$R = \frac{r\ (V-v)}{v} \text{ or } \frac{r}{v}(V-v)$$

V = First voltage reading
v = Second voltage reading
R = Resistance of insulation in ohms
r = Resistance of voltmeter in ohms

If a grounded circuit is used in making this measurement, care must be taken to connect the grounded side of the line to the frame of the machine. The voltmeter should be connected between the windings and the other side of the circuit.

The insulation resistance with the machine cold (at room temperature) should not be less than one megohm (1,000,000 ohms); when the windings are hot, it should not be less than:

$$\frac{3\ (\text{rated voltage})}{\text{KW plus 1000}} \quad \text{(In Megohms)}$$

If the resistance is low, the equipment should be dried out before it is started into regular service.

Methods of Drying

There are three general methods of drying the insulation windings:

External Heat
Internal Heat
A combination of External and Internal Heat

Where it is possible to have apparatus dried under vacuum while hot, this is, of course, an extremely effective process.

DRYING WITH EXTERNAL HEAT

It is extremely important that the insulation of new electrical apparatus should be protected against moisture after the apparatus has arrived at its destination. The most satisfactory procedure is to maintain the insulated parts and the air immediately surrounding them at a temperature of 15° to 25°C higher than the general air temperature of the room in which the apparatus is located, but not less than 40°C, actual temperature. This procedure will not only keep dry all insulation that is dry when the apparatus is received, but it will dry off surface moisture that may have accumulated during shipment of the equipment.

The method of producing and applying the heat will depend on many and widely varying conditions. Seldom will conditions be found ideal and, consequently, the problem of drying may often require on the part of the operator a great deal of ingenuity and resourcefulness. Since much damage can be done by the misapplication of heat to the windings of electrical apparatus, it is of paramount importance that this type of work be entrusted to competent persons only.

The application of heat to the windings should in no way injure the insulation by overheating it, nor should it be applied so rapidly that internal vapor pressures will be developed sufficiently to form pockets, or to rupture the insulation. Furthermore, it is essential that adequate provision be made for the circulation of hot air within the apparatus being dried and that openings for the escape of moisture-laden air and of gases be made at the top of the enclosure.

WITH STEAM HEAT

Where low pressure steam is available, radiators, or steam pipes placed below the end windings of a stator will provide safe and easily controlled heat. The enclosing parts should be set up against the frame, or a temporary enclosure should be used. There should always be ventilating openings at the top of the machines to provide for the escape of moisture.

WITH FORCED AIR

Hot air may be forced, or blown, through electrical apparatus to dry its insulation. The air may be heated by steam coils, in hot air furnaces, by electric heaters, or by open fires. Although it will remove surface moisture quickly, generally this method is inefficient and costly, unless a blower and air duct have been provided for the permanent installation and there is ample space to locate a heating unit in the duct.

OPEN FIRES are objectionable in many cases and should be used only when no other source of heat is available.

WITH ELECTRIC HEATERS

External drying of the insulation of electric rotating apparatus by electric heaters distributed under the end windings is strongly recommended. Space heaters are most convenient for this purpose.

DRYING WITH INTERNAL HEAT

The coil insulation of wound electrical apparatus may be dried by circulating current through the windings. Internal heat can be developed in this way without subjecting the insulation to voltages that might damage it during the drying operation. The procedure will depend upon the type of apparatus to be dried and on the facilities available for producing or applying the current.

There is always danger of serious injury to the windings when drying the insulation with current, since the heat generated in the inner parts is not readily dissipated; furthermore, coils containing moisture are much more susceptible to injury from overheating than they are when thoroughly dry. Gases and vapor generated within the insulation by high temperature may develop such pressure that they are forced through the insulation, breaking the continuity of the layers or actually rupturing the material. This method should be followed only under competent supervision.

The drying should be continued until the insulation resistance has dropped to a minimum and has then increased until at least one megohm for each 1000 volts operating voltage is indicated, but, in no case, less than one megohm, regardless of voltage. It may then be desirable to maintain the temperature at from 15° to 25° above ambient until ready for operation.

Usual Causes of Poor Performance

SPARKING AT THE BRUSHES

Sparking at the brushes may be due to any of the following causes:

1. *Rough or Dirty Commutator*

A rough or dirty commutator produces sparking, because it prevents a good contact between the brushes and commutator. The remedy is to clean the commutator if it is dirty and smooth the commutator if it is rough. The commutator may be cleaned by using a silken rag that has been dipped in kerosene and thoroughly wrung out. Resurfacing of a commutator should always be done with a grinding rig, whether it is to be ground concentric or in order to remove high bars or flat spots. A hand stone should never be used on a commutator to obtain a true surface, because it simply follows the irregularities in the surface and, in some cases, may even exaggerate them. The grinding rig consists of an abrasive stone set up similar to a lathe tool in a rigging or carriage which may be moved back and forth in an axial direction and equipped with a radial feed. It should be supported very rigidly so that the stone is subject to a very minimum of vibration.

Grinding should be done when the machine is running in its own bearings at rated speed. Great care must be exercised to prevent copper and stone dust from entering the windings. The grinding rig should be equipped with a vacuum cleaner arrangement fitted over the stone to catch all dust.

The stones used in grinding commutators might be classed as rough, medium and fine. The rough stone has a grit of about 80 mesh and is used only where a very large amount of copper is to be removed. It should be used very seldom because if sufficient copper is to be removed to warrant its use it would be better to take a cut off the surface in a lathe. The medium stone has a grit of about 120 mesh and is used for the bulk of the grinding work; the fine stone being used only to obtain a fine finish. The fine stone should have a grit of about 200 mesh.

After grinding all commutator slots should be cleaned out thoroughly and the edges of the bars beveled. This beveling accomplishes two things: it removes the burrs caused by the stone dragging copper over the slots, and eliminates the sharp edge at the entering side of the bar under a brush. The bevel on the bars is done with a special beveling tool and should be about 1/32 chamfer at 45° for medium thickness of bars. If it is apparent that enough copper is going to be removed by grinding so that the undercutting will be shallow, the commutator should be re-undercut before grinding. This is done by means of a small circular high speed saw about .003 inch thicker than the normal thickness of the mica. In undercutting, great care must be taken to see that a thin sliver of mica is not left against one side of the slot. Sometimes this sliver must be removed by scraping by hand.

After grinding, undercutting the mica, and beveling the edges of the bars, the commutator surface should be polished while operating at rated speed. Aloxite or sandpaper should be used first (never emery cloth or paper) to remove the burrs due to beveling. After a very fine grade of sandpaper has been used, a high polish can be obtained by burnishing with dense felt or canvas.

2. Incorrect Setting of the Brushes

The brushes may have been shifted. The correct brush position has been located at the factory and the rocker ring is locked and doweled to the frame to prevent movement. The brushholder should be adjusted to be approximately 1/16 inch from the face of the commutator, but should not be more than 1/8 inch from the face of the commutator.

3. Incorrect Spacing of the Brushes

Spacing of brush arms, as measured from the edges of the brushes, must be uniform around the commutator. This adjustment is made as the machine is assembled, but it sometimes needs to be checked, if commutation is poor or if brush arms have been disturbed by rough handling. The best method of making this check is to stretch a strip of paper around the commutator under the brushes, allowing the ends to overlap. The paper should be smooth and parallel with the edge of the commutator at all points. A fine, clear mark is made on the paper with a hard, sharp pencil exactly at the toe of each brush. The paper is removed and the spaces between marks are measured. If the measurements are not all the same, they show which arms are incorrectly spaced and in what direction to move them to make the spacing correct. After the arms are adjusted, the spacing should be rechecked by the same method. The difference in spacing never should be more than 1/32 inch.

4. Poor Brush Fit

The ends of all brushes should be fitted to the commutator so that each brush makes good contact over its entire bearing face. This can best be accomplished after the brushholders have been adjusted and the brushes inserted. Lift a set of brushes sufficiently to permit a sheet of sandpaper to be inserted. Draw the sandpaper in the direction of rotation under the brushes releasing the pressure as the paper is drawn back. Be careful to keep the ends of the paper as close to the commutator surface as possible as this will avoid rounding the edges of the brushes. It will be found that by this means a satisfactory contact is quickly secured. Use sandpaper "Grade 1-1/2" for the roughing cut, and "Grade O" for the final fit.

5. Incorrect Brush Pressure

Springs of brushholders must be adjusted so that the pressure on all brushes is uniform. From two to 2-1/2 pounds per square inch is a fair value for the average machine. In general, the tension should be as light as possible and still maintain proper contact with the commutator. The required pressure should be obtained with the lever of the spring in either the lowest or next to lowest notch. Brushes must not only fit their holders snugly, but also must slide freely at all points. Movement of brushes in holders must be as small as possible and still avoid binding.

6. Brush Wear

Brushes may have worn so much as to reach the end of travel of the pressure spring. the brushes should then be replaced.

7. Brush Sticking

Brushes may be sticking in the holders. This would prevent the brush from following the commutator surface. To correct this, take the brush from the holder and clean the brush and holder as grease and grit may have worked in to prevent free movement.

8. Machine Overload

Machine may be overloaded. Check meters to determine whether or not machine is operating at a load above its nameplate reading.

9. High or Loose Commutator Bar

Commutator bar may be high or loose. If bar is loose, commutator must be tightened. Tightening of a commutator should never be undertaken by inexperienced personnel.

A high commutator bar must be turned down in an engine lathe, or ground as covered in Paragraph 1, of this subdivision.

10. High Mica on Commutator

Mica should be undercut as explained in Paragraph 1, of this subdivision.

11. Short-Circuited Armature Coil

A short-circuited armature coil may be caused by a thin copper bridge span over the mica between two commutator bars, or the insulation may have broken down where the end connections of the armature coils cross. A short-circuited armature coil always produces sparking when it passes under a brush, because, being shorted, it has a circulating current in it when it makes contact with the brush and this contact serves to reduce the resistance of the short, allowing more current to flow, a certain amount of which passes through the brushes.

This short can be located by a simple test using a dry cell and a low-range voltmeter. First, lift all the brushes from the commutator except one pair, and to this pair of brushes connect the dry cell. Then with the low-range voltmeter, read the voltage between adjacent commutator bars in sequence around the commutator. The voltage readings will be the same until the shorted coil is reached and the voltmeter will read practically zero. To correct the shorted coil, it must be located and insulated.

Open Circuited Armature Coil

An open circuited coil produces severe sparking when the bars to which this coil is connected pass under the brush. Since the coil is open, no current can flow in that circuit. However, a voltage exists across this opening and, when the bars pass under a brush, the brush closes the open circuit causing a rush of current to flow. Also, when the bar leaves the brush, this current is ruptured, which causes the severe sparking. A test similar to the one used to locate the shorted coil is used to locate an open coil. However, the voltage readings will now all be zero until the open coil is reached and all voltage will be read across this open coil. An open coil can also be detected by the burned condition of the commutator bars to which it is attached. The open armature coil must either be repaired or replaced.

Short Circuit in One of the Field Circuits

To check for faults in these circuits, lift all the brushes and measure the resistance of the circuits between opposite brush arms. In checking these readings refer to the wiring-around-frame drawings and the test resistances given on the Master Plan Drawing. If the resistances vary more than 5 per cent from these values, check further as follows:

Check the resistance from the midpoint of each of the two circuits to their respective two brush rods - in other words, from A1 to brush rod #2 and brush rod #4, and from A2 to brush rod #1 and brush rod #3. This will indicate which section is at fault and, therefore, which coils to check individually.

The simplest way to check resistance may be to circulate a current through the circuit and measure the voltage drops across each coil and solve for the resistance of each coil. If any coil is found shorted, replace the complete coil on that pole.

Consult section on "Disassembly and Assembly" before removing coils.

FLASHOVER

A flashover happens when arcing occurs between adjacent brushholder brackets. In general, it is caused by excessive voltage, or by abnormally low surface resistance on the commutator between brushholders of opposite polarity. Any condition tending to produce poor commutation increases the danger of flashover. Among other causes, are the following:

1. Rough or dirty commutator.
2. A drop of water on the commutator from leaky steam pipes or other source.
3. Short-circuits on the line producing excessive overload.

Causes of Insufficient Voltage

The following causes may prevent exciters from developing their normal voltage. (Note: Usually, the Rototrol exciter does not need to develop its name plate voltage in order to obtain rated voltage on the main generator. In general, disregard the Rototrol exciter voltage and be concerned only with the ability of the exciter and regulator to produce normal voltage on the main generator.)

1. THE ROTOTROL EXCITER MAY NOT BE UP TO SPEED, DUE TO THE FACT THAT THE PRIME MOVER IS RUNNING SLOW. Speed has a pronounced effect on the voltage output of a Rototrol exciter. To correct this trouble, the prime mover must be speeded up so that it is operating at rated speed.

2. THE SWITCHBOARD INSTRUMENTS MAY BE READING INCORRECTLY. Meters must be checked periodically against a standard meter to be sure that they are reading correctly.

3. THE BRUSHES MAY BE INCORRECTLY SET. They should be returned to the correct position.

4. THE REGULATOR MAY NOT BE FUNCTIONING CORRECTLY. Refer to the regulator portion of the book.

5. THERE MAY BE A CIRCUIT FAULT IN A FIELD WINDING OR CONNECTION. The best way to check this is to measure resistances. The resistance of the commutating, forcing and compensating fields can be checked as outlined in paragraph 13 under "Commutation". In addition, the control field and the shunt field should also be checked for resistance. Always refer to the Master Plan Drawing for the proper values of resistance.

CLEANLINESS

The methods of cleaning insulation include wiping off the dirt with a "clean, dry cloth"; blowing it out with air pressure; drawing it off with suction apparatus; removing it in various ways with solvents, and washing it off with water--sometimes hot water and a solvent are required.

Wiping Cloths

When the apparatus is small and only dry dirt has collected on exposed parts, cleaning with a dry cloth may be satisfactory. Waste should not be used as the lint will adhere to the insulation and collect dust, moisture and oil.

Compressed Air

Blowing out dirt with air at not over 15 lbs. pressure is usually effective, particularly when the dirt has collected in places which cannot be reached with a cloth. Generally, cleaning can be done more quickly with compressed air than with a cloth. This applies especially to large apparatus. Do not direct compressed air against insulation until certain that it is free from moisture that may have accumulated in the air line from condensation. Too great an air pressure may loosen binding tape and blow dirt under it. Dirt blown out of a machine is likely to be drawn into others that are in operation near it. Remember, the use of compressed air simply transfers the dirt from one location to others, and unless the final location is outside the operation room, very little good may be accomplished.

Solvents

If the accumulation of dirt contains oil or grease, a solvent will usually be required to remove it. There are three types of solvents in general use for this purpose:

These are, petroleum distillates, such as benzine or gasoline (not benzene or benzol, which are extremely toxic and should never be used), carbon tetrachloride and a mixture of the two.

Benzine or gasoline has the least corrosive action on the insulation varnishes and for that reason--where conditions permit--are preferable to the other solvents.

Benzine, having a flash point of 100°F higher than gasoline, is perhaps the most generally desirable.

Solvents known commercially as "Stoddard Solvent" (described in U.S. Bureau of Standards as "Commercial Standard CS-3-28"), Cleaner's Naphtha, or Safety Type Solvents minimize the fire hazard and should be used in preference to gasoline or benzine, but ample precautions should, nevertheless, be used to prevent fires or explosions.

When this type of solvent will not clean the apparatus properly a mixture of carbon tetrachloride and petroleum may be used. A mixture of 50% carbon tetrachloride and petroleum solvents may be used. A mixture of 50% carbon tetrachloride and 50% benzine, or 60% carbon tetrachloride and 40% gasoline is non-flammable but the vapors mixed with the right proportions of air are explosive.

Carbon Tetrachloride

In extreme cases, it may be necessary to use straight carbon tetrachloride; however, its toxic effect must be considered.

This is a non-flammable compound, but due to its mild and somewhat pleasant odor, there is danger of working in excessively high concentrations. Since its vapor is heavier than air, it may accumulate in pits and confined spaces. Even moderate exposures are very dangerous after drinking intoxicating liquors.

This solvent is much more corrosive in its action than the petroleum solvents. It evaporates quickly, however, and may be used for cleaning windings with mild risk, if reasonable precautions are taken.

Applying Solvents

In cleaning electrical apparatus, solvents are generally used by wiping the insulation with cloths moistened with the cleaning fluid. In special cases, the solvents may be sprayed on the insulation, or the insulation parts may be dipped into the solvent.

CAUTION: NOTE CAREFULLY

When petroleum distillates are used, guard carefully against fire and explosion.

Both benzine and gasoline are very flammable and their vapors are extremely explosive when mixed with the proper percentage of air.

Be sure there is good ventilation and minimum fire risk.

If possible, do not let the worker's clothing become saturated with the solvent.

If the clothing should become saturated, it should be removed before leaving the work.

Always have fire extinguishers handy.

Keep metal tools from striking metal parts of the apparatus.

Workmen's shoes should not have protruding nails.

If using a hose to spray either cleaning solution or varnish, make sure that the nozzle is grounded.

When using carbon tetrachloride, workmen should be guarded against breathing the fumes and they should be under the close observation of someone familiar with artificial respiration.

Where the conditions are particularly bad, workmen located in pits or the holds of vessels should wear gas masks.

Adequate ventilation should be provided when any type of solvent is being used.

Water, or Water and Solvents

Electrical apparatus which has been filled with dirt by plant operations, dust storms or other unusual conditions, or has been submerged during a flood and is clogged with mud and foreign matter, will probably require a thorough washing out. In such cases, disassemble the apparatus and thoroughly wash all parts with water. Use an approved solvent to remove grease from the insulation. If water is applied to insulated parts with a hose, the pressure should not exceed 25 lbs. per square inch.

EXCESSIVE HEATING

Heating of Field Coils

Heating of field coils may develop from any one of the following causes:

1. Operating at too low a speed, requiring more than normal field current.
2. Too high generator voltage setting.
3. Partial short-circuit of one coil.
4. Overload on generator.

Heating of Armature

Heating of the armature may develop from any of the following causes:

1. Too great a load.
2. A partial short-circuit of armature coils with heating of the particular coils affected.
3. Short-circuits or grounds on armature or commutator.

Heating of Commutator

Heating of commutator may develop from any of the following causes:

1. Overload.
2. Sparking at the brushes.
3. Too high brush pressure.
4. Lack of inherent lubrication of brushes.

DISASSEMBLY AND ASSEMBLY

Removal of Armature from Shaft

STEP 1. Remove covers on front bracket.

STEP 2. Raise brushes.

STEP 3. Break connections to brushholders.

STEP 4. Remove bolts holding rocker ring to frame and remove rocker ring.

STEP 5. Remove bolt holding quill nut to shaft.

STEP 6. Insert the 1-1/2 inch press-off bolt, (supplied in main generator spare parts) in quill nut.

STEP 7. Turn bolt until armature is pulled off shaft.

STEP 8. Remove armature from frame assembly by drawing it through from the commutator end. Be careful not to damage coils or commutator. Do not support armature wholly or in part by pressure on the coils or commutator. Always use rope slings on the steel punchings.

Assembly of Armature on Shaft

STEP 1. Place armature on shaft and push on as far as possible by hand.

STEP 2. Place nut and spacer on one inch pull-on bolt (supplied with main generator spare parts).

STEP 3. Insert the one inch pull-on bolt through hole in quill nut and engage in hole in end of shaft.

STEP 4. Turn bolt until it is tight in hole in shaft.

STEP 5. Turn nut against spacer evenly and armature will move on shaft.

STEP 6. Remove bolt.

STEP 7. Insert bolt to hold quill nut to shaft.

STEP 8. Put on front bracket, make connections to brushholders, seat brushes and replace covers.

Removal of Poles and Coils

STEP 1. Perform steps (1) to (4) as in "Removal of Armature from Shaft".

STEP 2. Disconnect field connection, carefully marking each so that proper polarity will be obtained when reconnected.

STEP 3. Measure and record air gap.

STEP 4. Remove bolts holding pole to frame. Be careful to note and retain all liners between frame and pole as these must be replaced. SEE CAUTION NOTE.

STEP 5. Slide pole and coil out commutator end of exciter.

STEP 6. Coil may be removed from pole by sliding it off frame end.

STEP 7. In replacing the coils and poles be sure the proper air gap is finally attained, see measurement made in Step 3.

CAUTION:

Whenever a coil is removed, or for whatever other reason the Rototrol is dismantled, care must be taken to see that the poles and shims back of the poles are replaced in EXACTLY the same location they were in before removal. The air gaps were adjusted at the factory to obtain the required characteristics of the Rototrol exciter, and under no conditions should they be changed. The actual measured air gaps are given on the Master Plan Drawing and are measured at the center of the poles.

TYPE WRN-11 GENERATOR VOLTAGE REGULATOR

ORDER IDENTIFICATION

Voltage Regulator	Type WRN-11
General Order	WG-70070-TY
Shop Order	22-Y-1537
Automatic Control Unit	S. 1584370
Voltage Adjusting Unit	S. 1369698
Potential Unit	S. 1584368
Manual Control Unit	S. 1584387
Regulator Control Switch	S. 1584388
Standby Regulator Transfer Switch	S. 1584390
Current Transformer	S. 1304233

DRAWING REFERENCE LIST

WRN-11 Regulator Master Plan	
Bureau of Ships Plan	S6101-3203132
Westinghouse Electric Corp. Drawing	1-JH-470
WRN-11 Certification Data	
Bureau of Ships Plan	CVA60-S6102-1503122
Westinghouse Electric Corp. Drawing	30-B-7153
UN Current Transformer Master Plan	
Bureau of Ships Plan	91023-S6202-2244
Westinghouse Electric Corp. Drawing	20-A-1720

INDEX

ERRATA

Page 403.

Potential lead now on C should be connected to B

Page 417, Sub Paragraph 2a, Line 6.

(E-V) should be (E+V).

Page 419, Sub Paragraph c2, Line 1.

(E-V) should be (E+V).

Page 430

Footnote marked with * page number reference should be 434.

GENERAL

The output circuit of the automatic control unit has been modified to include a damping transformer as shown in Figure 2. When the damping transformer is added, the 400 ohm resistor in the Rototrol control field is shorted out. This modified circuit allows practically the full output voltage of the automatic control unit to be applied to the Rototrol control field and still maintain stability.

The primary winding of the damping transformer with an adjustable series resistor is connected across the a-c generator field. The secondary winding is connected in opposition series with the output of the automatic control unit. Any change in the generator field voltage produces a current which opposes the output current of the automatic control unit. The desired amount of damping is obtained by changing the value of the series resistance.

DAMPING TRANSFORMER ASSEMBLY

The damping transformer assembly (Fig. 1) meets the requirements of Military Specification MIL-T-16315. It has been approved by BuShips letter NObs 61991 (560G) Serial 560-73007, dated 23 December 1953.

This assembly weighs 75 pounds.

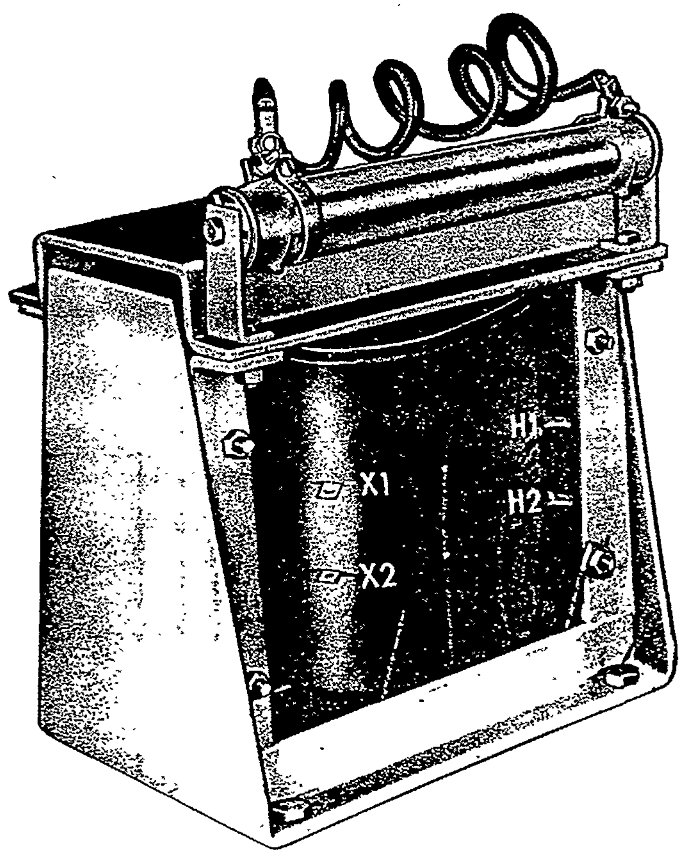


Figure 1

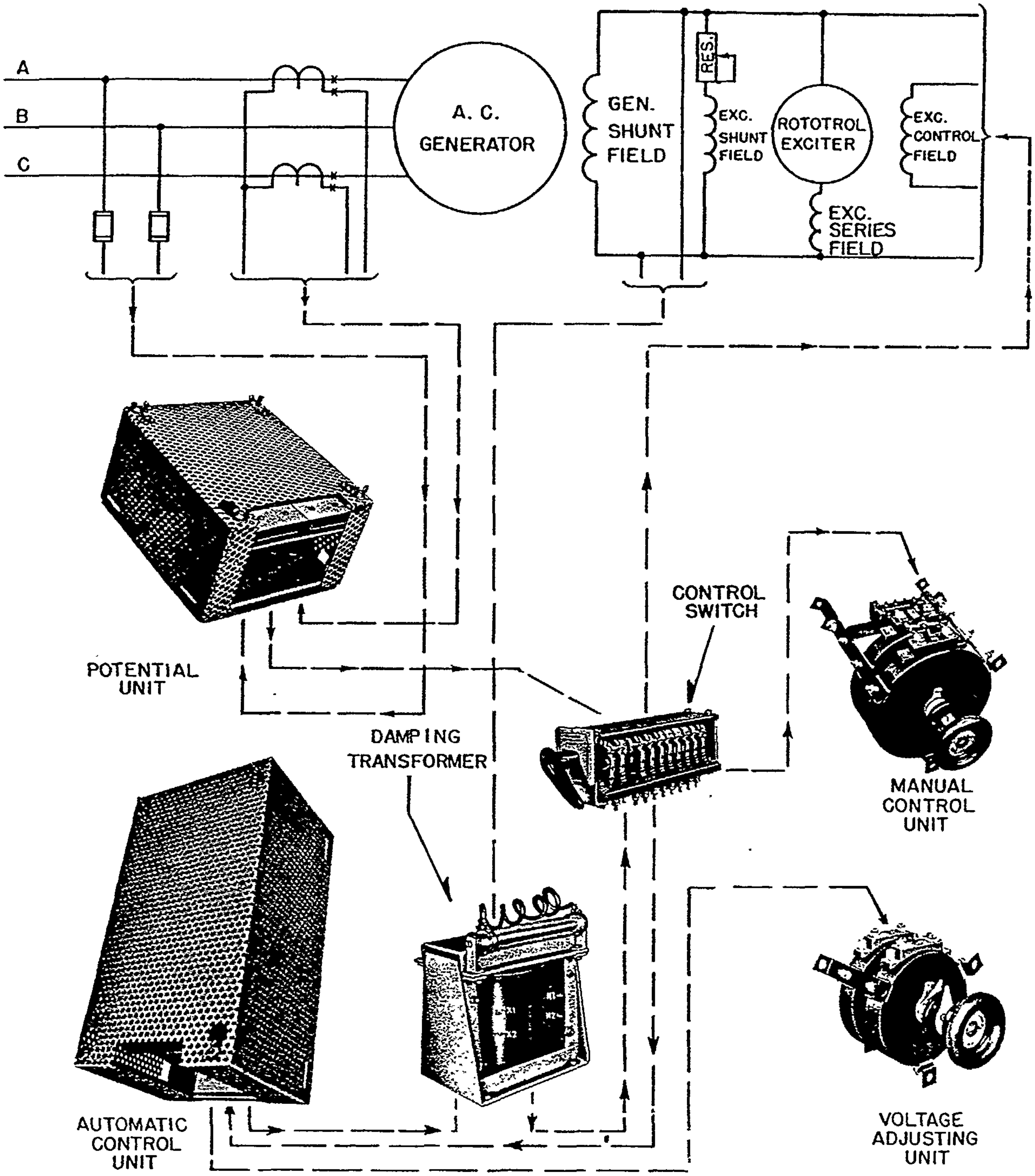
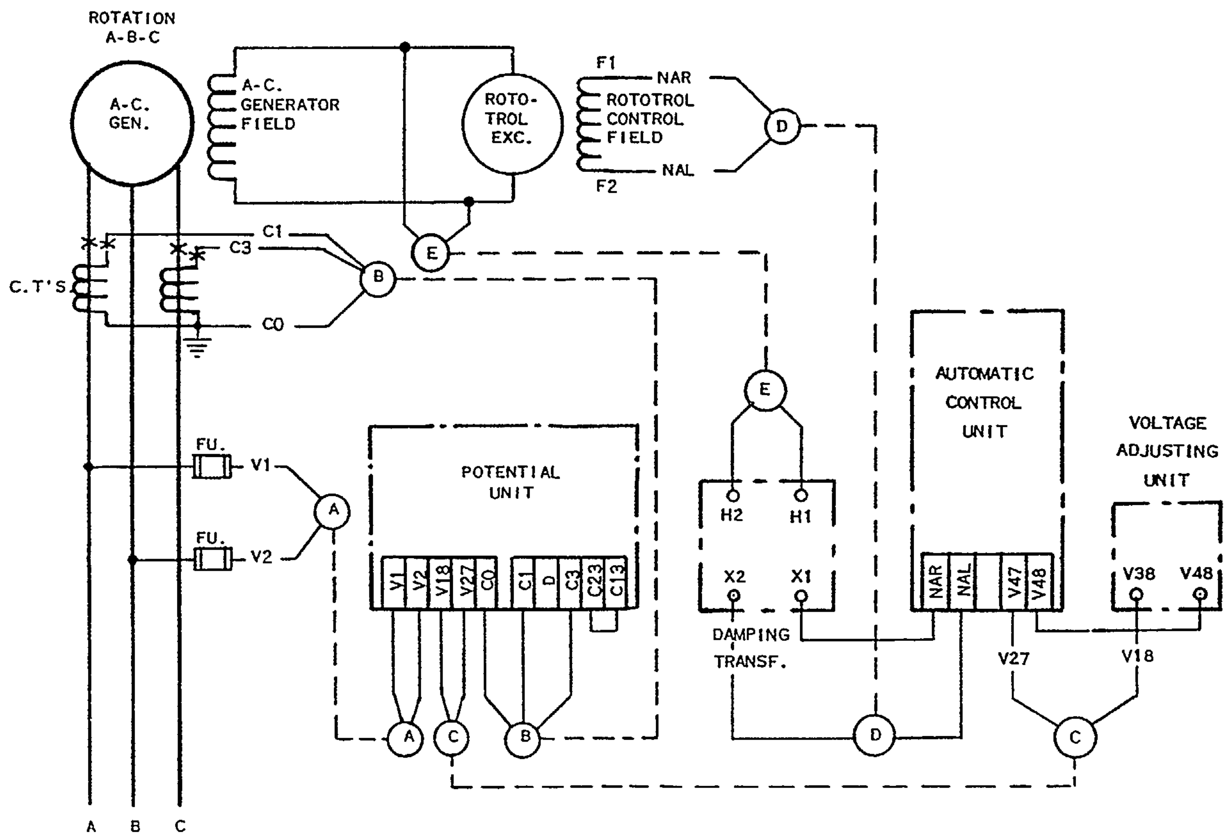

A
B
C
A. C.
GENERATOR
GEN.
SHUNT
FIELD
RES.
EXC.
SHUNT
FIELD
ROTOTROL
EXCITER
EXC.
CONTROL
FIELD
EXC.
SERIES
FIELD
POTENTIAL
UNIT
CONTROL
SWITCH
MANUAL
CONTROL
UNIT
DAMPING
TRANSFORMER
AUTOMATIC
CONTROL
UNIT
VOLTAGE
ADJUSTING
UNIT

Figure 2



ROTATION A-B-C
A-C. GEN.
A-C. GENERATOR FIELD
ROTO-TROL EXC.
F1
NAR
ROTOTROL CONTROL FIELD
NAL
F2
C.T'S
C1
C3
C0
FU.
V1
V2
POTENTIAL UNIT
V1 V2 V18 V27 C0 C1 D C3 C23 C13
DAMPING TRANSF.
H2 H1
X2 X1
AUTOMATIC CONTROL UNIT
NAR NAL V47 V48
VOLTAGE ADJUSTING UNIT
V38 V48
V27
V18
A B C

Figure 3

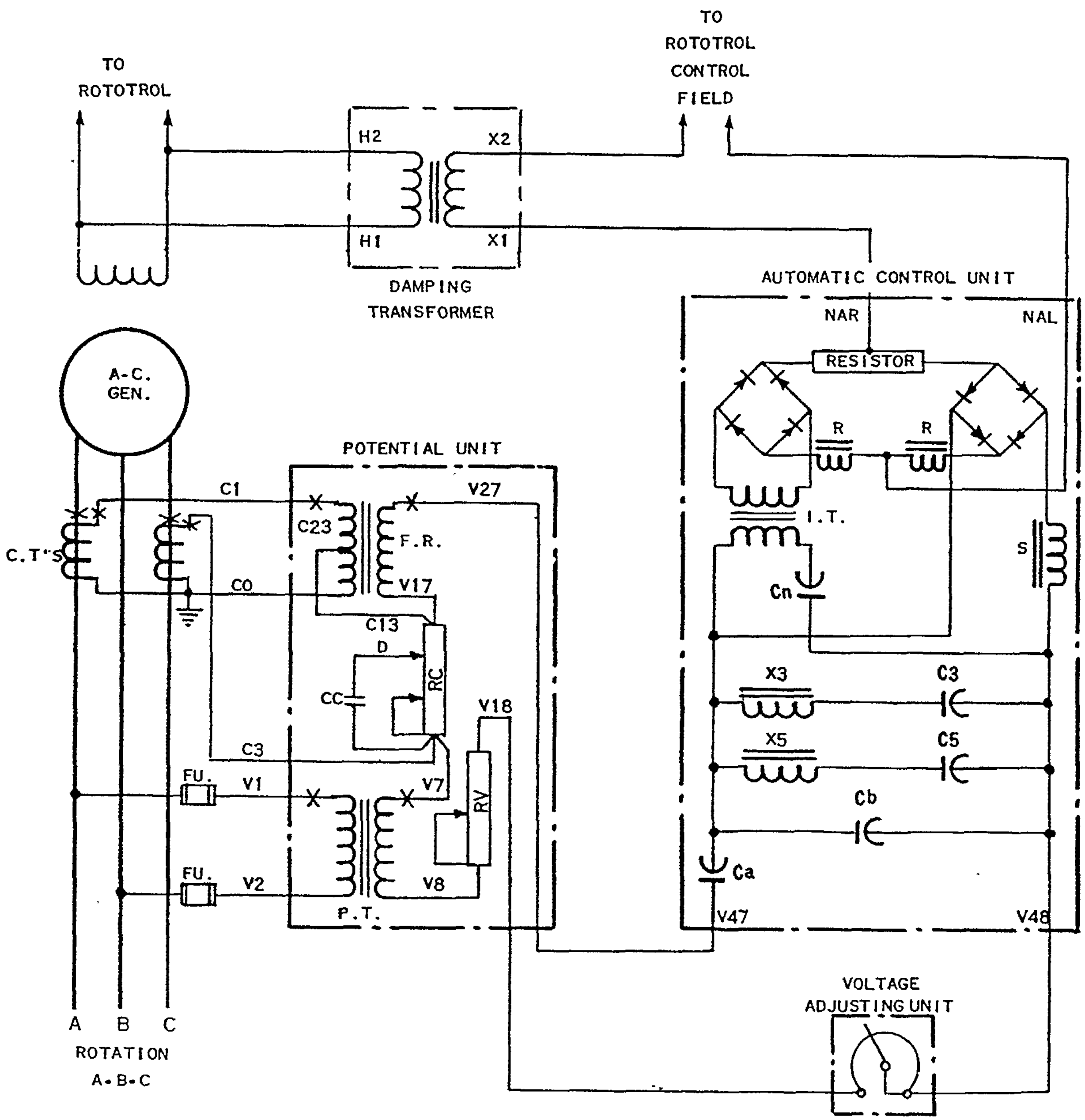

TO
ROTOTROL
TO
ROTOTROL
CONTROL
FIELD
H2
X2
H1
X1
DAMPING
TRANSFORMER
AUTOMATIC CONTROL UNIT
NAR
NAL
RESISTOR
R
R
I.T.
S
Cn
A-C.
GEN.
POTENTIAL UNIT
C1
V27
C23
F.R.
C.T'S
CO
V17
C13
D
RC
CC
V18
C3
FU.
V1
V7
RV
FU.
V2
V8
P.T.
X3
C3
X5
C5
Cb
Ca
V47
V48
VOLTAGE
ADJUSTING UNIT
A B C
ROTATION
A-B-C

Figure 4

TYPE WRN-11 GENERATOR VOLTAGE REGULATOR

SECTION A – INTRODUCTION

4A1. PREFACE

a) Careful reading of these instructions will provide information for the proper care and handling of the generator voltage regulating equipment, and lessen tendencies to damage the equipment, thus impairing its performance when placed in operation. It is recommended that the shipment should be checked immediately for loss or damage. If any such shortage or damage is found, it should be reported to the transportation company without delay.

b) The equipment will stand reasonable atmospheric and temperature conditions but should be stored in a location where temperature and moisture conditions are not extreme.

c) The open-type apparatus covers afford little protection against dust and dirt and although dust and dirt may not prove detrimental to operation, it is recommended that closed covers or containers should be used during storage.

4A2. INQUIRY DATA

a) When corresponding regarding the equipment described herein, refer to Type WRN-11 Voltage Regulating Equipment per General Order Number and M.S.O. Number specified in Certification Data. Complete identification of parts is contained on Master Plan specified in Certification Data.

b) Address inquiries to the nearest Westinghouse Sales Office - or to Westinghouse Electric Corporation, Switchgear and Control Division, East Pittsburgh, Pennsylvania, U.S.A.

4A3. VOLTAGE CONTROL

a) NECESSITY OF CONSTANT VOLTAGE. The ships' service generators supply power for auxiliary motors, lights, radio equipment, radar, and other electrically operated devices. A substantially constant voltage will operate this equipment more satisfactorily than fluctuating voltage. Low voltage will cause lights to be dimmed, motors to slow down or to pull out of step, radio equipment to function improperly, etc. A high voltage will cause some equipment to perform unsatisfactorily and other equipment such as lights and radio tubes to burn out. A fluctuating voltage will have the undesirable features of both high and low voltage. In addition to the effect on the operation of the equipment, varying voltage produces light flicker which is disturbing to personnel.

b) GENERATOR OPERATION WITH NO REGULATOR. If a generator has no automatic voltage regulating controls, (see Fig. VR-1), its voltage will vary with applied load. Thus, for instance, when a motor is started which draws high starting current, the terminal voltage of the generator supplying the power will drop. The generator voltage, if its excitation is not corrected, will remain lower than before the motor was started. The number of volts lower will depend upon factors such as the size of the motor, characteristics of its load, the design of the generator, etc. The operator can adjust the generator voltage to its proper value with the exciter field rheostat. After the motor's work is completed, or its breaker is opened removing it from the generator bus, the generator voltage will rise. The operator can again adjust the voltage to its proper value.

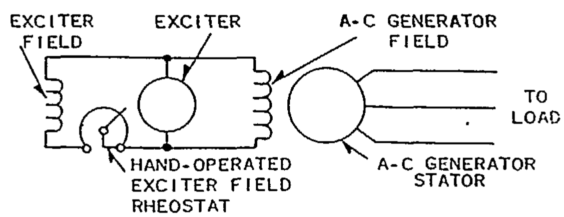


Fig. VR-1 — A-C Generator with Manual Voltage Control

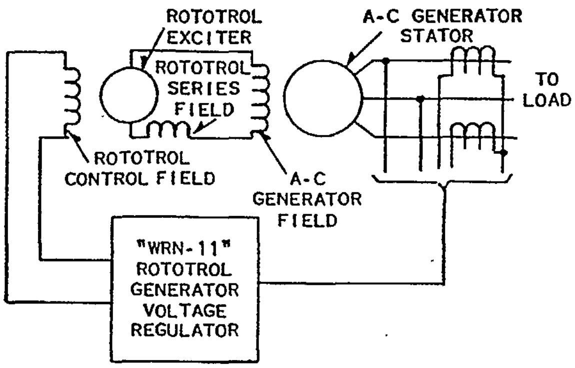


Fig. VR-2 — A-C Generator with Automatic Voltage Control

c) This method of generator operation has two main objections. First, the speed with which an operator can correct a voltage change is limited. A matter of seconds at least, and very possibly minutes, would be required (See Fig. VR-3). This length of time could easily be disastrous, especially under emergency conditions. Second, the constant attention of a special operator would be required to maintain proper voltage during operation of the generator.

d) GENERATOR OPERATION WITH AN AUTOMATIC REGULATOR. Because of the time delay in manual correction of the varying generator voltage, an automatic voltage regulator is used (See Fig. VR-2). The "WRN-11" Generator Voltage Regulator will hold the generator voltage at a constant value except for very brief transient conditions, and will correct voltage changes in a fraction of a second. It will maintain proper voltage at any load up to the rating of the machine. Thus, the main objections to manual control are overcome by the use of an automatic voltage regulator. Obviously, no special operator is needed.

e) The voltage regulator acts promptly to restore the generator voltage and thus keeps the electrical equipment operating properly at all times including emergencies. It increases the reliability and useful life of the electrical equipment.

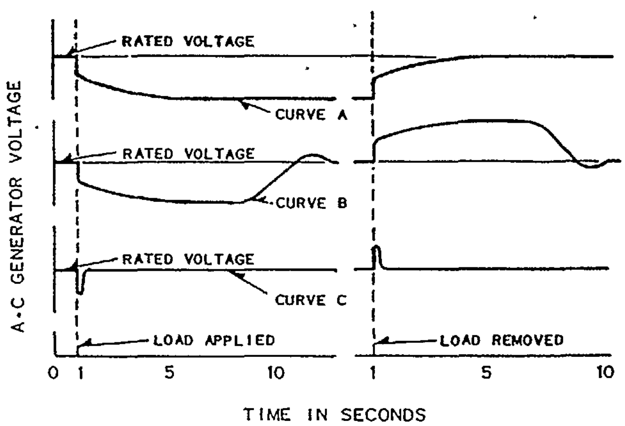
f) Figure VR-3 shows a comparison of voltage-time characteristics for three conditions of a-c generator operation; i.e., with no generator field correction, with hand-operated voltage control, and with automatic regulator control.

4A4. BRIEF DESCRIPTION OF REGULATING EQUIPMENT

a) The purpose of the automatic voltage regulator, on any installation, is to maintain the terminal voltage of the alternating-current generators at, or very close to, 450 volts, regardless of load variations. This is accomplished by means of a special direct-connected exciter, identified as a ROTOTROL exciter and a static electrical measuring circuit, known as the Type "WRN-11" Static Voltage Regulator.

b) The generator terminal voltage is impressed upon the static circuit. The output of this circuit is a d-c potential which varies in polarity, according to high and low generator voltage conditions, and energizes the control field of the ROTOTROL exciter. The terminal voltage of the exciter is controlled by the low-energy control field, thus effecting the required changes in the generator excitation and output voltage.

c) The apparatus comprising a set of regulating equipment is illustrated in Fig. VR-4 and described in Section B following.



CURVE A - VOLTAGE-TIME CURVE USING NO CORRECTIVE MEANS I.E. CONSTANT GENERATOR FIELD CURRENT

CURVE B - PROBABLE VOLTAGE-TIME CURVE USING MANUAL CONTROL

CURVE C - VOLTAGE-TIME CURVE USING AUTOMATIC REGULATOR

Fig. VR-3 — A-C Generator Voltage-Time Characteristics (load suddenly applied and suddenly removed)

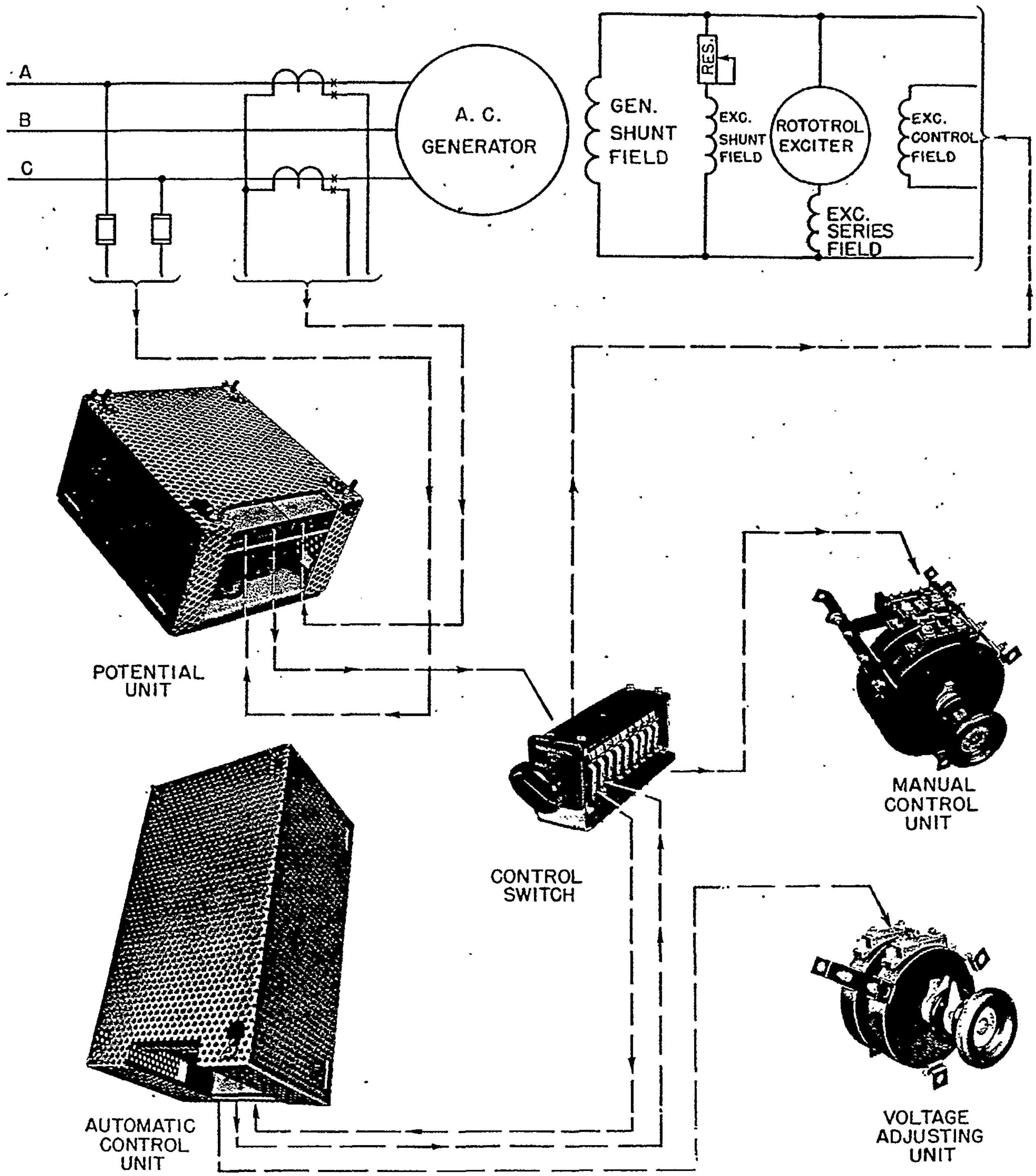


Fig. VR-4 — Pictorial Schematic Diagram

SEC. B—DETAILED DESCRIPTION

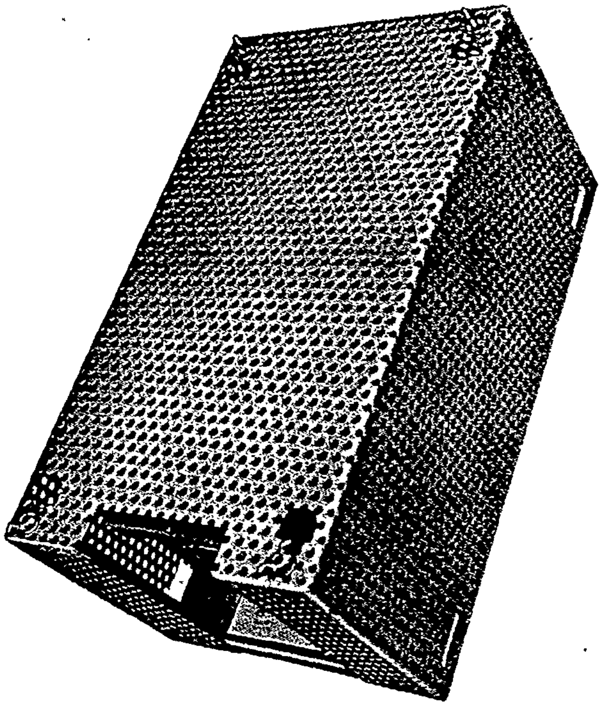


Fig. VR-5 — Automatic Control Unit

4B1. COMPONENT PARTS

a) The Type "WRN-11" Generator Voltage Regulating Equipment consists of five parts which are described in paragraphs 4B2 to 4B8.

4B2. AUTOMATIC CONTROL UNIT

a) This unit, which is shown in Figs. VR-5, -6 and -7, consists physically of an insulating transformer, a resistor, a pair of Selenium rectifiers and a set of condensers and reactors inclosed in a perforated metal case and mounted on a steel base. These parts are so connected to form the circuits described in detail in paragraph 4C3, (page 414). Connections to this unit are made at the terminal block which is located at the lower end of the base and is accessible through the opening in the top cover.

b) Complete identification of this unit is given by information contained on the nameplate, located on the base near the terminal block.

4B3. POTENTIAL UNIT

a) This unit, which is shown in Figs. VR-8 and -9, consists physically of a potential transformer, a filter reactor and a set of resistors. The circuit formed by these parts is described in detail in paragraph 4C3, (page 414). The terminal blocks, used for connections to this unit, are located at the bottom of the unit on a bracket below the potential transformer and are accessible through an opening in the top cover.

b) The nameplate located on the left side of the base gives complete identification of the unit.

4B4. MANUAL CONTROL UNIT

a) A single-plate rheostat, fixed-plate resistor and half-wave Selenium rectifier comprise this unit. Figures VR-10 and -11, show the arrangement and circuit details are described in paragraph 4C3, (page 414).

b) Connections are made at the terminal block located on a bracket at the top rear of the unit. The identification nameplate is located on the under side of the terminal block mounting bracket.

4B5. VOLTAGE ADJUSTING UNIT

a) The voltage adjusting unit is a two-plate rheostat with an overall resistance of 75 ohms and a rating of 2.5--1.8 amperes. The rheostat contains 71 steps of resistance which can be either inserted or taken out of the potential circuit thus raising or lowering the value at which the regulator holds the generator voltage.

b) The complete unit is shown in Fig. VR-12 and is identified by Westinghouse Style 1369698.

4B6. CURRENT TRANSFORMERS

a) Two current transformers, which are described in Sheet No. 1, Certification Data, are supplied for each generator. They are connected in phases A and C and their energy is supplied to the potential unit.

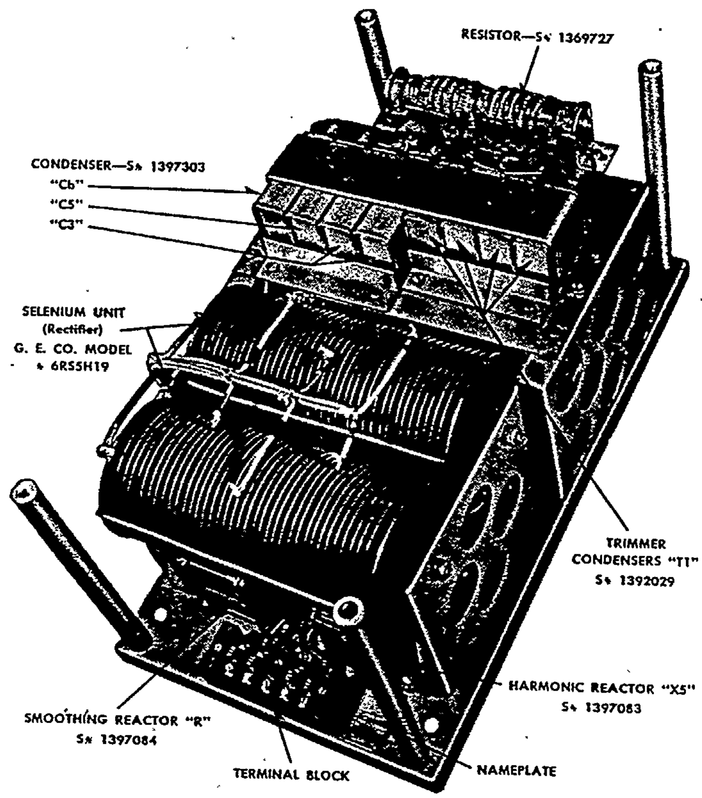


Fig. VR-6 — Automatic Control Unit— Cover Removed

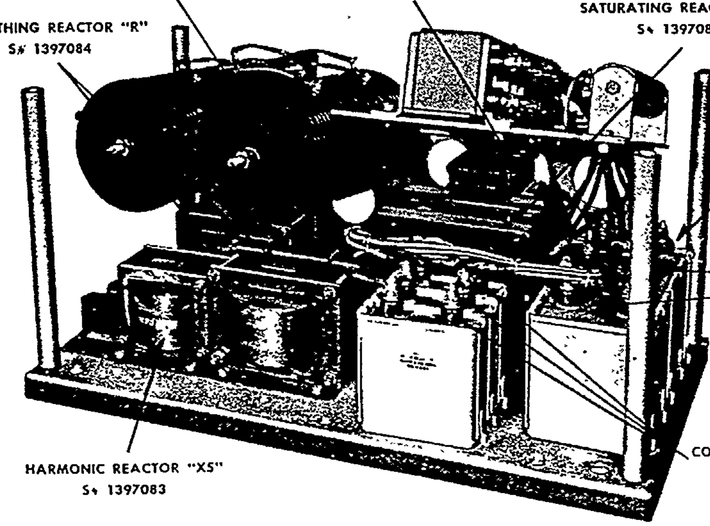


Fig. VR-7 — Automatic Control Unit — Cover and Right Side Brackets Removed

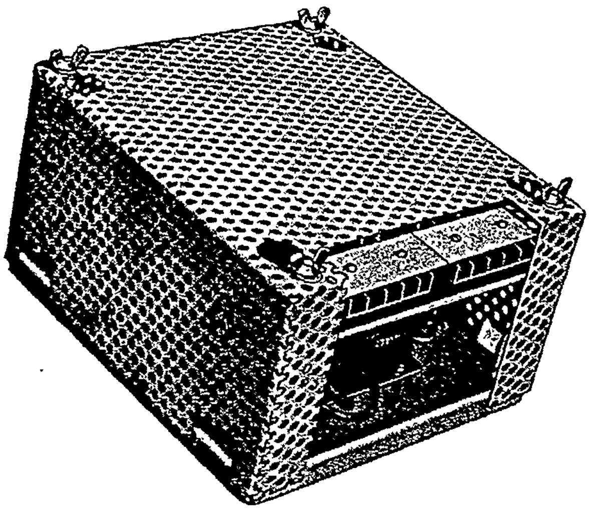


Fig. VR-8 — Potential Unit

4B7. REGULATOR CONTROL SWITCH

a) The regulator control switch is of the rotary drum-type provided with two positions, namely, MANual and AUTOmatic. In the MAN position the generator voltage is controlled by the operator by means of the manual control unit (See Fig. VR-41). In the AUTO position the generator voltage is under full control of the regulator (See Fig. VR-40) and will be maintained at a value pre-determined by the setting of the voltage adjusting unit.

b) The complete switch is shown in Fig. VR-13 and identification is given on the nameplate located on the rear end bracket. Switch details are described in paragraph 4E2c (page 437).

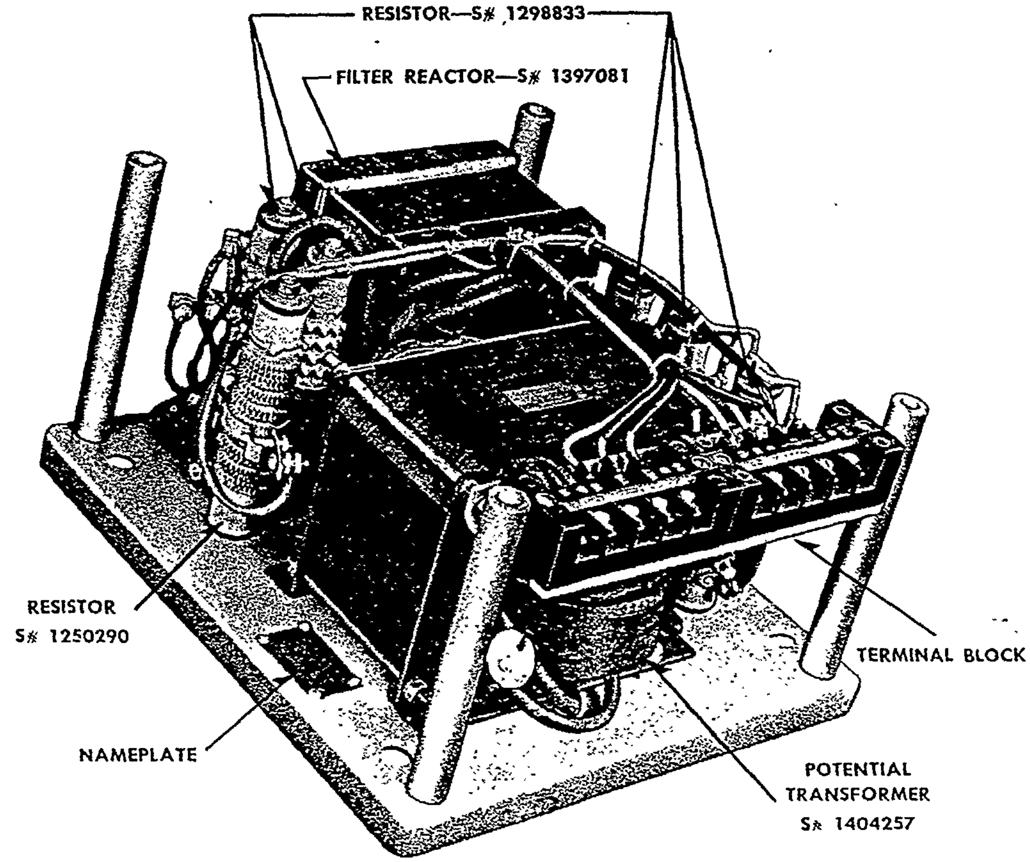


Fig. VR-9 — Potential Unit — Cover Removed

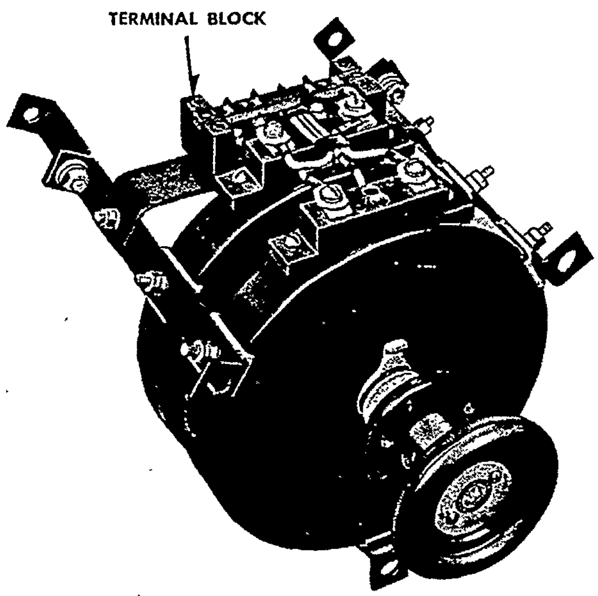


Fig. VR-10 — Manual Control Unit — Front View

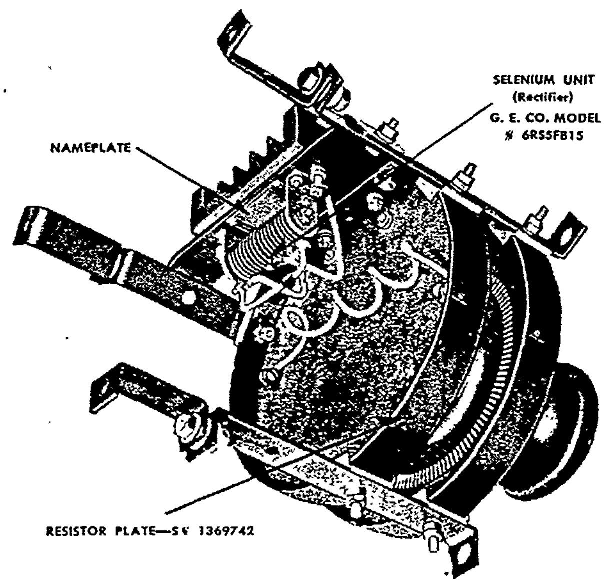


Fig. VR-11 — Manual Control Unit — Rear View

4B8. STANDBY REGULATOR TRANSFER SWITCH

a) The rotary drum-type standby regulator transfer switch is provided with either two or thr- positions. It is used to transfer generator voltage control during automatic operation from the "normal" units to the "standby" units. Figs. VR-42, -43, -44 and -45 show pictorially the operations and switch positions. The complete switch is shown in Fig. VR-13 and identification is given on the nameplate located on the rear end bracket.

4B9. SPECIFICATION TABLES

a) The following specifications and weights are applicable to the component parts. For additional data, see Master Plan and Certification Data:

Apparatus	BuShips Spec.No.	Weight (Pounds)
Automatic Control Unit	17R2	125
Potential Unit	17R2	60
Manual Control Unit	17R2	12.5
Voltage Adjusting Unit	17R4	9.5
Current Transformer	17I20	See Cert. Data
Control Switch	17S18	5.5
Standby Regulator Transfer Switch	17S18	4.5

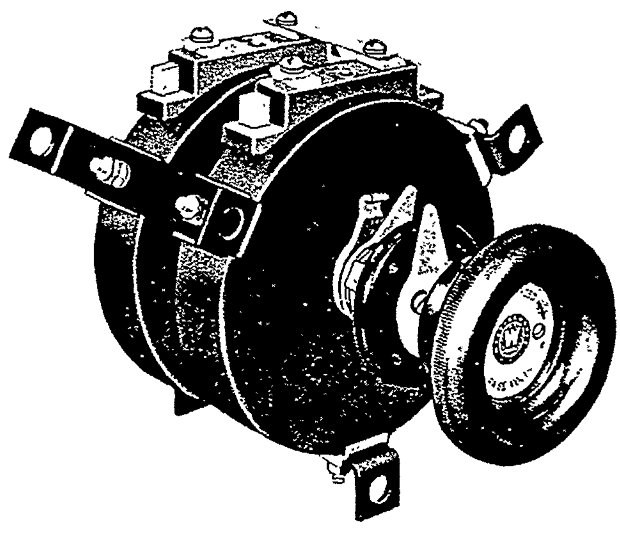


Fig. VR-12 — Voltage Adjusting Unit

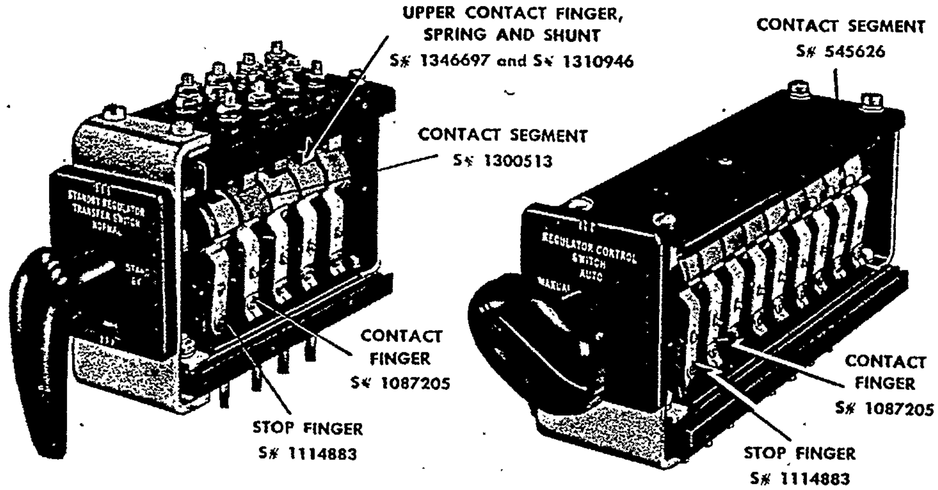


Fig. VR-13 — Transfer and Control Switches.

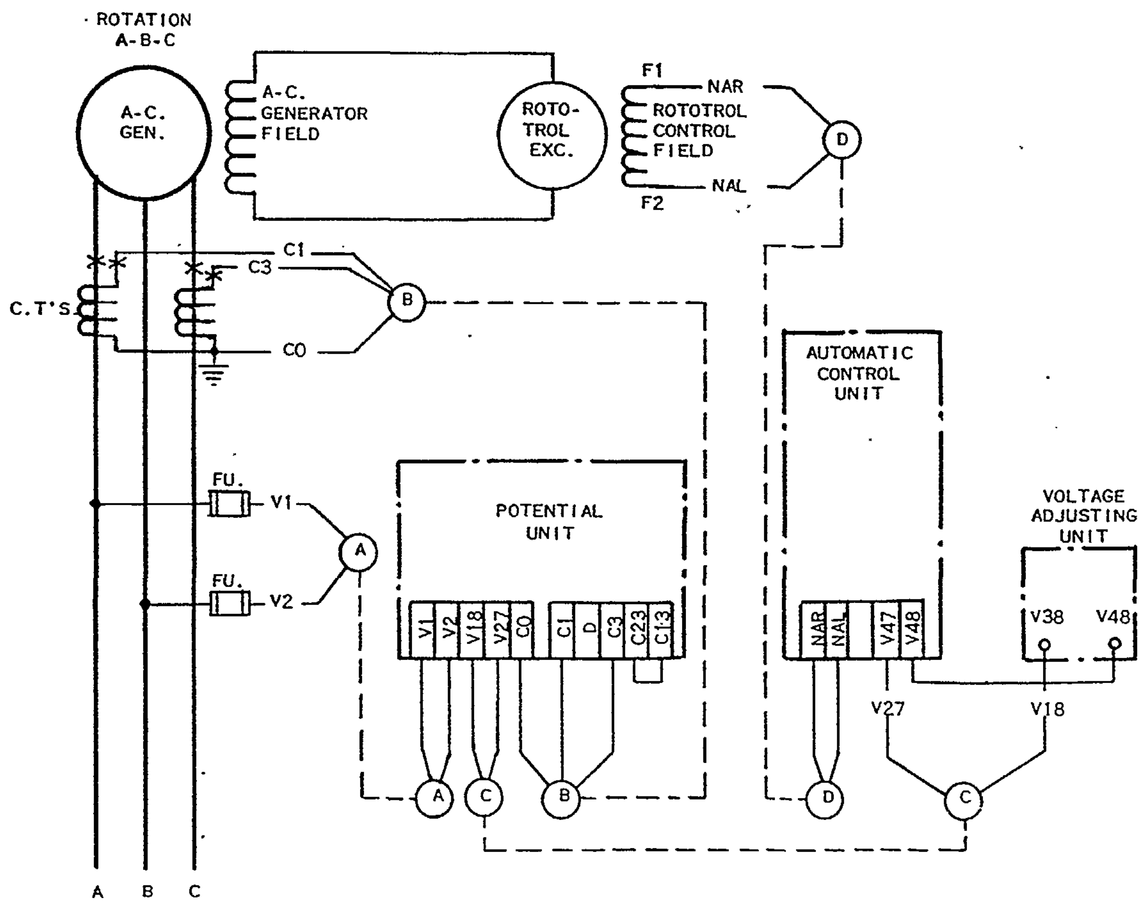


Fig. VR-14 — External Connection Diagram for Regulator (no standby unit)

SEC. C—PRINCIPLES OF OPERATION

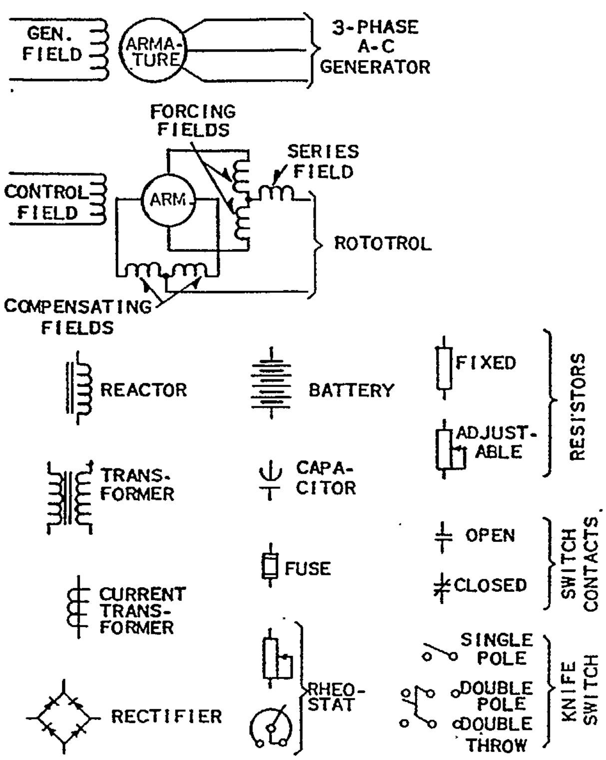


Fig. VR-15 — Diagram Symbols

4C1. OVERALL OPERATION OF SYSTEM

a) The terminal voltage of an a-c generator is controlled by adjusting its field excitation. In the ROTOTROL regulating scheme this is accomplished by a "static" regulator and a ROTOTROL exciter. The regulator is called, "static" because it has no moving parts.

b) Figure VR-14 shows the main units of this regulating scheme. The potential unit is energized by the a-c generator bus voltage and current. Its output is a single-phase a-c voltage which is used to energize the automatic control unit through the voltage adjusting unit.

c) The automatic control unit is a voltage-sensitive device, the output of which is a d-c voltage. The polarity and magnitude of this d-c voltage will be determined by the magnitude of the impressed a-c voltage.

d) The control signal, or output of the automatic control unit, is impressed upon the ROTOTROL exciter control field. The ROTOTROL exciter is a direct-current generator, which has very high power amplification; that is, a large output power can be controlled by a very small amount of power in the control field. Current in one direction through the ROTOTROL control field will cause its output voltage to rise, while current in the opposite direction will cause its voltage to decrease.

e) When the generator output voltage is exactly at the desired value, the output voltage of the automatic control unit will be zero. If the generator voltage increases above the regulated value, the d-c output voltage will be in the direction to decrease excitation voltage through the ROTOTROL exciter. When the generator voltage falls below regulated value, the d-c output voltage will be in the direction to increase the a-c generator excitation.

f) This shows how an incorrect value of a-c line voltage impressed on the automatic control unit, causes a corrective action to be applied to

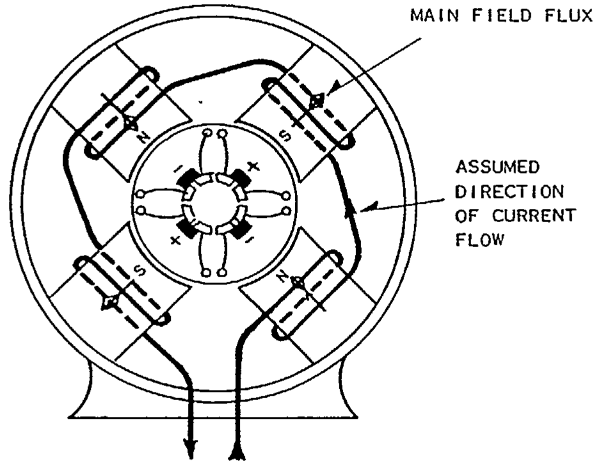
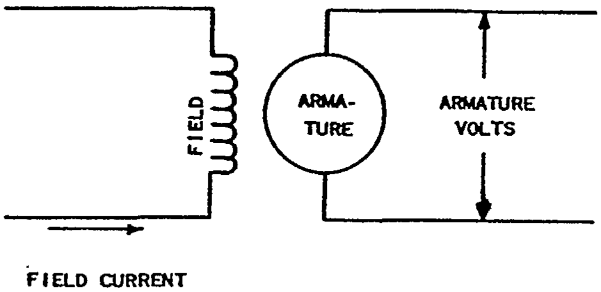
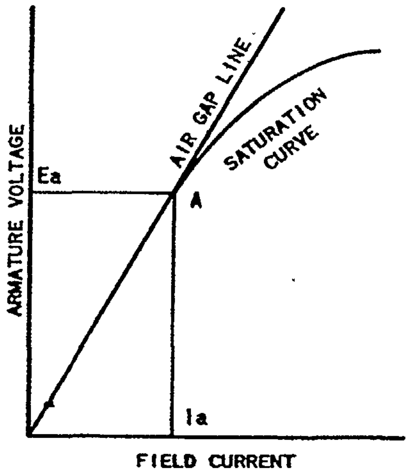


Fig. VR-16 — Field Winding Diagram of Conventional D-C Generator



D-C GENERATOR FIELD AND ARMATURE
(a)



TYPICAL D-C GENERATOR SATURATION CURVE
(b)

Fig. VR-17 — D-C Generator Schematic Diagram and Saturation Curve

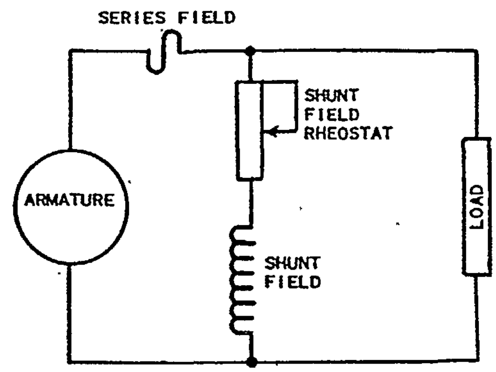
the a-c generator excitation system. The following paragraphs explain the individual units in detail.

4C2. ROTOTROL EXCITER

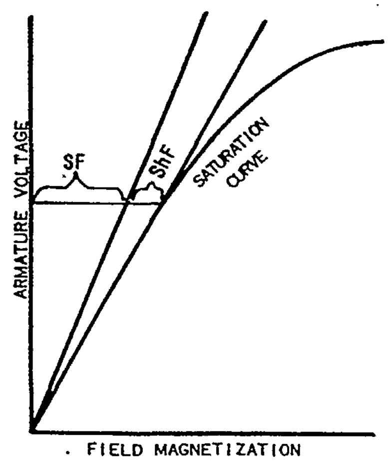
a) The ROTOTROL exciter is a four-pole, d-c generator of special design. The major features which distinguish the ROTOTROL exciter from a normal exciter are the special field windings and the laminated-steel frame.

b) The ROTOTROL exciter can be explained by reference to a conventional d-c generator which has only a single field winding as shown in Fig. VR-16. Field and brush polarity are shown on this figure. This figure shows a single field circuit that may be excited or energized in a number of ways. It may be connected in series with the armature and excited from armature current, as a series field; or across the armature and excited from the armature voltage as a shunt field. Another possibility is to excite the field from a separate source of voltage. It may be used to represent either the ROTOTROL series field or its shunt field.

c) Only a few slots, armature conductors and commutator segments are shown in the figure.



D-C GENERATOR SCHEMATIC
SHOWING SERIES AND SHUNT FIELDS
(a)



SATURATION CURVE FOR D-C GENERATOR SHOWING EXCITATION FROM SERIES AND SHUNT FIELDS.
(b)

Fig. VR-18 — D-C Generator Schematic Diagram and Saturation Curves (showing shunt and series field characteristics)

A large number of slots, etc., will be used in the machine but showing them on this figure would unnecessarily complicate it.

d) A schematic diagram for the d-c generator is shown in Fig. VR-17 (a). If this generator is driven at constant speed, its armature voltage will vary with field current as shown in Fig. VR-17 (b). For field current up to the value "Ia" of the figure corresponding to part "A" on the saturation curve, the voltage is proportional to field current. At field currents above this value the iron becomes "saturated" and additional field current is less effective in producing voltage.

e) The ROTOTROL exciter is operated over an armature voltage range corresponding to the region below "A" of the saturation curve. This permits "tuning" of the machine. A ROTOTROL is said to be tuned when it has self-energized field windings such that for any armature voltage the flux produced is just sufficient to sustain that voltage. Such a circuit is illustrated in Fig. VR-18 (a). In this circuit the load current passes through the series field which provides part of the field magnetization corresponding to "SF" in Fig. VR-18 (b). The remaining required magnetization is obtained by proper adjustment of the shunt field rheostat. When adjusted properly the two fields together will supply all of the field magnetization required up to the voltage where the saturation curve is no longer linear. These two fields are conventional four-pole fields as the one shown in Fig. VR-16.

f) The "WRN-11" regulator output power is not sufficient to give the desired rate of change to the ROTOTROL exciter voltage by energizing a normal main field winding. Thus, practical use of a phenomenon, which is suppressed in the ordinary d-c generator, is utilized in this ROTOTROL. This phenomenon is associated with the unbalance of voltage generated in the armature of a generator when the magnetic flux densities through its field poles are not equal. With the proper type of armature winding this difference in voltage generated will appear between brushes of like polarity. For instance, in the 4-pole ROTOTROL exciter, strengthening one south pole and weakening the other south pole with a special field winding, will cause a voltage to appear between the two positive brushes. This winding is called the "control field" and is shown in Fig. VR-19 (a). The field and brush polarities produced by the control field winding are shown for a low-voltage condition where the control signal is to "raise". The control field may be of either polarity, depending upon the signal received from the static regulator.

g) The voltage between the two positive brushes, produced by the control field winding, is used to energize another special field called the "forcing field". This field is shown in Fig. VR-19 (b). It acts to increase the flux in each pole, or decrease the flux in each pole, depending upon the polarity of the control field. In Fig. VR-19 (b) it is shown as increasing the flux in each pole, thus raising the generated voltage.

h) The flow of forcing current through the armature winding causes an armature reaction reducing flux in one north pole and increasing flux in the other. This causes a voltage to be generated between the negative brushes. If unopposed, the resulting current flow between the two negative brushes, would cause an armature reaction in opposition to the control field. This opposition would greatly reduce the effect of the control field if not compensated for in some way. The coils shown in series with forcing fields in Fig. VR-19 (c), called "compensating coils", oppose this armature reaction due to forcing current. The compensating coil fields then act to hold the voltage between the negative brushes, and the armature reaction which would oppose the control field, to a minimum.

i) A group of fields are connected in series between the negative brushes. They are compensating fields that operate similarly to the compensating fields mentioned above. They are shown in Fig. VR-19 (d).

j) Fig. VR-20 shows all of the fields mentioned above. The fields are practically in the same order on this figure as they are on the machine. A slight change has been made for simplicity. The poles are shown unduly long to give sufficient space to clearly show individual fields. The polarities, current and flux directions are those resulting from a "raise" control signal.

k) The ROTOTROL exciter load current as well as the unbalanced currents must flow through the forcing and compensating fields. The coils are wound on the field poles in such a direction that

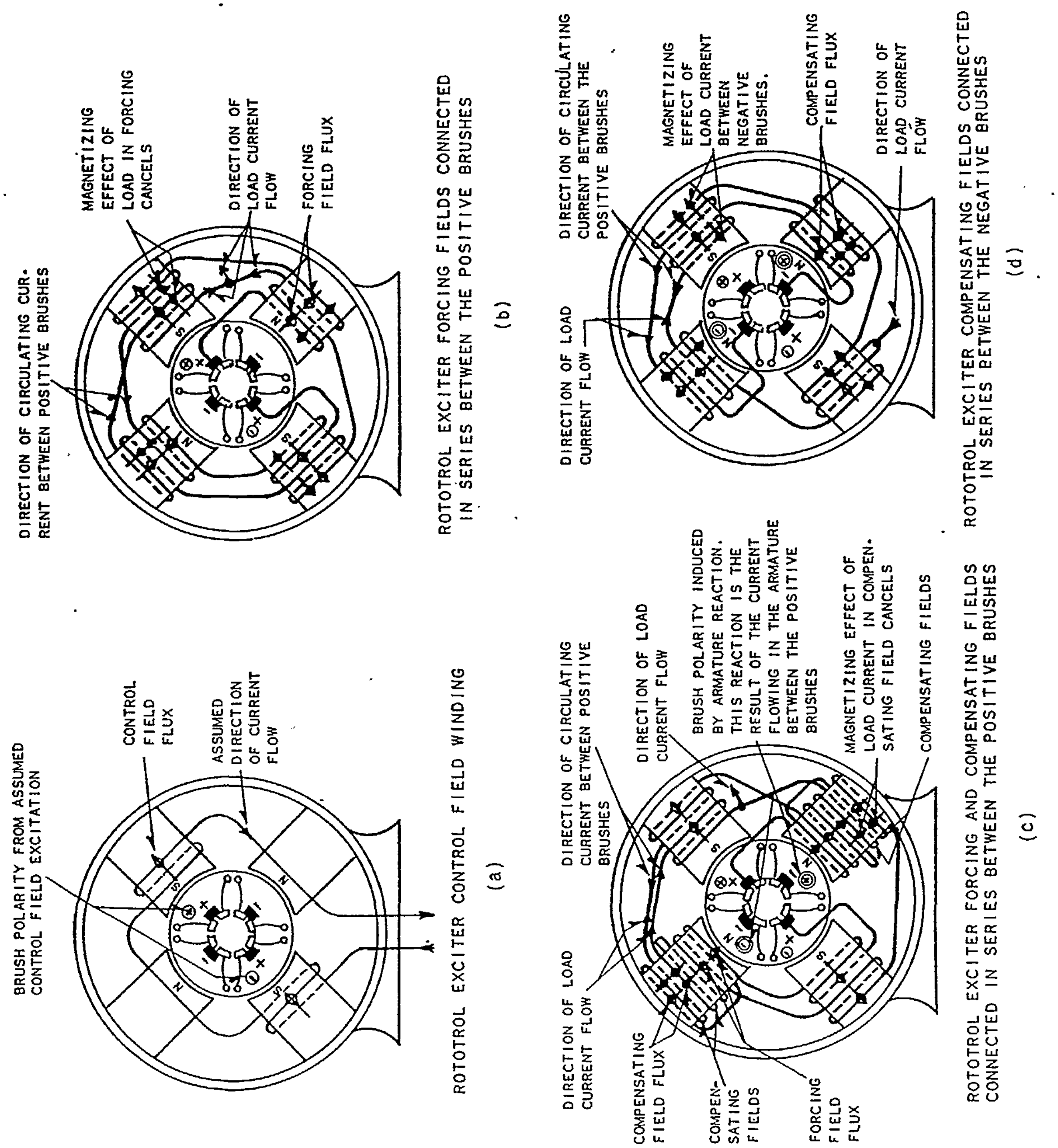


Fig. VR-19 — Field Winding of ROTOTROL Exciter

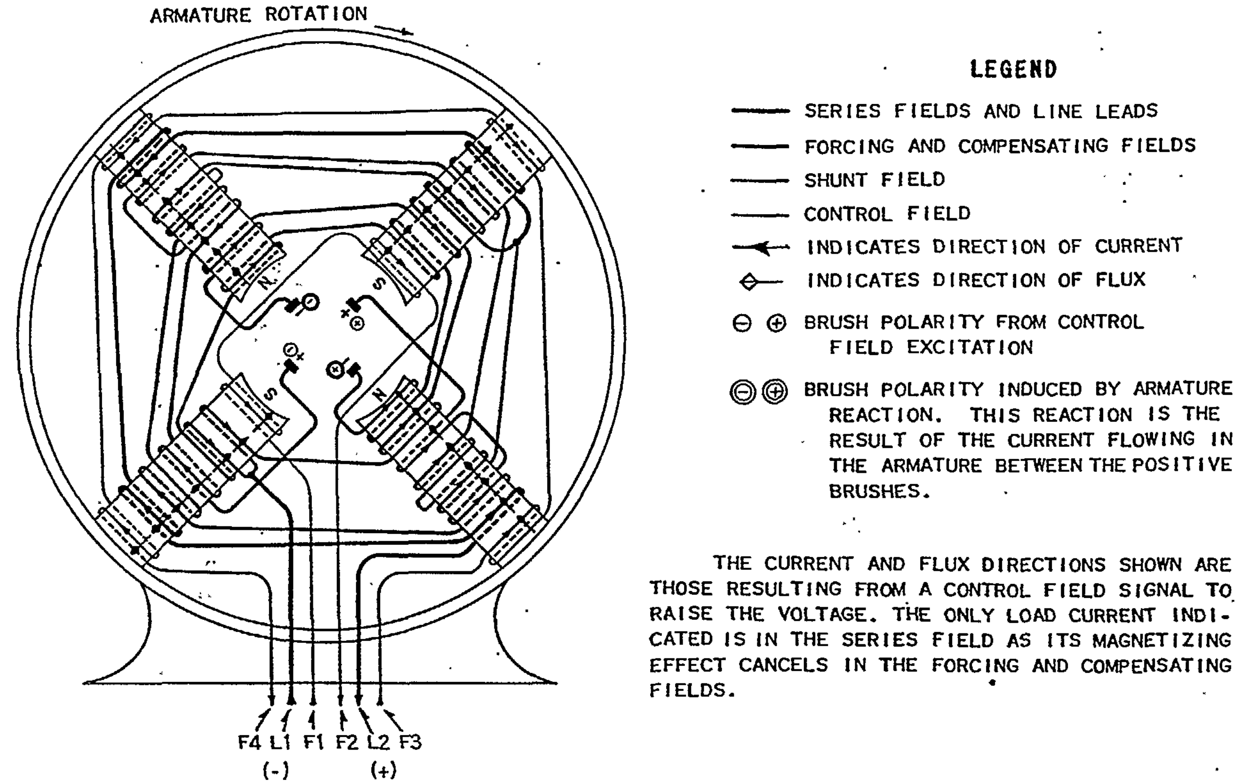


Fig. VR-20 — Schematic Diagram of ROTOTROL Exciter (showing all fields except interpole fields)

the load current cancels so far as magnetizing effect is concerned, while the magnetizing effects of the unbalance currents add. This can readily be seen by studying Figs. VR-19 (b), (c) and (d).

l) In addition to the field windings described above a set of commutating pole windings are included in the ROTOTROL exciter. No diagram is included to show them. These windings produce the proper magnetic flux in the commutating poles to assist commutation of the current in the armature. During the time that a commutator segment passes under a brush, the current passing through the coil connected to that segment must be brought to zero and reversed. If the current is not reversed before the commutator segment emerges from the brush edge there may be sparking and damage to brushes and commutator. The commutating pole flux produces the necessary voltage in the armature coils to cause this reversal in current. For additional information on the interpole windings, refer to Chapter 3, "Rototrol Exciter, Commutation".

m) The overall operation of the ROTOTROL exciter is as follows:

1. Starting with the voltage at normal, no appreciable current will flow in the control winding. Thus, as a result, no unbalanced current will flow, in the forcing fields.

2. When the voltage of the a-c generator drops, due to an increase in load, the regulator produces a current in the ROTOTROL control field in the "raise" direction. This strengthens one south pole and weakens the other. The resultant voltage unbalance causes a current to flow in the forcing fields connected between the positive brushes. This current flowing through the forcing fields on all four poles raises the flux, and thus the ROTO-

TROL exciter output voltage. When the a-c generator field current has been raised to the proper value, producing normal a-c generator voltage, the output of the regulator to the ROTOTROL control field will decrease to approximately zero. As a result, the forcing field current will also fall to a small value. The ROTOTROL series and shunt self-energizing fields will sustain the output voltage at the new condition.

4C3. VOLTAGE REGULATOR

a) THE AUTOMATIC CONTROL UNIT will be explained first because it is the voltage-sensitive element and this is the heart of the regulator.

1. Fundamental Concepts. A review of some of the basic parts used in building up an electrical device will be included here to assist in comprehending the automatic regulator operation.

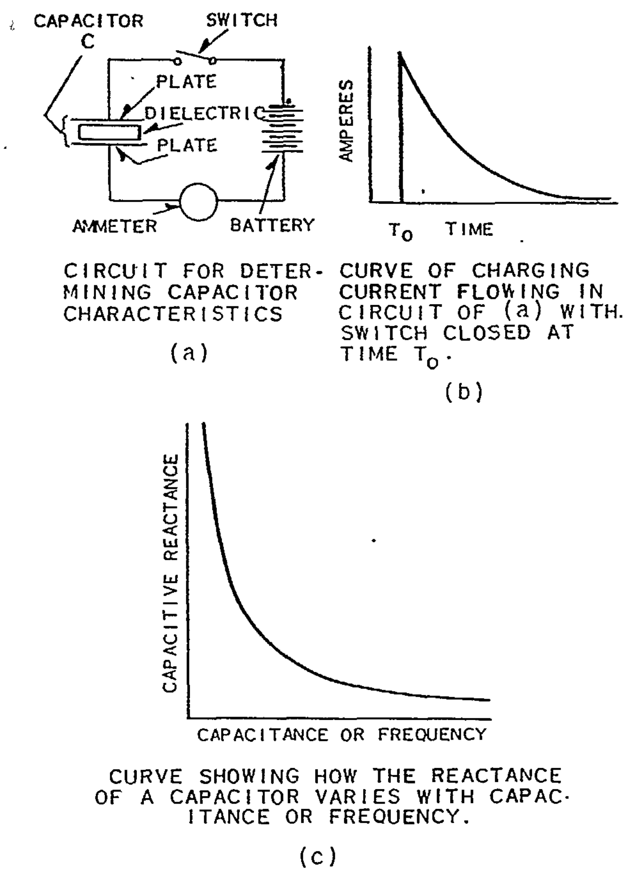


Fig. VR-21 — Capacitor Characteristics

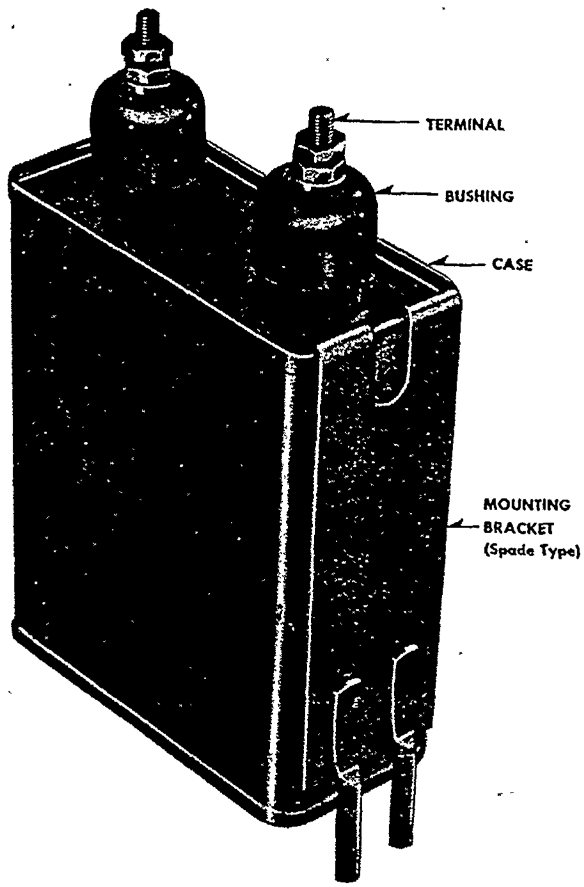


Fig. VR-22 — Condenser

a. Capacitor.

1. A capacitor is made up of two conducting surfaces separated by an insulator called a "dielectric". A property of a condenser is that even though no current can flow through it, it can absorb and hold a charge or quantity of electricity. Thus, when a direct-current voltage is applied across a condenser, a current will appear to flow for a short time. This current is called the charging current (See Figs. VR-21 (a) and (b)). The magnitude of this current will depend upon the physical properties of the condenser such as size of plates, their separation, the material used for a dielectric, etc., and of course, the voltage applied. These

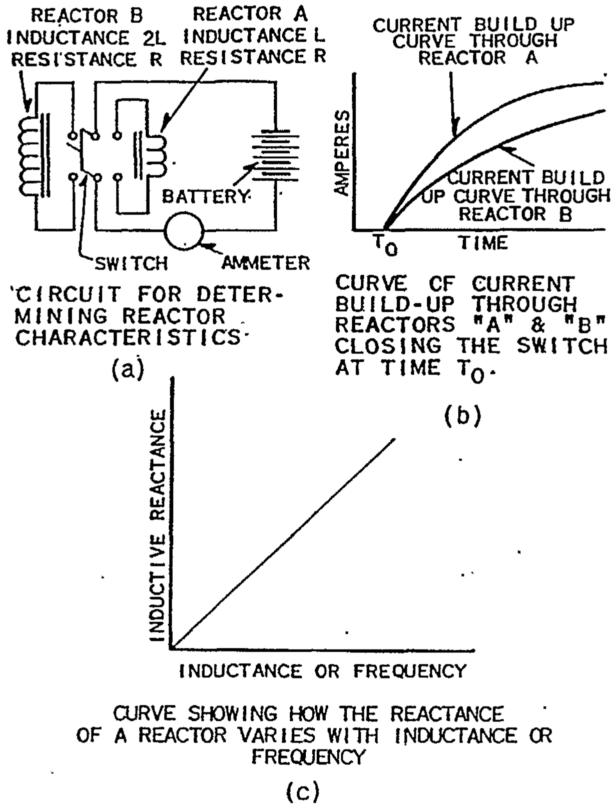


Fig. VR-23 — Reactor Characteristics

physical properties determine the characteristic known as capacitance. Capacitance will be discussed more later.

2. When an alternating voltage is applied to the plates of a condenser, it charges the plates in one direction or polarity, then discharges and recharges in the other direction. Thus, a capacitor appears to offer a path for alternating-current flow.

3. The more rapidly the voltage applied to a capacitor alternates, the greater will be the current flow with the same voltage applied. Thus, the higher the frequency, the lower will be the reactance of a capacitor. The reactance is a measure of the opposition offered to current flow, or a kind of "resistance". Also the greater the capacitance, the less will be the reactance of the capacitor. Capacitance is expressed in "farads" or more often in the more practical unit of "microfarads". The properties we are concerned with primarily are: (a) a capacitor offers a definite opposition to the flow of current; this is known as capacitive reactance and (b) the capacitive reactance of a capacitor depends upon its capacitance and the frequency of the applied voltage.

4. The manner in which reactance varies with capacitance or frequency is shown in Fig. VR-21 (c).

5. Fig. VR-22 shows a typical capacitor ready for installation. A terminal is brought out from each plate for circuit connections.

b. Reactor.

1. A simple reactor is merely a coil of wire. This coil has a property known as inductance. Inductance is a property similar to mechanical inertia. That is, the inductance will oppose any change in current through the coil. Thus, when a direct-current voltage is applied to the coil, (See Fig. VR-23 (a), the current will build up as shown in Fig. VR-23 (b)).

2. Two curves are shown in Fig. VR-23 (b). Comparison of these curves shows how the current builds up more slowly through a larger inductance if the circuit resistance remains uncharged. Thus, increasing the inductance increases the reactor's opposition to current flow. In other words, in-

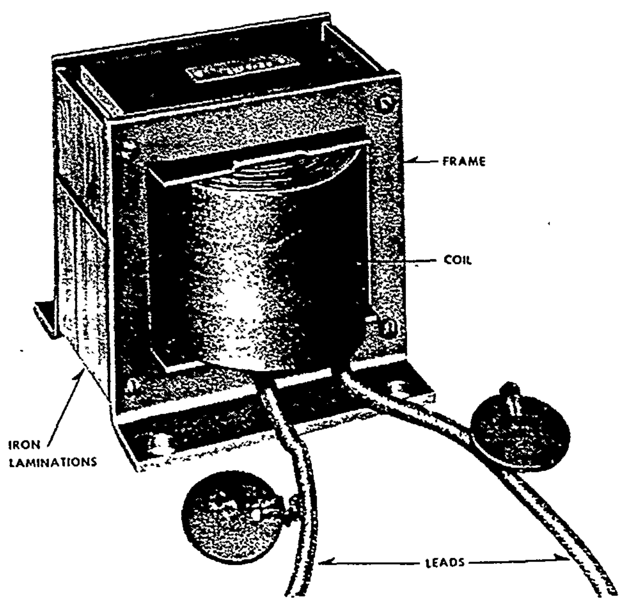


Fig. VR-24 — Harmonic Reactor

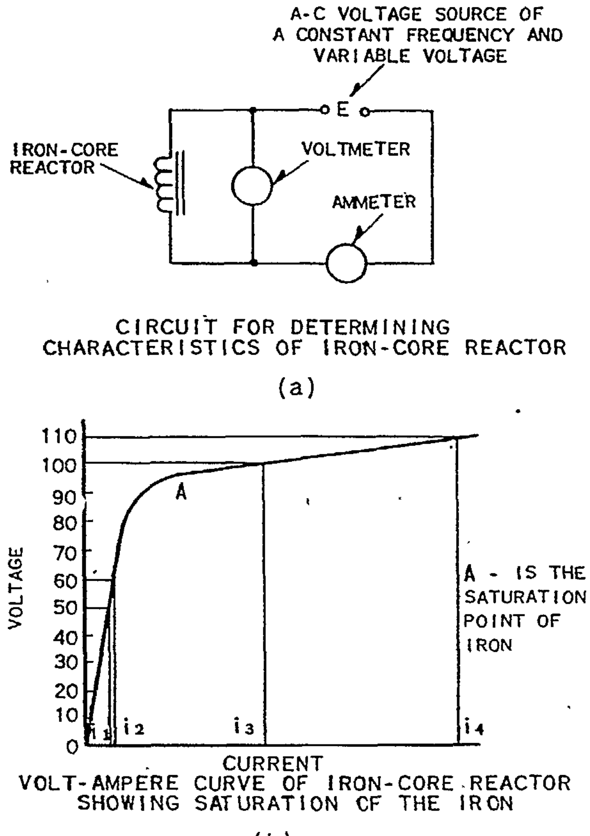


Fig. VR-25 — Characteristics of an Iron-Core Reactor

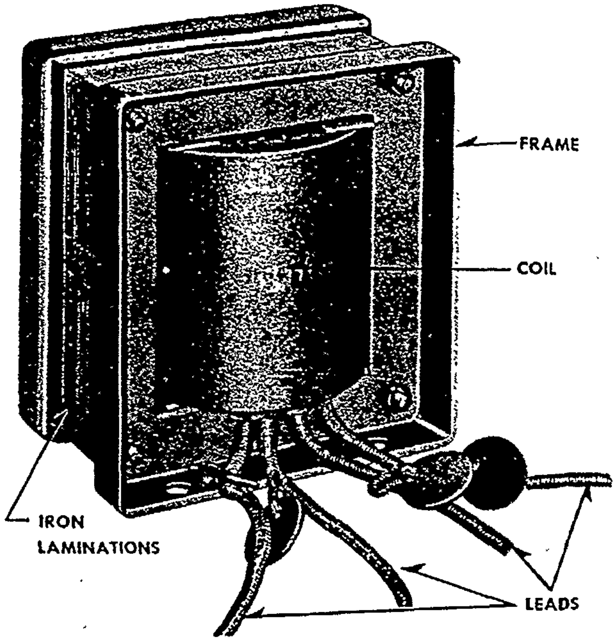


Fig. VR-26 — Saturating Reactor

creasing the inductance increases the inductive reactance.

3. The inductance of the reactor depends upon the number of turns on the coil and the material used for the "flux" path. Iron is usually used for the flux path and the kind of iron alloy as well as the amount and shape has effect upon the inductance.

4. When an alternating voltage is impressed upon a reactor, an alternating current will flow through it. Since this voltage of one polarity exists only for a short time, the current will build up only a short way on the curve of Fig. VR-23 (b). Thus, the greater the inductance of a reactor, the lower will be the current resulting from a certain alternating voltage.

5. Another feature is that as the frequency is increased, less time is allowed for the current to rise. Thus, the higher the frequency the greater the opposition to current flow or the greater the inductive reactance.

6. To review, the inductive reactance of a reactor depends upon the inductance and the frequency. The manner in which the inductive reactance varies with inductance and frequency is shown in Fig. VR-23 (c).

7. Fig. VR-24 shows a typical reactor. The coil and iron are indicated as are the leads used for circuit connections.

c. Saturated Reactor.

1. A reactor that has an iron core will have much more inductance than the same coil without the iron. However, if the voltage across the reactor coil is increased, the current through the coil and the voltage across it will be proportional only for a limited range. Fig. VR-25 (a) shows a circuit that may be used to investigate the relationship between voltage and current of an iron core reactor. As the voltage (E) of this figure is varied, the voltmeter and ammeter are read and recorded. Fig. VR-25 (b) shows a typical curve determined in this manner.

2. This reactor has an unusual property in the saturated region. Here a slight change in voltage will result in a large change in current. This is indicated on Fig. VR-25 (b). Thus a change in voltage from 50 to 60 per cent results in a small change in current flow from i_1 to i_2. An equal change in voltage from 100 to 110 per cent will result in a current change from i_3 to i_4 which is much greater than the change from i_1 to i_2. This property is utilized in the regulator as will be shown later.

3. The saturating reactor used in the regulator is shown in Fig. VR-26.

d. Rectifier.

1. The control field of the ROTOTROL exciter requires a direct-current voltage to control the exciter output. Since the regulator is energized entirely by alternating current, a device for changing alternating current to direct current is necessary. This device is a rectifier.

2. The rectifier is made up of an assembly of rectifying discs. Each disc has the property of permitting current to flow through it in only one direction. Actually, a negligible current does flow in the opposite direction. When E_1 of Fig. VR-27 is positive, current flows through section 1 of the rectifier, through the load, then returns to line E_2 through section 3. During the other half of the a-c cycle when E_2 is positive, sections 4 and 2 carry current. This results in an unidirectional or d-c current in the load.

3. Figure VR-28 shows a rectifier with a-c and d-c terminals indicated.

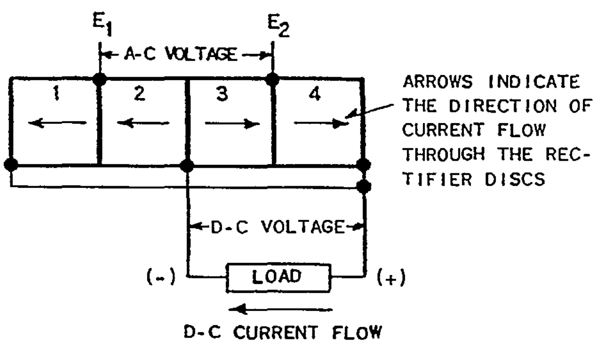


Fig. VR-27 — Principle of Rectifier Operation

2. The Voltage Sensitive Circuit element consists essentially of two parallel circuit branches (See Fig. VR-29). One branch contains a capacitor and the other a saturating reactor. The volt-ampere curves of the two circuit elements are both shown in Fig. VR-30. The curve of the reactor illustrates how its current increases more rapidly than voltage. It will be noted that currents through the two branches are equal at only one value of voltage. This is called the balance point of the two impedances. The operation of the voltage regulator depends upon the fact that when the voltage increases above this point, the current flowing through the reactor is greater than the current through the capacitor. When the voltage decreases below the balance point, the capacitor current is greater. When this unbalance occurs a current will flow in the ROTOTROL control field. This will raise or lower the exciter voltage, thus adjusting the a-c generator excitation until its voltage satisfies the balance point of the regulator.

a. The load resistances (m) and (p) of Fig. VR-29 are assumed to be identical. When the a-c voltage is the value (E), as shown in Fig. VR-30, the current flowing in load (m) is equal to the current in (p). When the line voltage is the value (E-V), a greater current will flow in the reactor branch. In other words, a higher d-c voltage will appear across (p) than (m). If the a-c voltage is the value (E-V), the opposite condition of a lower voltage on (p) will occur.

b. Fig. VR-31 (a) shows the d-c terminals of both rectifiers of Fig. VR-29 connected in series through a resistor. This resistor is shown as a uniform resistor between the rectifiers to simplify the vector diagram of Fig. VR-31 (b). In this

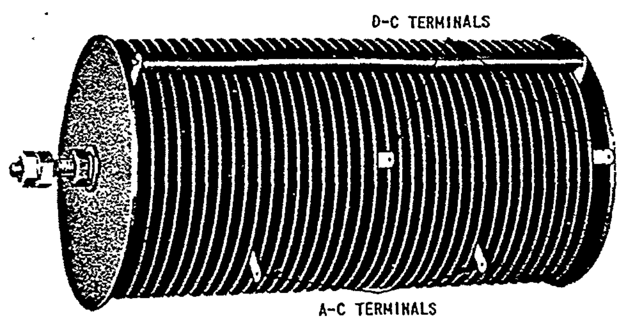


Fig. VR-28 — Selenium Unit (Rectifier)

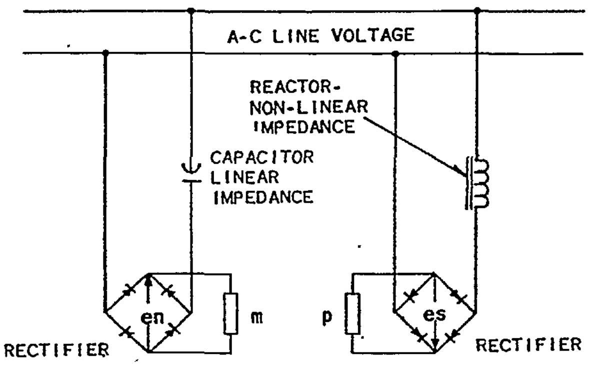


Fig. VR-29 — Simplified Voltage-Sensitive Circuit

figure, d-c voltage is plotted vertically against resistor length horizontally. Thus, the voltage indicated at any point in the vector diagram is the voltage existing a proportional distance along the resistor from the reference. Since (a-f) on this diagram is drawn the same length as the resistor, vector (E_{hi}) is the voltage of point (i) above the reference (h).

c. For the assumed balanced condition where (e_s) is equal to (e_n), the points (c) and (g) coincide on the vector diagram. However, should (e_s) become larger than (e_n), (c) and (g) would no longer coincide as is indicated by the dashed voltage gradient line. In this case (g) will be positive with respect to (c). The reverse will occur with a lower voltage on (e_s) than on (e_n).

3. The Automatic Control Circuit, Fig. VR-32, is a combination and modification of the circuits shown in Figs. VR-29 and VR-31 (a). The elements added are:

a. An Insulating Transformer I.T. (shown in the capacitor branch).

This transformer is necessary in one branch since the d-c rectifier terminals are connected together, and a common a-c source is used for both branches of the circuit. If this transformer were not used, it would be possible to have a near short-circuit across the a-c line. The current under this condition would be limited only by the forward resistance in two rectifier legs plus the

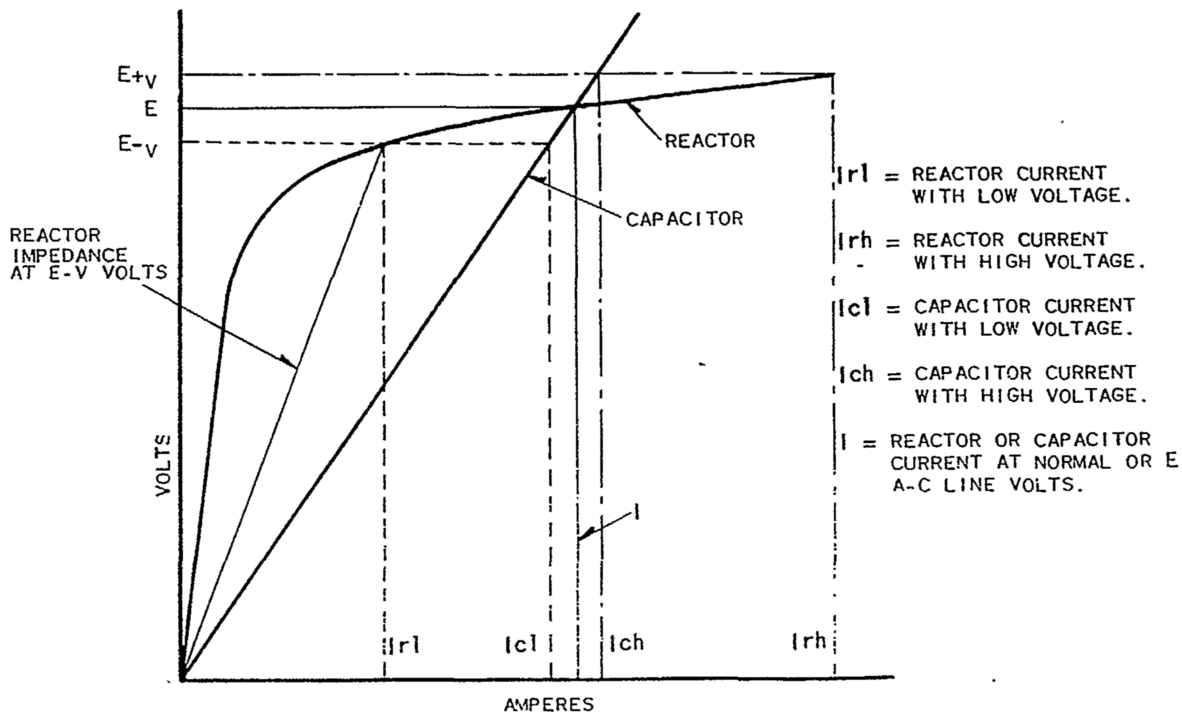


Fig. VR-30 — Volt-Ampere Characteristics of a Capacitor and a Saturated Reactor

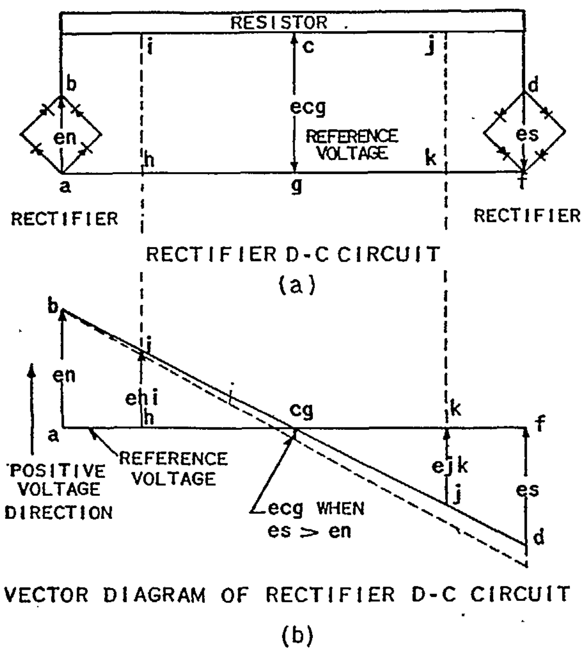


Fig. VR-31 — Schematic and Vector Diagrams of a Rectifier D-C Circuit

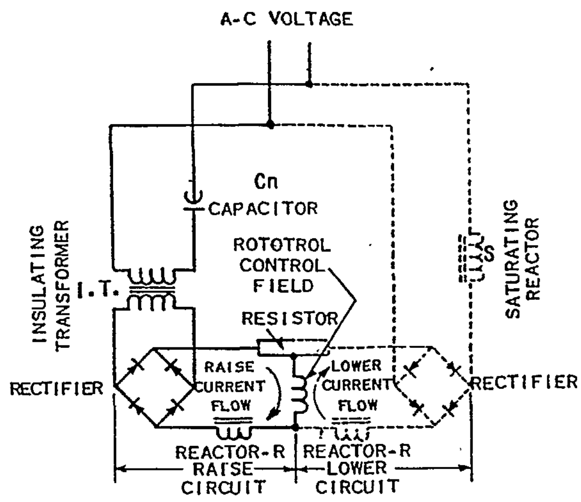


Fig. VR-32 — Voltage-Sensitive Circuit of Regulator

small resistance in one side of the d-c circuit. The use of this transformer isolates the a-c line from the rectifier in one branch. This eliminates a metallic path between the two a-c lines through the rectifiers.

b. The Reactors (R) (in the d-c circuit).

Their purpose is to reduce the a-c ripple in the d-c voltage.

c. The ROTOTROL Control Field.

This field raises or lowers the exciter output voltage. The control field is connected across terminals (NAR) and (NAL) of Fig. VR-33 which corresponds to (c) and (g) of Fig. VR-31 (a). The performance of the circuit can be explained for the following three conditions.

1. With the a-c voltage at a value corresponding to (E) of Fig. VR-30 on the a-c line terminals, no d-c voltage will appear across the ROTOTROL control field and thus no corrective action will result.

2. With high a-c voltage, say (E-V), on the line terminals, (NAL) will be positive with respect to (NAR) and will pass a current through the ROTOTROL control field in the "lower" direction. In other words, the "lower" current of Fig. VR-32 exceeds the "raise" current. This will be in the direction to cause the generator field excitation to be lowered and thus restore generator voltage to its proper value.

3. With low a-c voltage, say (E-V), on the line terminals, (NAR) will be positive with respect to (NAL) and pass a current through the ROTOTROL control field in the "raise" direction. In Fig. VR-32 the "raise" current exceeds the "lower" current. This will increase excitation and restore the a-c generator voltage to normal.

d. Fig. VR-33 shows the circuit of the static regulator in detail. The four units shown are the a-c generator unit, the potential unit, the voltage adjusting unit and the automatic control unit. The circuit of Fig. VR-33 incorporates the circuit of Fig. VR-32 in the automatic control unit together with a group of reactors and capacitors. These reactors and capacitors are used to provide frequency compensation as described in the following section.

4. Frequency Compensation is provided to maintain the generator voltage within a specified band as the generator speed or frequency is changed. The voltage-sensitive circuit consists of the reactor (S) in parallel with the capacitor (Cn) (See Fig. VR-33). Fig. VR-21 (c) and Fig. VR-23 (c) show how a capacitor and a reactor vary in reactance

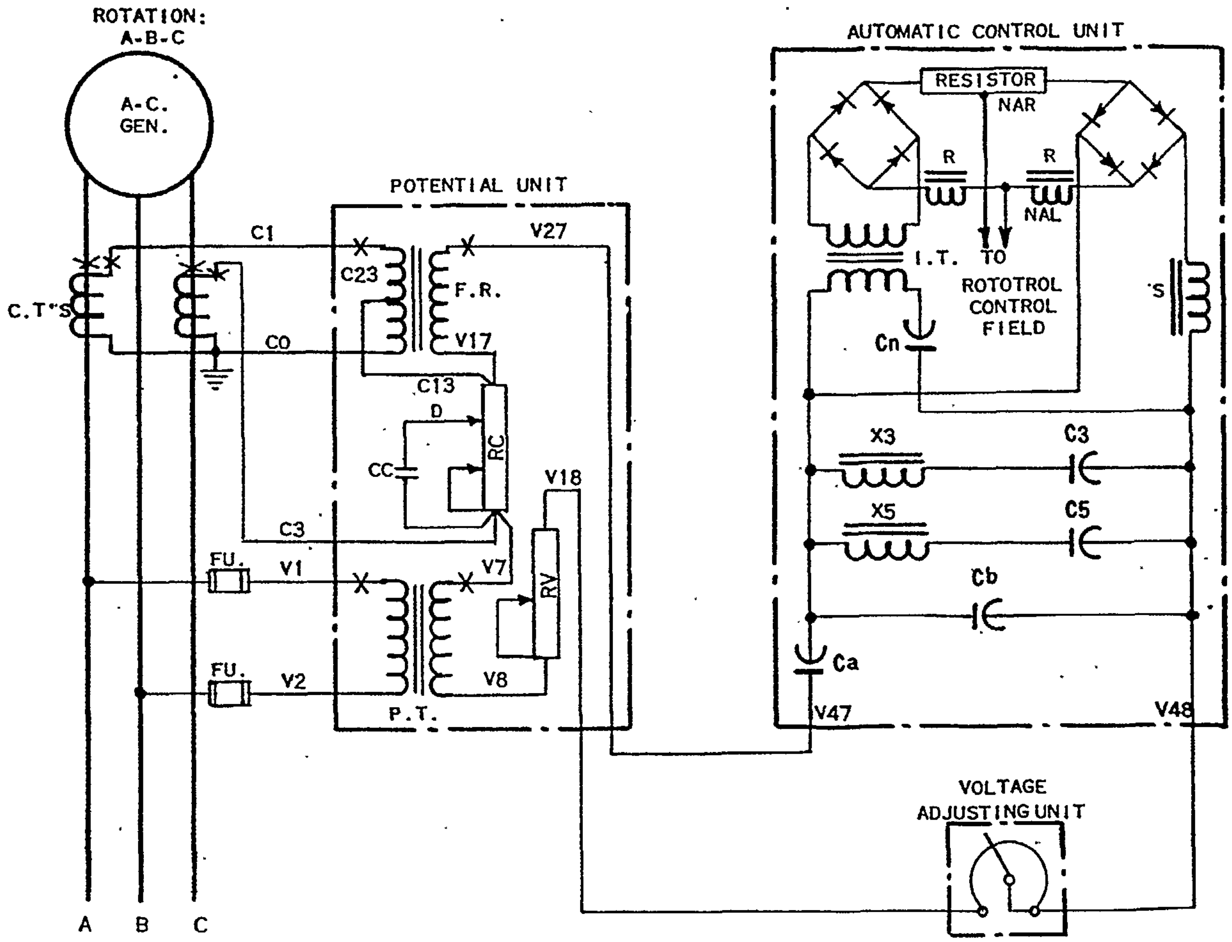


Fig. VR-33 — Schematic Diagram of Regulator (no standby unit)

with frequency. Since they vary in an entirely different manner, it is obvious that the circuit of Fig. VR-32 is sensitive to frequency. In other words, if frequency compensation is not provided, the regulated generator voltage will change as the speed of the generator changes.

a. In the "WRN-11" regulator, frequency compensation is introduced by means of a circuit between the a-c terminals of the generator and the voltage-sensitive circuit. The operation of this circuit may be explained as follows:

b. The effect of an increase in frequency when the voltage-sensitive circuit is operating at the balance point will be to increase the current in the capacitor branch and decrease the "lower" current in the reactor branch. This will cause a greater "raise" current to flow, which is the same effect as is caused by a decrease in voltage. In order to compensate for this effect it is necessary to increase the voltage across the voltage-sensitive circuit as the frequency increases. Correspondingly, the voltage across the voltage-sensitive circuit must be decreased as the frequency is decreased below normal. This kind of response can be obtained most easily by means of a series condenser of the proper value. This condenser (Ca) in Fig. VR-33, is of such a value that, together with the reactance of the circuit, primarily (F.R.), it will accurately compensate for frequency variations.

c. Electrically this is accomplished by the series element, the capacitor and reactance, experiencing a change in impedance as frequency varies. This impedance change results in a corresponding change in the voltage drop across them. This change in voltage drop added to the line voltage of varying frequency impresses the correct voltage in the voltage-sensitive circuit for that frequency.

d. Fig. VR-34 (a) shows the circuit elements lumped in boxes. This is done for convenience in showing the vector diagram to explain the frequency compensation more rigorously.

e. The vector diagram of Fig. VR-34 (b) includes the three conditions of low, normal and high frequency. The voltage across the voltage-sensitive network is used as the reference voltage. Its variation with frequency is clearly shown on this diagram. The capacitor and reactor vectors change in length with frequency as explained above.

f. The power factor of the voltage-sensitive network is a function of frequency. The angle between (V_{AB}) and (V_{BC}) is dependent upon the power factor of the voltage sensitive network. Consequently, the angle of (V_{BC}) with (V_{AB}) changes with frequency.

g. This diagram shows how the generator voltage (AE) remains constant with changing frequency.

5. Harmonic Filtering. The a-c current through the saturating reactor in the voltage-sensitive circuit is distorted (See Fig. VR-35 (b)). If this current were allowed to flow through the potential unit and frequency compensating circuit it would cause errors in the performance of these circuits. For this reason the capacitors (C3, C5 and Cb) and reactors (X3 and X5) are connected across the circuit. The values of these units are chosen so they tend to prevent the reactor current distortion from affecting the rest of the regulator circuit.

b) VOLTAGE ADJUSTING UNIT

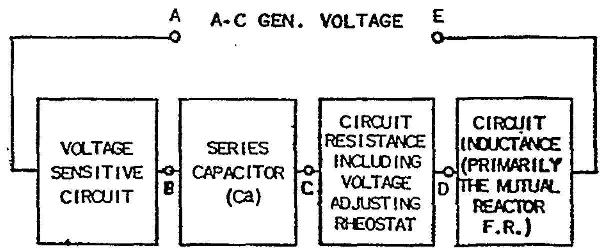
1. The voltage adjusting unit indicated in Fig. VR-33 and shown in Fig. VR-12, page 407, is a rheostat. Its function is to enable the operator to adjust the generator voltage to any desired value from 436 to 482 volts. The electrical operation of this rheostat can be explained as follows:

2. For a given frequency, a specific voltage must exist between (V-27 and V-48) of the automatic control unit to satisfy the regulator. Any deviation from this voltage will be corrected by the regulators in the manner described previously.

3. With the voltage adjusting rheostat, the resistance between the generator terminals and (V-47 to V-48) can be changed, causing a proportional change in voltage drop. This drop necessitates a change in the a-c generator voltage to produce the required voltage across (V-47 and V-48). Thus, the a-c generator voltage can be set to any operating value, by adjusting the rheostat.

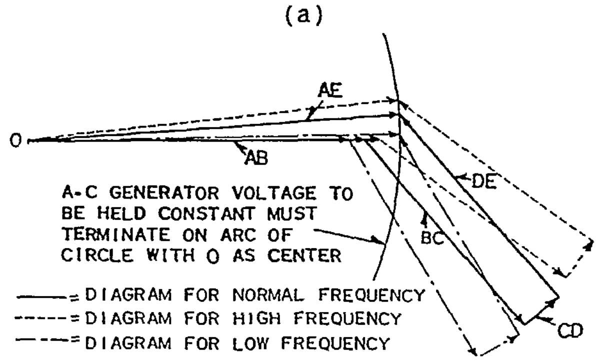
c) THE POTENTIAL UNIT receives its energy directly from the a-c generator bus. The unit consists of the following parts:

1. The Potential Transformer (P.T.) is a two-winding transformer that supplies energy to the entire circuit.



REGULATOR CIRCUIT ELEMENTS OF FIGURE 33 LUMPED FOR VECTOR DIAGRAM OF FIGURE (b).

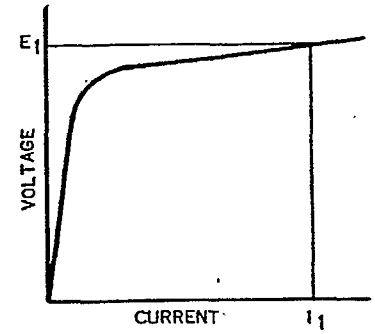
(a)



CIRCUIT VECTOR DIAGRAMS FOR DIFFERENT FREQUENCIES

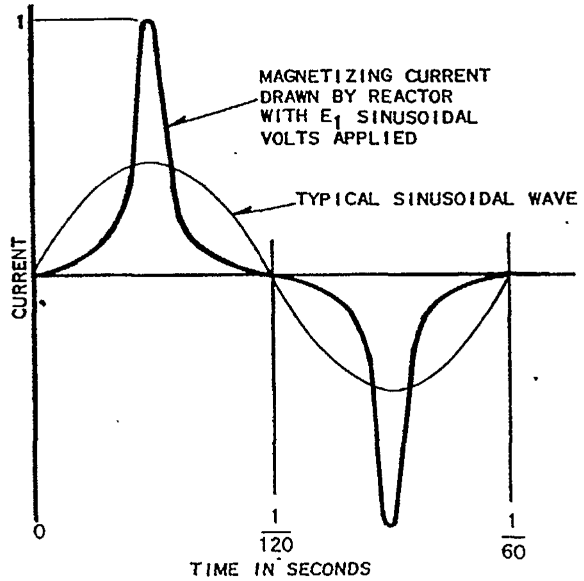
(b)

Fig. VR-34 — Frequency-Compensation Block and Vector Diagram



IRON-CORE REACTOR SATURATION CURVE
SEE FIGURE 25(B)

(a)



CURRENT DRAWN BY SATURATING REACTOR AS A RESULT OF APPLYING E_1 SINUSOIDAL VOLTS (60 CYCLES PER SECOND)

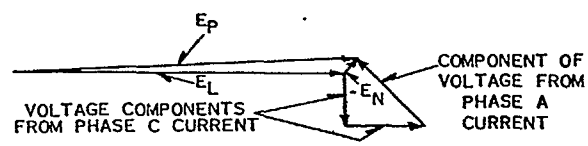
(b)

Fig. VR-35 — Saturating Reactor Curves

2. The Voltage Adjusting Resistor. (RV) performs electrically the same as the voltage adjusting unit explained in Paragraph b, page 421. It permits adjustment of the generator terminal voltage to the minimum desired value with the voltage adjusting unit shorted. It thus determines the location of the range of a-c generator voltage adjustment.

3. Positive-Sequence Filter for Three-Phase Response.

a. The automatic control unit used in the "WRN-11" regulator responds to single-phase voltage. Since the a-c generator load is frequently not balanced between the three phases the voltage drops in the windings may be different, thus, its three terminal voltages are not always equal. If the automatic control unit were connected across one phase of the generator only, that phase would be regulated for constant voltage. The other phase voltages would differ by the amount of the unbalance. In the "WRN-11" voltage regulator, a single-phase voltage is used, but a correction is introduced to compensate for unbalance. The resultant voltage



E_L = GENERATOR LINE VOLTAGE CONTAINS BOTH POSITIVE AND NEGATIVE SEQUENCE VOLTAGES THAT IS $E_L=E_P+E_N$.

E_P = POSITIVE SEQUENCE VOLTAGE IS OBTAINED BY SUBTRACTING E_N FROM E_L OR $E_P=E_L-E_N=E_P+E_N-E_N=E_P$.

CURRENT-PRODUCED VOLTAGE DROPS YIELD $-E_N$. THE REVERSE NEGATIVE SEQUENCE VOLTAGE. THE REVERSE VOLTAGE IS OBTAINED BY SELECTING THE PROPER CONNECTIONS. THEY ARE EXAGGERATED ON THIS DIAGRAM FOR CLARITY.

Fig. VR-36 — Vector Diagram of Positive-Sequence Filter

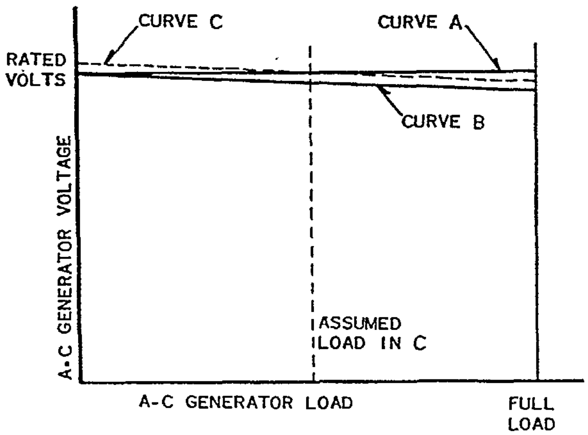
which is measured by the regulator may be considered as being proportional to a balanced three-phase voltage, called "positive-sequence voltage". This is the voltage actually generated in the machine windings.

b. Eig. VR-33 shows the two current transformers which energize the mutual reactor (F.R.) and resistor (RC). These elements are connected in series with the potential transformer (P.T.) to form a positive-sequence filter. Thus the voltage across (V8-V27) is proportional to the positive-sequence voltage of the generator and is not affected by voltage unbalance. This makes the regulator sensitive to the three-phase voltage rather than to only a single-phase voltage.

c. The mutual reactor (F.R.), as seen in Fig. VR-33 has a winding that is energized from both the (A and C) phase-current transformers. The flux produced by this current-transformer-energized winding induces a voltage in the other winding between (V17 and V27). This induced voltage is added to the drop in resistor (RC). Their sum is proportional to the negative-sequence voltage at the generator terminals (See Fig. VR-36). The negative-sequence voltage is the component of the three-phase voltage which represents the unbalance in voltage resulting from load unbalance. It is subtracted from the generator voltage to give the positive-sequence voltage across (V8-V27).

4. Parallel Operation of A-C Generator.

a. When generators are operated in parallel their kilowatt-load division will depend upon the prime movers. The reactive-load division will depend upon their field excitation or, in other words, their automatic regulators when they are used.



CURVE A = A-C GENERATOR VOLTAGE USING NO REACTIVE DROOP COMPENSATION IN REGULATOR.

CURVE B = A-C GENERATOR VOLTAGE USING REACTIVE DROOP COMPENSATION IN THE REGULATOR. GENERATOR LOAD ASSUMED TO BE AT RATED POWER FACTOR (0.8 LAG).

CURVE C = FOR ANY A-C GENERATOR LOAD THE CURVE B IS RAISED BY THE VOLTAGE ADJUSTING RHEOSTAT TO GIVE RATED VOLTAGE AT THE LOAD CONDITION AS SHOWN BY CURVE C.

Fig. VR-37 — A-C Generator Voltage Regulation Curves (showing effect of reactive-droop compensation)

b. The condition existing on two similar generators with unequal field currents is that the generator with the higher field current will have a greater voltage induced in its windings. If they are in parallel, the higher-voltage machine will force a current through the windings of both machines. This current, limited primarily by the impedance of the windings which are mostly reactance, is of a very low power factor. It will be leading in one machine and lagging in the other. This current is commonly known as circulating or cross-current, and the device to limit it as a cross-current compensator or reactive-droop compensator.

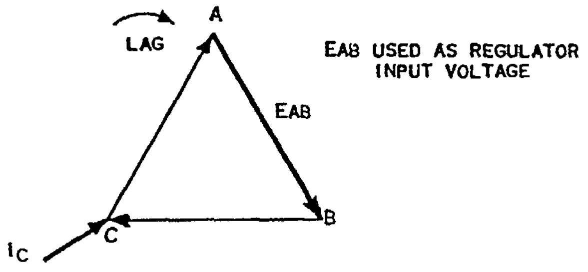
c. This compensator acts to reduce the voltage of a generator carrying lagging current. This reduction in voltage or "droop" with increase in inductive reactance load gives rise to the name "reactive droop compensator". Fig. VR-37 shows comparative voltage regulation curves with and without this compensator.

d. The resistor (RC) in the potential unit of the regulator is used as a reactive droop compensator. (RC) carries phase C current. The relationship between the regulator input voltage (E_{AB}) and the phase current (I_C) is shown in Fig. VR-38 (a). The drop in (RC) at unity power factor load is at 90^o to the regulator input voltage. The drop in (RC) has no effect here as is shown in Fig. VR-38 (b). The regulator responds to the sum of the generator voltage and the compensator drop as shown in Fig. VR-38 (b).

e. The effect of changing the load current at constant lagging power factor is shown in Fig. VR-38 (c). This diagram shows how the generator voltage is reduced as the lagging load current is increased. Increasing the value of resistance in RC will have a similar effect.

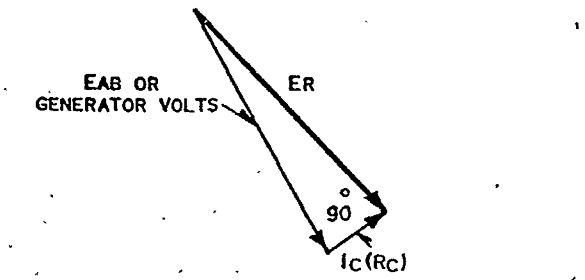
f. The effect of changing the power factor at constant load current is shown in Fig. VR-38 (d). This diagram shows how the generator voltage is reduced as load power factor lags.

g. With generators in parallel, the operation of the compensators will be to minimize any reactive current difference between the generators. Assume that two generators are operating in parallel supply-



VECTOR DIAGRAM OF A-C GENERATOR VOLTAGE SHOWING THE POSITION OF PHASE (C) CURRENT AT UNITY POWER FACTOR

(a)

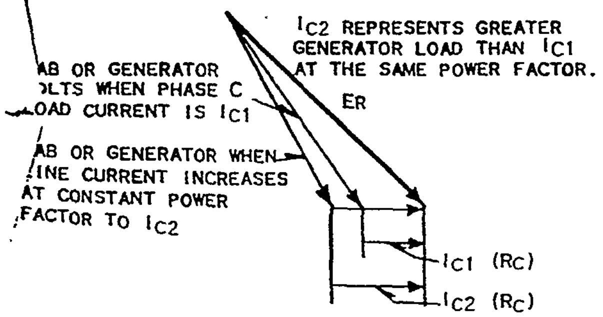


IC(RC) = VOLTAGE DROP ACROSS RESISTOR RC ENERGIZED BY PHASE C CURRENT SHOWN AT UNITY POWER FACTOR LOAD IN THE DIAGRAM. IT IS SHOWN EXAGGERATED FOR CLARITY.

ER = VOLTAGE TO WHICH REGULATOR RESPONDS AND WHICH IS HELD CONSTANT IN MAGNITUDE

VECTOR DIAGRAM SHOWING REACTIVE DROOP COMPENSATOR DROP AT UNITY POWER FACTOR

(b)



VECTOR DIAGRAM SHOWING OPERATION OF THE REACTIVE DROOP COMPENSATION AS GENERATOR LOAD CURRENT CHANGES AT CONSTANT POWER FACTOR.

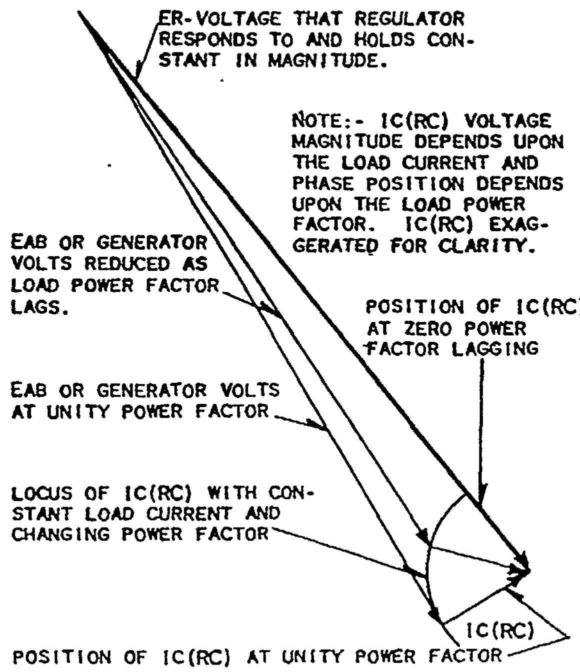
(c)

ing a lagging power factor load. While they are balanced, each will be supplying the same amount of reactive load. The real load will not be considered here as the regulator has no control over kilowatt load. If an unbalance should occur for some reason, the conditions and action will be as follows:

1. Assume generator A to suddenly receive an increase in excitation and generator B, a decrease in excitation.

2. Under these conditions generator A will be carrying more lagging current than generator B.

3. Generator A, since it is carrying more lagging current than before, will have its excitation reduced by the reactive-droop compensator as shown in Figs. VR-38 (c) and (d).



VECTOR DIAGRAM SHOWING OPERATION OF THE REACTIVE DROOP COMPENSATOR AS THE GENERATOR LOAD POWER FACTOR CHANGES AT CONSTANT LOAD CURRENT

(d)

Fig. VR-38 — A-C Generator Vector Diagrams (showing various power factor conditions)

4. Since generator B is carrying less lagging current than before, its compensator will allow its excitation to increase.

5. This action will restore balance since the generator with low excitation had it increased and the generator with high excitation had it reduced.

6. Summary

Initial conditions: Gen. A - High excitation causing increased lagging current. Gen. B - Low excitation causing decreased lagging current.

Corrective Action: Gen. A - Compensator reduces excitation Gen. B - Compensator raises excitation.

Result: Gen. A and Gen. B each have the same excitation and equally divide the reactive currents.

h. In the "WRN-11" the reactive-droop compensator is the resistor (RC) in the potential unit. To introduce droop in the generated voltage with an increase in lagging load current, the contacts (CC) are closed, which shorts out resistance. The resistor drop I_c (RC) is subtracted from the line voltage as explained in paragraph c-3c,page 423. Thus, shorting out a portion of (RC) has the effect of adding a resistance drop to the line voltage.

d) MANUAL CONTROL UNIT

1. The manual control unit provides an alternate method of a-c generator voltage control. It will maintain essentially constant excitation voltage. For a constant a-c generator load, this will result in constant a-c voltage. Load changes will require adjustment of the manual control unit to provide constant output voltage.

2. The circuit of the manual control unit is illustrated in Fig. VR-39 (a). The principle of operation is based on the fact that the voltage across a rectifier unit remains essentially constant over a wide range of current. The rectifier (R1), in series with a fixed resistor, is connected across the ROTOTROL output. The voltage across this rectifier is compared with the voltage across the section of the potentiometer between the potentiometer tap and the positive line.

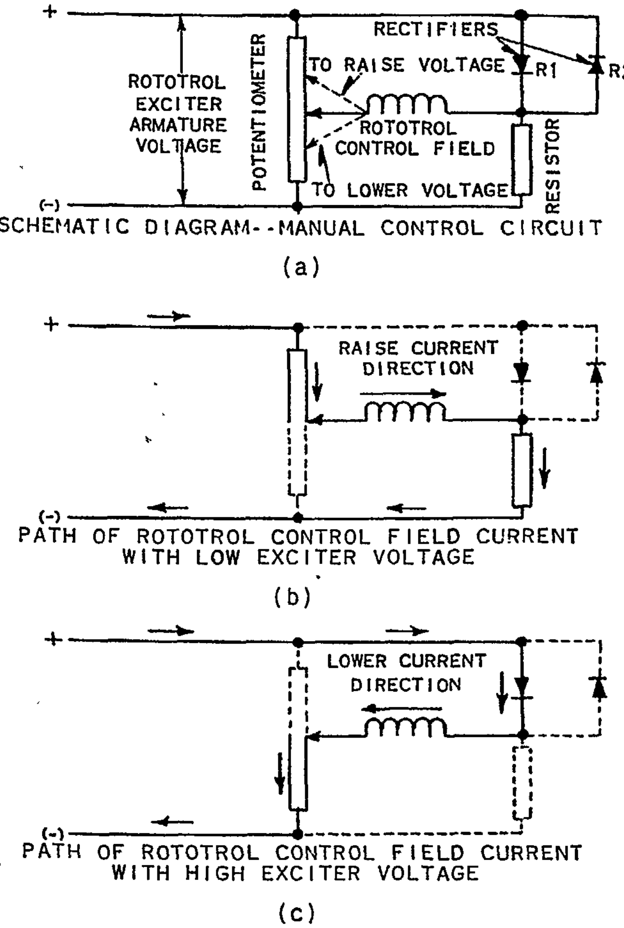
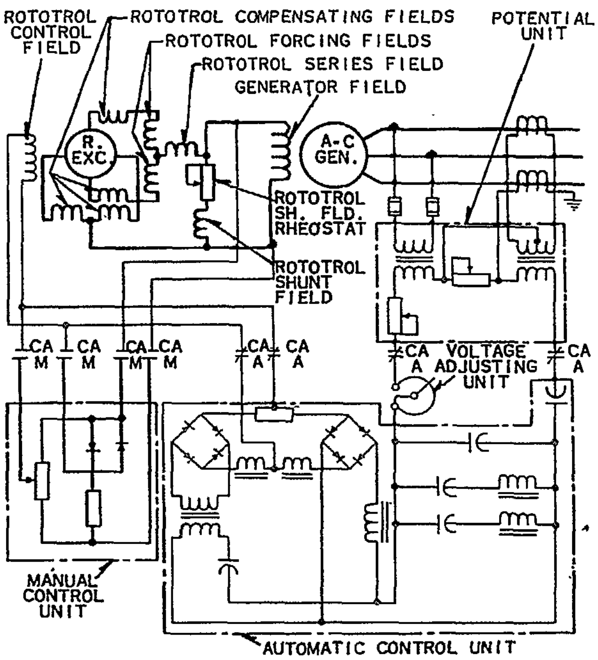


Fig. VR-39 — Schematic Diagrams of Manual Control Unit ("Raise" and "Lower" conditions)

3. The drop across any section of the potentiometer will vary with the exciter voltage. When the ROTOTROL armature voltage is such that the voltage across the specified section of the potentiometer equals the voltage across the rectifier (R1), there will be no current through the ROTOTROL control field and thus no tendency to change the ROTOTROL voltage, hence the a-c generator excitation. If the ROTOTROL voltage is low, the voltage drop across the section of the potentiometer is lower than the voltage across rectifier (R1). This will cause a current to flow through the ROTOTROL control field in the "raise" direction as shown in Fig. VR-39 (b). This control field current will cause the exciter voltage to increase, returning it to the original balanced value. An increase in exciter voltage will cause the opposite sequence



SCHEMATIC DIAGRAM OF VOLTAGE REGULATOR SYSTEM SHOWING MANUAL AND AUTOMATIC CONTROL UNITS. THE REGULATOR CONTROL SWITCH (CA) IS TURNED TO "AUTO" PLACING THE AUTOMATIC REGULATOR IN CONTROL. ALL ENERGIZED CIRCUITS ARE SHOWN IN RED.

Fig. VR-40 — Schematic Diagram Showing Automatic Operation

of events and result in return to normal voltage, see Fig. VR-39 (c).

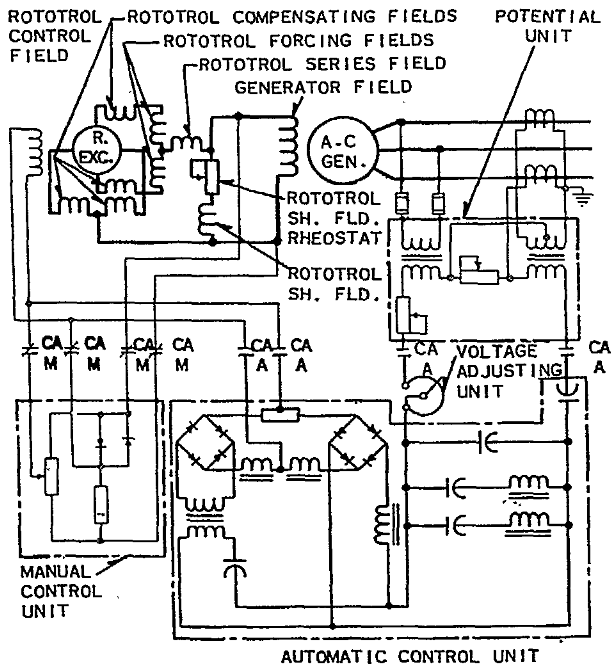
4. Rectifier (R2) enables the operator to control the a-c generator voltage with reversed polarity on the ROTOTROL.

5. Adjustment of the potentiometer tap permits a change in the exciter voltage. Under manual control the a-c generator voltage can be adjusted to any value from zero to the maximum determined by the saturation of the exciter, which is much higher than required by the specifications.

6. A photograph of the manual control unit is shown in Fig. VR-10, page 407. The two rectifier sections referred to in the above description are actually one rectifier stack with a tap. Reference to the diagram of Fig. VR-39 (a) will show how this is possible. The component parts are indicated on the photograph of Fig. VR-11, page 407.

e) WIRING DIAGRAMS

1. Fig. VR-40 shows a typical wiring diagram of the voltage regulator system. This figure shows all of the energized circuits in red for automatic voltage regulator control. The manual control circuit is shown as not energized. Turning the regulator control switch (CA) to MAN transfers the control from the automatic regulator to the manual control unit. This condition is shown in Fig. VR-41.

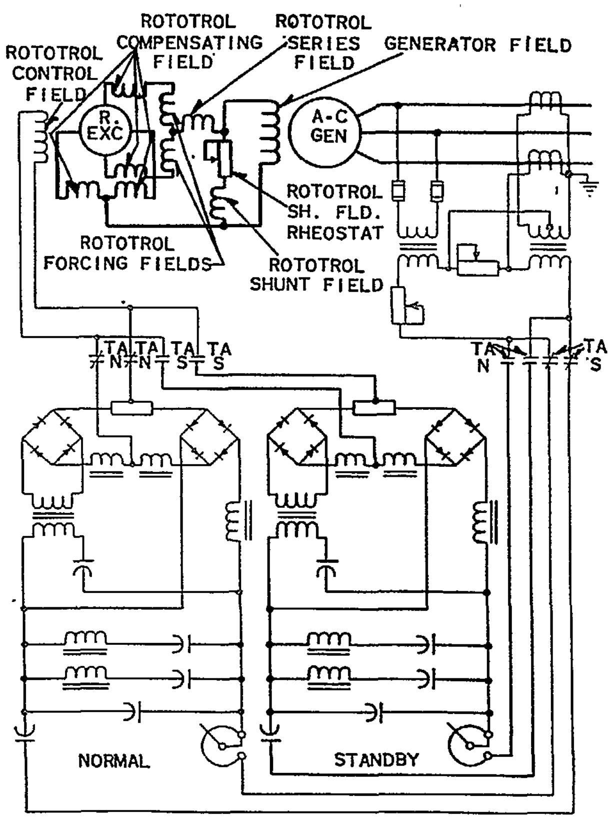


SCHEMATIC DIAGRAM OF VOLTAGE REGULATOR SYSTEM SHOWING MANUAL AND AUTOMATIC CONTROL UNITS. THE REGULATOR CONTROL SWITCH (CA) IS TURNED TO "MAN" PLACING THE MANUAL CONTROL UNIT IN CONTROL OF THE ROTOTROL EXCITER VOLTAGE. ALL ENERGIZED CIRCUITS ARE SHOWN IN RED.

Fig. VR-41 — Schematic Diagram Showing Manual Operation

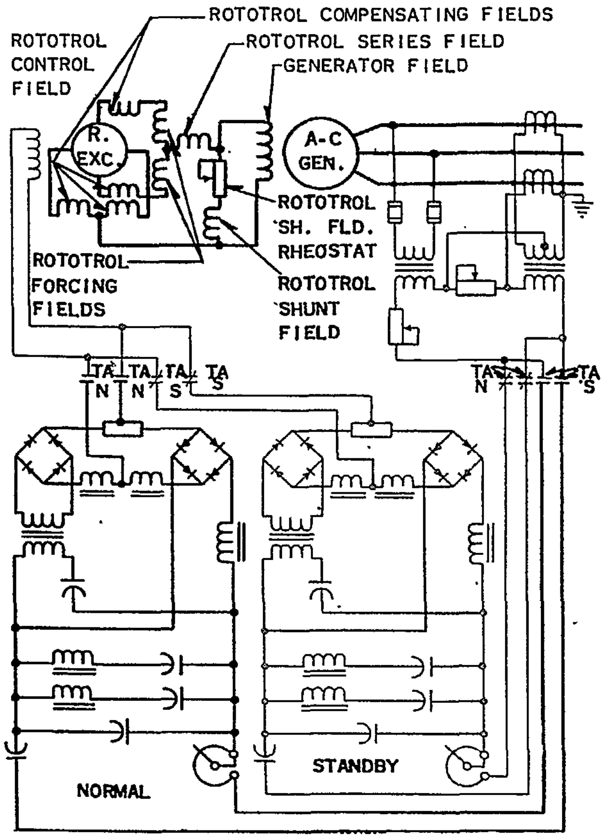
2. Fig. VR-42 shows a normal and a standby automatic control unit. This figure shows the normal unit in control and Fig. VR-43 shows the standby regulator in control.

3. Fig. VR-44 shows a wiring diagram for two generators with one standby automatic control unit between them. Each generator is under control of its own normal automatic voltage regulator. Fig. VR-45 shows generator No. 1 under standby regulator control. Energized circuits are shown in red.



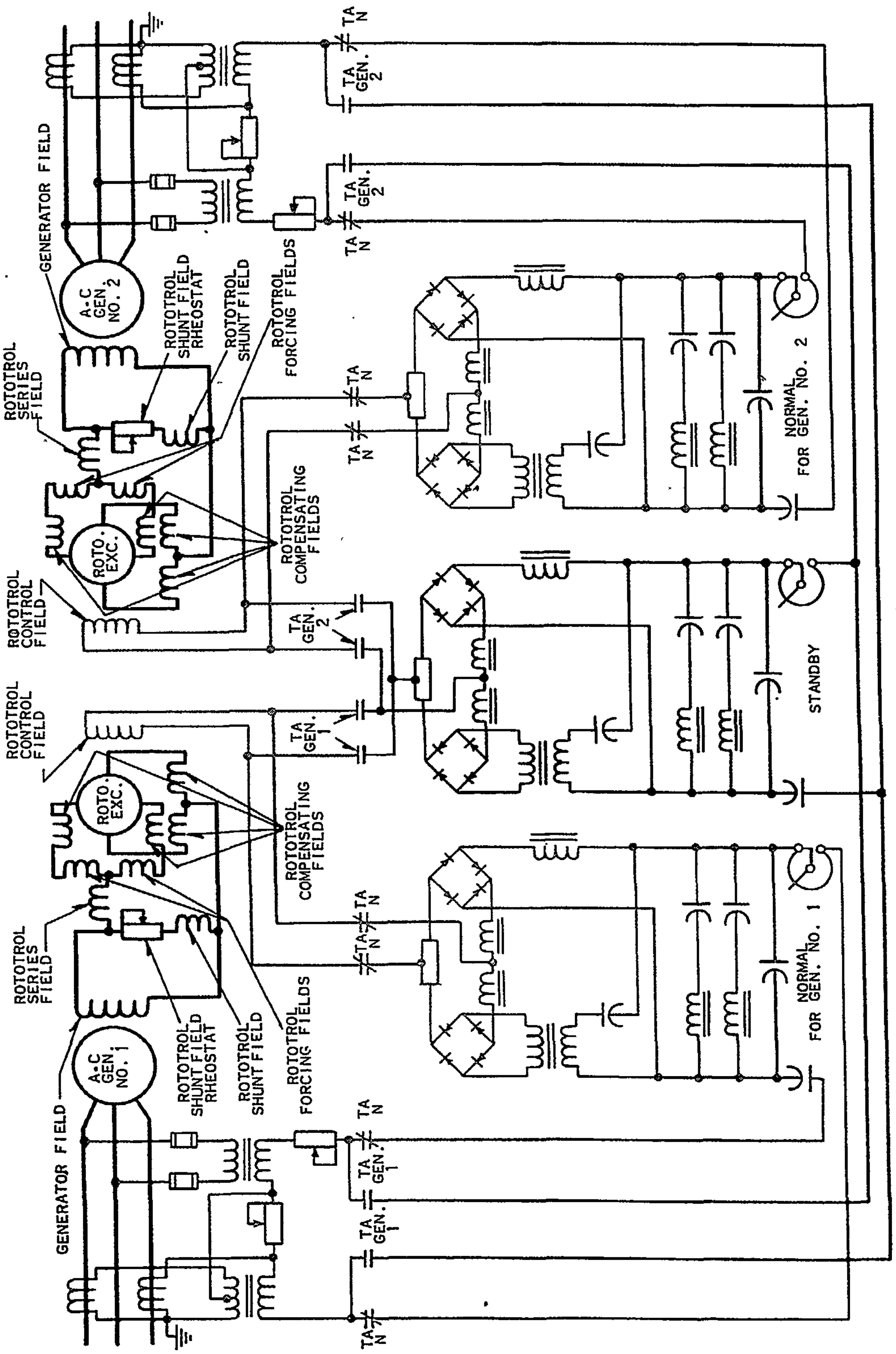
SCHEMATIC DIAGRAM OF VOLTAGE REGULATOR SYSTEM SHOWING NORMAL AND STANDBY AUTOMATIC CONTROL UNITS. ALL ENERGIZED CIRCUITS ARE SHOWN IN RED FOR THE NORMAL REGULATOR IN OPERATION.

Fig. VR-42 — Schematic Diagram Showing Normal Automatic Regulator in Control (one generator)



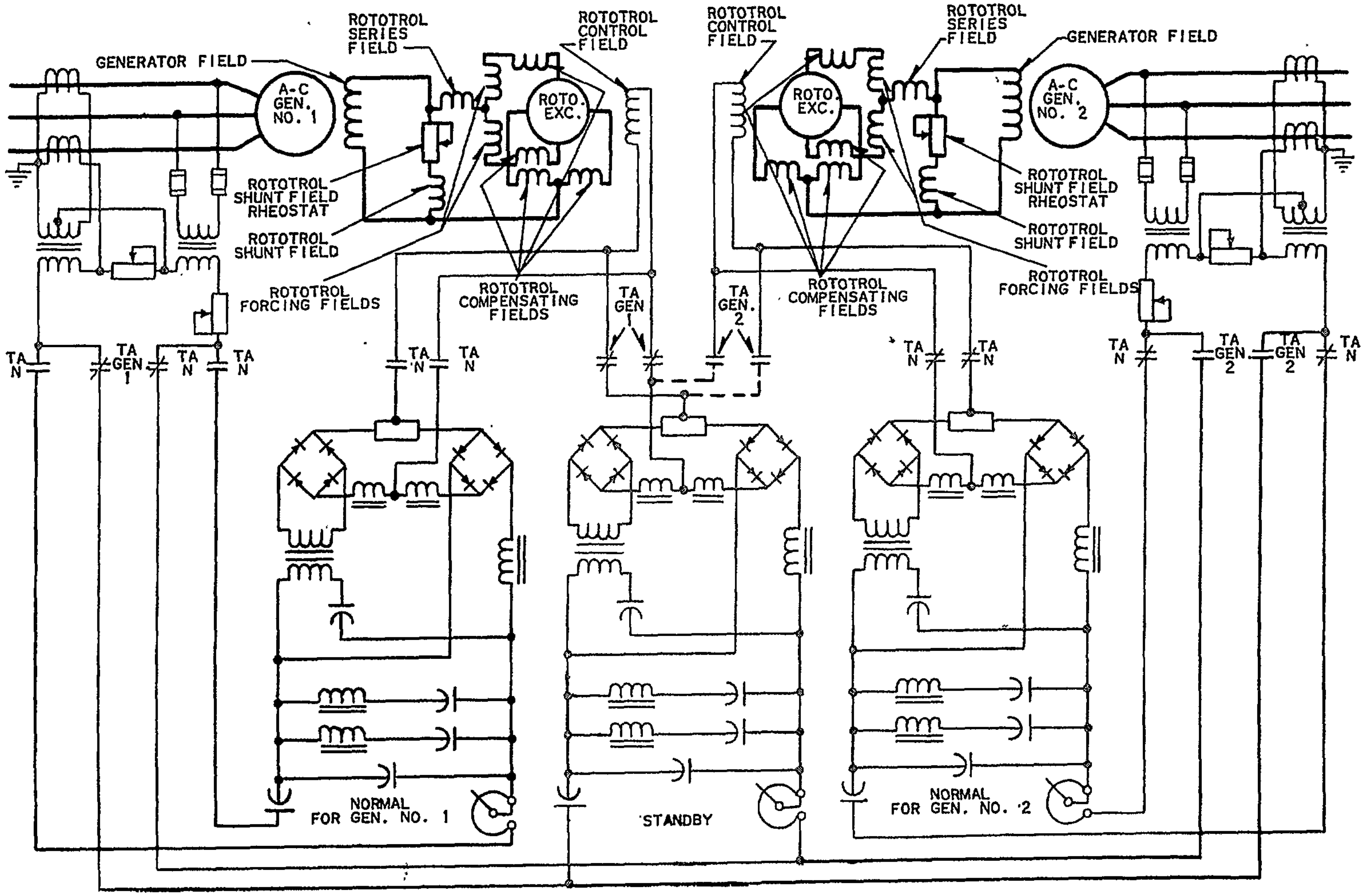
SCHEMATIC DIAGRAM OF VOLTAGE REGULATOR SYSTEM SHOWING NORMAL AND STANDBY AUTOMATIC CONTROL UNITS. ALL ENERGIZED CIRCUITS ARE SHOWN IN RED FOR THE STANDBY REGULATOR IN OPERATION.

Fig. VR-43 — Schematic Diagram Showing Standby Automatic Regulator in Control (one generator)



SCHEMATIC DIAGRAM SHOWING TWO GENERATORS EACH HAVING ITS OWN NORMAL AUTOMATIC REGULATOR AND ONE STANDBY REGULATOR BETWEEN THEM. THIS FIGURE SHOWS EACH GENERATOR UNDER CONTROL OF ITS OWN REGULATOR. ALL ENERGIZED CIRCUITS ARE SHOWN IN RED.

Fig. VR-44 — Schematic Diagram Showing Normal Automatic Regulators in Control (two generators with common standby)



SCHEMATIC DIAGRAM SHOWING TWO GENERATORS EACH HAVING ITS OWN NORMAL AUTOMATIC REGULATOR AND ONE STANDBY REGULATOR BETWEEN THEM. THIS FIGURE SHOWS THE NO. 1 GENERATOR UNDER THE CONTROL OF THE STANDBY REGULATOR AND THE NO. 2 GENERATOR UNDER THE CONTROL OF ITS OWN NORMAL REGULATOR. ALL ENERGIZED CIRCUITS ARE SHOWN IN RED.

Fig. VR-45 — Schematic Diagram Showing One Normal and One Standby Regulator in Control (two generators with common standby)

SEC. D—OPERATING INSTRUCTIONS

4D1. INITIAL OPERATION

a) The following steps should be observed in starting a generating system either the first time or after repairs have been made.

1. GENERATOR WITH ONE REGULATOR (or with NORMAL and STANDBY regulators)

STEP 1. Be sure the generator line circuit breaker is open or no load is connected to the generator.

STEP 2. ∅ Turn the regulator transfer switch (TA) to NORMAL.

STEP 3. Turn the regulator control switch (CA) to MAN.

STEP 4. Turn the voltage adjusting unit to extreme LOWER.

STEP 5. Turn the manual control unit to extreme LOWER.

STEP 6. Start the prime mover and bring it up to rated speed.

STEP 7. * Turn the manual control unit to the extreme RAISE position. When the generator voltage starts to rise turn the handle back toward LOWER. Set the generator voltage at 450 volts. Mark the position of the manual control unit handle.

STEP 8. Set the handle of the voltage adjusting unit close to the LOWER stop.

STEP 9. Turn the regulator control switch (CA) to AUTO. The generator voltage is then under automatic regulator control. The voltage may not be 450 volts but the voltage adjusting unit can be used to adjust this voltage. Mark the position of the voltage adjusting handle for 450 volts. Turn the handle to the extreme LOWER and RAISE positions. The generator voltage should vary from not more than 436 volts to at least 482 volts. If this range is not met the following procedure should be used:

Turn the voltage adjusting unit to the extreme LOWER position. The generated voltage at 60 cycles per second should be between 430 and 436 volts. If it is not, adjust the tap of the resistor (RV). Shorting-out resistance lowers the voltage. Be sure to de-energize the unit before working on it.

STEP 10. ∅ Turn the STANDBY voltage adjusting unit to approximately the same position as the NORMAL unit.

STEP 11. ∅ Turn the regulator transfer switch (TA) to STANDBY. The generator voltage is then under the control of the standby regulator. The voltage may not be 450 volts but can be adjusted by the standby voltage adjusting unit.

STEP 12. ∅ Repeat step 9. Since the resistor (RV) is common to the two regulators (NORMAL and STANDBY) the range should be satisfactory. If it is not an adjustment can be made by using another tap on the saturating reactors. The higher numbered taps raise the voltage level of the regulator.

2. TWO GENERATORS WITH COMMON STANDBY REGULATORS.

a) On systems where a common standby regulator is supplied for two generators, each normal regulator should be checked individually as described above. The standby regulator should be checked on each generator. To place the No. 1 generator under standby regulator control, turn the regulator transfer switch (TA) to GEN. 1.

3. SINGLE GENERATOR UNDER LOAD

a. The no-load checks on the regulating system should be made before load is applied. When applying load to the generator for the first time, the following procedures should be used:

∅ Applies to systems using a standby regulator.

* Be sure the generator is up to full rated speed. It is desirable to speed the generator to a few percent overspeed to facilitate build-up if difficulty is encountered. If this fails, consult "Voltage Build Up", page of this book.

STEP 1. Remove the parallel operation jumper between (C3 and D) on the potential unit terminal block.

STEP 2. Turn the regulator transfer switch (TA) to NORMAL GEN 1 or GEN 2, whichever applies.

STEP 3. Turn the regulator control switch (CA) to MAN.

STEP 4. Turn the manual control unit to extreme LOWER.

STEP 5. With the generator disconnected from the bus, bring the prime mover up to speed. Bring the voltage up as described in paragraph 4D1 a1 a (Step 7). Set the generator voltage at 450 volts.

STEP 6. Apply load, maintain 450 volts and normal frequency.

STEP 7. Remove load, still maintaining 450 volts.

STEP 8. Set the regulator control switch (CA) to AUTO.

STEP 9. Adjust the voltage to 450 volts by the voltage adjusting rheostat.

STEP 10. Apply load at a power factor between rated and unity. Hold normal frequency and increase the load to full load. The difference between the maximum and minimum of the average of the three-phase voltage observed from no load to full load should not exceed nine volts. Should the voltage not meet this requirement, the load voltages may be raised by increasing the resistance in (RC).

STEP 11. Turn the voltage adjusting rheostat to each extreme. The voltage range should at least be 436 to 482 volts.

STEP 12. Set 450 volts, remove the load and turn the regulator transfer switch to STANDBY regulator, if one is provided.

STEP 13. Repeat steps 8 to 11 inclusive with the standby regulator.

4. PARALLEL OPERATION OF GENERATORS

a. The reactive-droop compensators should be used when generators are to be operated in parallel. This will cause equal division of reactive load between generators. Each generator to be operated in parallel should be checked in the following manner:

STEP 1. A new or repaired generating system should be checked as described in paragraphs 4D1 a 1, 2 and 3 before operation in parallel.

STEP 2. Replace jumper between (C3 and D) on the potential unit terminal block. This puts the reactive-droop compensator into operation.

STEP 3. Place the system in operation under automatic regulator control. Set the voltage at 450 volts and 60 cycles per second. Keep the generator speed constant.

STEP 4. Apply rated load at rated power factor. Note the generator voltage, it should be approximately 4 per cent low or 432 volts. To reduce the load voltage reduce the resistance in resistor (RC).

STEP 5. Repeat steps 1 to 4 inclusive on the other generator. The full-load voltage on the generators should be equal or very nearly equal. (If the no-load voltage is not the same on the two generators, the change in voltage as load is applied should be compared.)

STEP 6. If the changes in voltage on the two generators are not more than one volt different, they are ready to be operated in parallel.

STEP 7. When two unloaded generators can be paralleled the following procedure gives a satisfactory means of adjusting the reactive droop compensation:

(a) Follow steps 1, 2 and 3 above.

(b) Bring the second generator, Gen. B, up to speed and bring its voltage up under manual voltage control as described in "Initial Operation" on page 430. Keep both machines running at 60 cycles per second through out the test.

(c) With the first machine, Gen. A, set at exactly 450 volts or its exact voltage noted, parallel the two generators.

(d) Turn the manual control of Gen. B toward LOWER. The ammeters of the two generators will indicate a current circulating between the two machines. Set this current with the manual control rheostat, at 60 per cent of the rated current of one generator.

(e) Note the voltage of the Gen. A. It should be approximately 4 per cent low or 432 volts.

(f) Set both generator voltages at 450 volts so no current is flowing between the machines.

(g) Set the voltage adjusting unit of Gen. B at the point marked for 450-volt operation. Turn the regulator control switch (CA) of Gen. B to AUTO. Adjust its voltage to 450, no current should be flowing in the generator line.

(h) Turn the regulator control switch (CA) of Gen. A to MAN with the manual control unit handle set for 450 volts.

(i) Repeat steps (d) and (e) with Gen B. under automatic control.

(j) The voltage observed in step (c) and that observed in step (i) should be compared. The change in voltage (or, if both tests started at exactly 450 volts, the final voltage) should be within one volt of each other.

(k) The full-load voltage of a generator can be lowered by shorting-out more of the resistance (RC).

(l) When the limit of step (j) is met, the generators are ready to be operated in parallel.

4D2. NORMAL OPERATION

a) New or repaired equipment should be checked as described under "Initial Operation" page 430. Equipment that has not been used for a considerable time should also be checked as above. After the initial checks have been made the regulating system may be operated according to the following procedure.

1. SINGLE GENERATOR OPERATION

STEP 1. Be sure the generator line circuit breaker is open or no load connected to the generator.

STEP 2. ∅ Turn the regulator transfer switch (TA) to NORMAL.

STEP 3. Turn the regulator control switch (CA) to MAN.

STEP 4. Turn the voltage adjusting unit to the position marked for 450 volts.

STEP 5. Turn the manual control unit handle to extreme LOWER.

STEP 6. If the generator is to be operated in parallel be sure the jumper is on the potential unit terminal block between (D and C3). If it is not to be operated in parallel, remove this jumper.

STEP 7. Start the prime mover and bring it up to speed.

STEP 8. Turn the manual control unit to extreme RAISE position. When the generator voltage starts to rise turn the handle back toward LOWER. Set the generator voltage at 450 volts.

STEP 9. Turn the regulator control switch (CA) to AUTO. If the voltage is not 450 volts adjust it with the voltage adjusting unit.

STEP 10. ∅ To use the standby regulator turn the regulator transfer switch (TA) to STANDBY. The standby regulator can be used the same as the normal regulator.

STEP 11. Close the generator circuit breaker. The generator is ready to be loaded.

STEP 12. If the generator is to be operated on manual control, it will require adjustment as the generator load is changed to maintain 450 volts.

2. PARALLEL OPERATION

The following procedure is to be followed in paralleling a generator with a bus or another generator.

STEP 1. Follow steps 1 to 10 (above) inclusive of "single generator operation" for each generator.

STEP 2. Parallel the generators or generator and bus which connects them to the load.

STEP 3. Balance the kw load or power by adjustment of the prime mover.

STEP 4. Turn the voltage adjusting unit to cause each generator to have the same power-

∅ Applies to generating systems equipped with standby regulators.

factor load. Turn the voltage adjusting handle to LOWER on the generator with the most lagging power factor. This will equalize the currents of the two generators if they are similar machines.

STEP 5. If the line voltage is not 450 volts, move both voltage adjusting rheostats simultaneously to get 450 volts.

STEP 6. When the generators are operated under manual control, the manual control handle takes place of the voltage adjusting rheostats in the above conditions. As with single-generator operation, the manual adjustment must be used to hold the voltage constant as the load varies. This is done automatically when the regulator is in control.

3. SHUTTING DOWN

STEP 1. Disconnect each generator from the bus.

STEP 2. Turn the manual control handle to extreme LOWER.

STEP 3. Turn the regulator control switch (CA) to MAN. The voltage will then drop to zero.

STEP 4. Shut down the prime mover.

4D3. EMERGENCY TROUBLE CHART

The following chart is for emergency procedure only. Remedies are given in the Trouble Shooting Chart.

CAUTION: - Operating personnel should note the following high voltage conditions which exist in the regulator circuit. Reference should be made to the Master Plan or diagrams included in the book for identifications:

Voltage between V7 -R8 equals 485
Voltage between V18 - V27 equals 760
Voltage between V47 - V48 equals 765
Voltage between V48 - F equals 545

a) SINGLE-GENERATOR OPERATION

1. High Voltage - Voltage rises to a high value and fails to respond to normal treatment.

a. Check generator speed.

b. If the speed is normal place the generator under the control of the standby regulator by turning the regulator transfer switch (TA) to STANDBY if a standby regulator is supplied.

c. If no standby regulator is supplied or if the standby regulator fails to bring the voltage down to the normal value, turn the regulator control switch (CA) to MAN. Lower the voltage with the manual control unit handle.

d. If the voltage still remains high shut the system down. The trouble is probably in the control field circuit. See page 435, paragraphs 4e1 to 4e6.

2. Low Voltage - Voltage falls to a low value and fails to respond to normal treatment.

a. Check generator speed.

b. If the speed is normal place the generator under the control of the standby regulator by turning the regulator transfer switch (TA) to STANDBY if a standby regulator is supplied.

c. If no standby regulator is supplied or if the standby regulator fails to bring the voltage up to the normal value, turn the regulator control switch (CA) to MAN. Raise the voltage with the manual control unit handle.

d. If the voltage remains low shut the system down. The trouble is probably in the control field circuit. See page 435, paragraphs 4e1 to 4e6.

b) PARALLEL MACHINE OPERATION

Regulator trouble under parallel operation will be indicated by unbalance in the generator power factor meters and a system voltage that is probably 10 or 20 volts from normal.

1. HIGH SYSTEM VOLTAGE

a. Under this condition one generator will have a very low "lagging" power factor. Switch the control of this generator to the standby regulator. The power factor of this generator should swing toward unity. The power factors can then be balanced with the voltage adjusting units.

b. If this fails to correct the trouble, switch the control of the generator with lagging power factor to manual control with the manual control handle set for normal voltage. Equalize the power factor meter readings with the manual control.

c. If the trouble still persists, take the faulty generator out of operation. Check the circuit as described under "Trouble Shooting"

2. LOW SYSTEM VOLTAGE

a. Under this condition one generator will have a very low "leading" power factor. Switch the control of this generator to the standby regulator. The power factors can then be balanced with the voltage adjusting units.

b. If this fails to correct the trouble, switch the control of the generator with leading power factor to manual control with the manual control handle set for normal voltage. Equalize the power factor meter readings with the manual control.

c. If the trouble still persists, take the faulty generator out of operation. Check the circuit as described under "Trouble Shooting".

4D4. TROUBLE SHOOTING CHART

a) SINGLE-MACHINE OPERATION

It is very unlikely that trouble will be encountered on more than one regulator under parallel operation, consequently a trouble shooting chart for a single regulator will be given first and a short treatment of parallel operation will follow. SECURE THE BOARD before checking any circuits or replacing any parts.

The ROTOTROL brushes should all be raised if the machine is to be run for mechanical checks or any time when the voltage is not intended to be controlled by the regulator or the manual control. The ROTOTROL should never be rotated in the direction opposite to that specified.

1. Regulator Circuit Check. The regulator can be checked as a unit according to the following procedure:

a. Remove the fuses between the generator's bus and V1 and V2, so power may be applied to V1-V2 without putting power on the generator.

b. The ROTOTROL should be at rest or all of its brushes raised.

c. Turn the regulator control switch (CA) to AUTO.

d. Turn the regulator transfer switch (TA) to NORMAL (to STANDBY if the standby regulator is to be checked).

e. Apply a-c voltage to V1 and V2 of between 100 and 400 volts at approximately 60 cycles per second.

f. Using a d-c voltmeter check the voltage across NAR-NAL. NAR should be positive on the regulator and F1 should be positive with respect to F2 at the machine.

g. Raise the voltage to 450 volts, turn the voltage adjusting rheostat to extreme LOWER and the d-c polarity should reverse NAL and F2 should now be positive.

2. Manual Control Unit Check. The manual control unit can be checked individually according to the following procedure:

a. The regulator control switch (CA) must be turned to AUTO.

b. Apply approximately 50 volts d-c to MP and MN of the manual control unit, making MP positive. If step (a) were not observed the ROTOTROL armature would practically short-circuit this voltage.

c. Turn the handle to extreme LOWER.

d. A d-c voltmeter across MR and ML should indicate a voltage with ML positive.

e. Turn the handle to extreme RAISE.

f. The voltmeter should now indicate a voltage with MR positive.

3. Voltage Build-Up. If the machines contain insufficient residual magnetism to build up the voltage, the field must be "flashed" as follows:

a. Turn the regulator control switch (CA) to MAN.

b. Turn the manual control handle one quarter turn from the LOWER stop.

c. Run the generator at minimum speed.

d. Apply 5 to 15 volts d-c between MR and ML of the manual control unit or F1 and F2 of the

ROTOTROL. Make MR or F1 positive. Watch the a-c generator voltage. Remove the d-c voltage when the a-c voltage reaches 300 to 400 volts, and control the voltage with the manual control unit.

e. If the system now fails to build up on manual control, switch to automatic control.

f. Should the system voltage still fail to build up and both units have been checked as described above, it indicates trouble in the control field circuit. Check all connections, contacts of switches and ROTOTROL control field.

4. Quick Check. The following checks may be made to determine quickly if the trouble is in the regulator:

HIGH VOLTAGE

a. Measure the d-c voltage across NAR-NAL of the automatic control unit. NAL should be positive. No voltage or wrong polarity indicates automatic regulator trouble. The magnitude of the d-c voltage will depend upon how much above the regulator balance point the generator voltage is. However, it should be over 10 or. 15 volts under the above conditions.

b. If in step (a) a satisfactory voltage is obtained, measure the voltage on F1-F2 of the ROTOTROL. F2 should be positive the same amount that NAL was. If it is not, the trouble is in the circuit between the regulator and the ROTOTROL. Check all connections and switches.

c. Slow the set down if possible to 75 per cent speed. If the voltage remains high the regulator is at fault. If the voltage drops at any reduced speed, the control field circuit is at fault. If step (b) has been performed and voltage found on the field, measure the resistance between F1-F2. It should be between 50 and 60 ohms.

LOW VOLTAGE

d. Measure the d-c voltage across NAR-NAL of the automatic control unit. NAR should be positive. Wrong polarity indicates automatic regulator trouble. At no input voltage, the d-c output voltage will be zero.

e. Check the control field circuit. This can be done as follows:

1. Turn the regulator control switch to AUTO.

2. Turn the regulator transfer switch to the regulator being checked.

3. Remove lead NAL from the automatic control unit.

4. Measure the resistance between NAR and the lead (not terminal block point) of NAL.

5. This resistance should be between 50 to 60 ohms.

6. If it is not locate the trouble. F1-F2 on the ROTOTROL should be 50 to 60 ohms. Check connections and switches.

5. Regulator Circuit Check

HIGH VOLTAGE

a. With normal regulator but not with standby.

Probable Cause and Remedy.

1. Normal regulator LOWER circuit open (See Fig. VR-32, page 419). No voltage across saturating reactor circuit rectifier a-c terminals with voltage on V48-PS. Repair open circuit or replace defective part.

2. Voltage may appear across the a-c rectifier terminals and the d-c rectifier circuit be open. Repair any loose or open connections and replace any damaged parts.

3. One of the rectifiers shorted. No voltage across one or more legs of the rectifier with voltage on the other legs. Replace rectifier.

4. Capacitor C_n shorted. No voltage across C_n with voltage on circuit. Circuit voltage appears across insulating transformer from PS to PF. Replace capacitor.

5. Capacitor C_a may be shorted. Measure voltage from V47 to PS. This should be approximately 300 volts at normal voltage. If damaged, replace.

6. Check connections from normal regulator through transfer switch. See that all connections

are tight and the switch contacts make satisfactorily.

b. With normal and standby regulators but not with manual control.

Probable Cause and Remedy.

1. It is very unlikely that both regulators would be simultaneously faulty. Such a condition would indicate switch or wiring trouble. Check switch contacts and wiring connections.

c. With normal, standby and manual control.

Probable Cause and Remedy.

1. This indicates a faulty control field circuit. Check circuit and field. Field F1-F2 should measure between 50 and 60 ohms. See that the field is not reversed.

LOW VOLTAGE

d. With normal regulator but not with standby.

Probable Cause and Remedy.

1. Normal regulator RAISE circuit open (See Fig. VR-32, page 419). No voltage across a-c terminals of capacitor circuit rectifier with voltage on V48-PS. Replace defective part.

2. Voltage may appear across a-c terminals of rectifier and d-c circuit be open. Check d-c circuit between rectifiers. Repair any loose or open connections and replace any damaged parts.

3. The saturating reactor (S) may be short-circuited. If the voltage across the reactor is less than the voltage across the rectifier in the saturating reactor circuit, the reactor is showing a shorted winding. Replace the reactor.

4. Rectifiers may be shorted. No voltage will appear across shorted legs with power on regulator. Replace rectifier.

5. Check wiring from normal unit through transfer switch. See that all connections are tight. Check switch contacts and clean them.

6. Reactor F.R. in POTENTIAL UNIT may be shorted. Measure voltage across C13-V27. If this voltage is not at least half of the generator voltage, the reactor winding is probably shorted. replace reactor.

e. With automatic regulators but normal voltage with manual control.

Probable Cause and Remedy.

1. It is very unlikely that both regulators would be simultaneously faulty. Such a condition would indicate switch or wiring trouble. Check switch contacts and wiring connections.

f. Low voltage with normal, standby and manual control.

Probable Cause and Remedy.

1. This indicates a faulty control field circuit. Check circuit and field. Field F1-F2 should measure between 50 and 60 ohms. See that the field is not reversed.

b. PARALLEL MACHINE OPERATION

Under single-machine operation the generator voltage is the chief symptom of regulator trouble. Under parallel operation, the chief symptom of regulator trouble, is power factor. System voltage will assist in locating the trouble.

HIGH SYSTEM VOLTAGE, POWER FACTORS UNEQUAL

1. The generator with its power factor indicating excessive lag may have a defective regulator. The load power factor generators will be reading lead or close to unity, depending upon the load. Proceed on the faulty regulator as described in "High Voltage" for a single machine.

LOW SYSTEM VOLTAGE, POWER FACTORS UNEQUAL

2. The generator with its power factor indicating lead is probably at fault. The other generators will be indicating a low lagging power factor. Proceed on the faulty regulator as described in "Low Voltage" for a single machine.

SEC. E—MAINTENANCE OF REGULATOR

4E1. INSPECTION

a) Routine inspections and cleaning will insure optimum service from the regulator. The circuit is entirely static and requires no oil or grease. SECURE THE BOARD before checking or testing any circuits. The following checks should be made every month:

CHECK 1. Remove ground from current transformers.

CHECK 2. Remove potential fuses in V1, V2 leads.

CHECK 3. Check circuit for grounds with a "megger".

CHECK 4. Replace fuses and ground connection.

CHECK 5. Check all connections to make sure they are tight. This includes all the regulator units, switches, current transformers and ROTOTROL.

CHECK 6. Operate system on normal regulator, standby regulator and manual control to be sure that all are operating satisfactorily.

CHECK 7. Remove any accumulation of dust or dirt either with a dry cloth or by blowing it out with dry, compressed air.

CHECK 8. Remove switch covers and blow out switches. Clean switch contacts with a dry cloth or a cloth dampened with carbon tetrachloride, benzine or alcohol. Replace switch covers.

4E2. REPAIR OF PARTS EXTERNAL TO THE REGULATOR; i.e. RHEOSTATS AND SWITCHES

a) VOLTAGE ADJUSTING RHEOSTAT

1. The brush assembly can be removed by loosening the nut from the rear end of the shaft The two plates may be separated by loosening the mounting straps. This facilitates working on the front plate.

b) MANUAL CONTROL UNIT

1. Replacement of the brush assembly is substantially the same as on the voltage adjusting unit.

2. Removal of rectifier or terminal block is accomplished by disconnecting the leads and removing the mounting bolts.

c) SWITCHES

1. Stationary Contacts

a. Remove slide cover.

b. Remove lead connections to faulty contact. Be sure the circuit is dead.

c. Remove the nuts from contact screw.

d. Contact assembly can then be removed through the side of the switch.

e. Reverse the above procedure to replace the contact.

2. Movable Contacts

a. Remove the handle on the front. This handle is fastened to the shaft by a pointer screw.

b. Remove the rear end plate by taking out the four mounting screws. Two are in the top and two are in the insulating base.

c. Withdraw the rotor from the rear.

d. The contact segment key notches are numbered. A record should be made of these numbers to facilitate correct re-assembly.

e. Remove the shaft end plate.

f. The contact segments and insulating spacers can be slid off the shaft.

g. Reassembly is easily accomplished with the aid of the chart made in step (d).

4E3. LOCATION OF DEFECTIVE PART

a) The previous explanations have been concerned with observations on an energized unit. The checks listed here are to be made without power on the unit. The test equipment needed consists of a screwdriver, a pair of pliers and an ohmmeter.

b) MANUAL CONTROL UNIT (Fig. VR-10, page 407).

1. Turn regulator control switch (CA) to AUTO.

2. Remove an outside lead from the terminal block of the front resistor plate with a screwdriver.

3. The resistance between the outside binding posts of this plate should be 200 ohms.

4. The resistance between the center binding post and either outside one should vary between zero and 200 ohms as the handle is turned from one stop to the other. No open-circuit (very high resistance) should be noted at any point of this check.

5. The resistance across the fixed-resistor plate should be between 100 and 200 ohms depending upon the position of the shorting connection.

6. The resistance between the rectifier tap and terminal should not be zero in either direction; i.e., with the ohmmeter leads reversed.

7. Replace lead on front resistor plate.

c) VOLTAGE ADJUSTING UNIT (Fig. VR-12, page 407).

1. Turn regulator control switch (CA) to MAN.

2. The resistance across the resistor (leads V38 and V48 on most schemes, see Master Plan) should vary from zero to 75 ohms, as the handle is turned. Turning the handle toward LOWER should short-out resistance. No open circuits (high resistance points) should be observed on this test.

d) POTENTIAL UNIT (Fig. VR-9, page 406).

1. Turn the regulator control switch (CA) to MAN.

2. Remove the potential fuses between V1, V2 and the generator bus.

3. Remove the three current-transformer leads C0, C1, and C3 at the terminal block.

4. Megger between terminals V1 or V2 and ground; also between any other convenient terminal on the block and ground. This should be at least .5 megohm.

5. The resistance between V1 and V2 should be 2.05 ohms.

6. The resistance between V18 and V27 should be between a minimum of 6.3 ohms and a maximum of 23.8 ohms. The value depends upon the setting of the resistance.

7. The resistance between V27 and C13 should be 3.2 ohms.

8. The resistance C0 to C1 should be .084 ohm with C23 a center tap.

e) AUTOMATIC CONTROL UNIT (Fig. VR-6, page 405; and Fig. VR-7, page 405).

1. Turn the regulator control switch (CA) to MAN.

2. Remove wire (-) from resistor tube.

3. Take an ohmmeter around the circuit. A high-inductance coil will show a slowly increasing deflection. No coil in this circuit has so high an inductance that a second or two will not give the correct reading.

Capacitors will show an open-circuit to the ohmmeter but an initial deflection will be noted. Reverse the ohmmeter leads and an even greater deflection will be observed and then it will show a very high resistance. This indicates a good capacitor.

Measured resistance should be within 20 per cent of the value called for.

4. Measure the resistance across the resistor tube, piece 32. It should be 12 ohms.

5. Measure the resistance from NAL to F(+) and F(-). The resistance should be 1.9 ohms. This measures piece 24.

6. Measure the resistance across each leg of the rectifiers, piece 34. On each leg reverse the ohmmeter leads. Any rectifier with a shorted leg should be removed.

7. Measure resistance of saturating reactor S, piece 25, across S to V48. The resistance should be approximately 2.2 ohms.

8. Resistance of piece 26, the insulating transformer, is:

a. Secondary is 1.6 ohms, from SS to SF.
b. Primary is 1.1 ohms, from PS to PF.

9. Resistance of reactor, piece 23, is 5 ohms. Measure from PS to F.

10. Resistance of reactor, piece 22 is 1.4 ohms. Measure from PS to F.

11. Check capacitors:

a. Cn consists of one capacitor, piece 27, V48-PF.

b. C3 consists of two capacitors, piece 29 and four capacitors, piece 30, V48-F.

c. C5 consists of one capacitor, piece 29, V48-C5.

d. Cb consists of two capacitors, pieces 29 and 28, V48-PS.

e. Ca consists of one capacitor piece 27 and three capacitors, piece 28, V47-PS.

Should any of these show a short-circuit, be sure to isolate the trouble before removing any capacitors. A short in capacitor Cb will also show a short on Cn, C3 and C5. Remove the connections to one terminal of each capacitor to be checked individually. Do this before removing capacitor.

12. Replace (-) wire on resistor tube Rdc.

13. Megger between terminal block and ground, The insulation resistance should be at least 0.5 megohm.

CERTIFICATION DATA FOR VOLTAGE REGULATOR

A NAVY CONTRACT NOBS 61436
B U.S.A. DEPT. OF NAVY
C WESTINGHOUSE ORDER G.O. WG70070-YS.O 22-Y-1537 & 22-Y-1957
D WESTINGHOUSE TYPE WRN-11 VOLTAGE REGULATOR
E NUMBER OF SHIPS- 1
F SHIPS IDENTITY CVA 60
G REGULATOR EQUIPMENT ON ORDER (TABULATION)

ITEM	DESCRIPTION	STANDARD NAVY STOCK NUMBER	QUANTITIES: 1 NORMAL PER GEN.	S.O. 22-Y-1957 FOR STOCK	FOR STOCK				SPARE PARTS ITEM SHEET 3 THIS DWG.	IDENTIFICATION (STOCK ORDER OR STYLE NUMBER)
1	POTENTIAL UNIT	HI7WX-11383	8	1					—	1584368
	SPARES								1-2	
2	VOLT.ADJ. UNIT	HI7WAL-12102	8	1	8				—	1369698
	SPARES								12-13	
3	AUTO. CONT. UNIT	HI7WX-11384	8	2	8				—	1584370
	SPARES								3 TO 8	
4	MAN. CONT. UNIT	HI7WX-11385	8	1					—	1584387
	SPARES								9 TO 11	
5	REG. CONT. SW.	HI7WX-11510	8	1					—	1584388
	SPARES								15 TO 17	
6	REG. TRANSF. SW.	HI7WX-11387	8	1					—	1584390
	SPARES								16 TO 20	
7	CUR. TRANSF.	HI7WX-40111	8	2	8				—	1304233
8	DAMP. TRANSF.	PI7WX-2998	8	1					—	1649939
	SPARES								14	

H. MASTER PLAN REFERENCES
(1) REGULATOR ONE NORMAL-ONE STANDBY PER.GEN. DWG. 1-JH-466 SUB. 3
BU. NO. S6101-H-3193602 REV. A
(2) CURRENT TRANSFORMER 4000/5 DWG 20-A-1720 SUB. 1
BU. NO. 91023-S6202-2244 REV. 1

DRAFTSMAN DATE G. J. Turba 6-30-53 CHECKER O. Vasuus 6-30-53 CERTIFIED J. L. Neuly 7-9-53	CERTIFICATION DATA TYPE WRN-11 ROTARY AMPLIFIER VOLTAGE REGULATOR	WESTINGHOUSE ELECTRIC CORP. EAST PITTSBURGH, PA., U.S.A. DWG. 30-B-7153 SUB 5 NAVY DEPT BUSHIPS
BUSHIPS APPROVAL LETTER NOBS 61436 (560G) SER. 560-79782 A 12 APRIL 1954		BUSHIPS NO. CVA60-S6102-1503122 REV B SHEET 1 OF 3

CERTIFICATION DATA FOR VOLTAGE REGULATOR

GENERATOR DATA
(1) WESTINGHOUSE G.O. WG70070 S.O. 49P586
(2) 1500 KW. ,450 VOLTS, 3PHASE, 60 CYCLE, 1200 R.P.M., .8 P.F.
CLOCKWISE ROTATION VIEWED FROM TURBINE COUPLING
(3) APPLICATION - SHIPS SERVICE
(4) CERTIFICATION DATA: DWG 44 A 7362
BU NO. CVA60-6102-A-1456234

EXCITER DATA
(1) WESTINGHOUSE G. O. WG 70070 S O. 49P587
(2) DIRECT-CONNECTED ROTOTROL- TYPE, EXCITER, 10 KW, FR. 123.11 ESK.
(3) CERTIFICATION DATA: DWG. CD 4546
BU. NO. S6101-1456363

APPLICABLE MILITARY SPEC. MIL-R-2729 DATED 8-23-51

EXCEPTIONS TO MILITARY SPEC.

(1) OPERATION OF A-C GENERATORS IN PARALLEL
(A) THE MAXIMUM DIFFERENCE IN REACTIVE KVA SUPPLIED BY GEN. FROM THAT SUPPLIED BY ANOTHER GEN, BASED ON THE CONTINUOUS KVA. RATING OF ONE MACHINE SHALL NOT EXCEED 15% AT LOADS UP TO 90%. AT ANY LOAD FROM 90% TO FULL LOAD THE DIVISION OF REACTIVE KVA SHALL BE WITHIN THE LIMIT SPECIFIED IN PARAGRAPH DIOF (I) OF MIL-R-2729

(B) THE CIRCULATING CURRENT BETWEEN GENERATORS OPERATING AT NO-LOAD SHALL NOT EXCEED 7.5% OF THE CONTINUOUS CURRENT RATING OF ONE GENERATOR AT ANY GENERATOR FREQUENCY FROM PLUS 5% TO MINUS 5% OF RATED FREQUENCY

DRAFTSMAN DATE S.J. Turba 6-30-53 CHECKER [signature] 6-30-53 CERTIFIED [signature] 7-53 BUSHIPS APPROVAL LETTER NOBS 61436(560G) SER. 560-79782A 12 APRIL 1954	CERTIFICATION DATA TYPE WRN-11 ROTARY AMPLIFIER VOLTAGE REGULATOR	WESTINGHOUSE ELECTRIC CORP. EAST PITTSBURGH, PA. U.S.A. DWG. 30-B-7153 SUB 5 NAVY DEPT. BUSHIPS BUSHIPS NO. CVA60-S6102-1503122 SHEET 2 OF 3	REV. B

CERTIFICATION DATA FOR VOLTAGE REGULATOR
LIST OF REPAIR PARTS
NAVY CONTRACT NOBS 61436
WESTINGHOUSE G.O.WG70070 S.O. 22-Y-1912

ITEM NO.	NUMBER OF SETS	NUMBER PER SET	NAME OF PIECE	IDENTIFICATION MFR'S STYLE NO	PLAN OR DWG. PC.	PLAN OR DWG. NO.	STD. NAVY STOCK NO'
			POTENTIAL UNIT			WESTINGHOUSE ELECTRIC CORP DWG. I-JH-466 BUSHIPS PLAN NO. S6101-H-3193602	
1	2/5	5	RESISTOR (2 OHMS)	1298833	12		HI7WX-11372
2	2	1	RESISTOR (10 OHMS)	1250290	13		HI7WX-11371
			AUTOMATIC CONTROL UNIT				
3	3/2	2	RESISTOR (12 OHMS)	1369727	32		HI7WX-11373
4	3/4	4	CONDENSER (10 MFD)	1397305	27		HI7WX-11380
5	3/4	4	CONDENSER (2 MFD)	1397304	28		HI7WX-11504
6	3/4	4	CONDENSER (1 MFD)	1397303	29		HI7WX-11379
7	3	1	CONDENSER (,25 MFD)	1392029	30		HI7WX-11374
8	3/2	2	SELENIUM RECTIFIER	1597650	34		HI7WX-11513
			MANUAL CONTROL UNIT				
9	2	1	SELENIUM RECTIFIER NO. 6RS5FBI5	1584392	41		HI7WX-11512
10	2	1	CONTACT ARM	1344345	43		HI7WAL-10059
11	2	1	SPRING	1370148	44		HI7WAL-10038
			VOLTAGE ADJUSTING UNIT				
12	2	2	CONTACT ARM	1344344	47		HI7WX-10054
13	2	2	SPRING	1370148	48		HI7WAL-10038
			DAMPING TRANSFORMER				
14	2	1	RESISTOR (500 OHMS)	1616077	61		HI6R43473-9255
			REGULATOR CONTROL SW.				
15	2	9	CONTACT SEGMENT	545626	50		HI7WX-10440
			SW. COMMON PARTS				
16	2	2	STOP FINGER	1114883	51 57		HI7WX-10144
17	2	18	CONTACT FINGER	1087205	52 58		HI7WX-10095
			STANDBY REG. TRANSF. SW.				
18	2	8	UPPER CONT. FINGER & SHUNT	1346697	54		HI7WX-S-1346697
19	2	8	UPPER CONTACT FINGER SPRING	1310946	55		HI7WX-S-1310946
20	2	8	CONTACT SEGMENT	1346691	56		HI7WX-S-1346691

WEIGHT PER SET 40 LBS (UNBOXED)

REFER TO MFR'S. DWG., PIECE, AND STYLE NO. WHEN REORDERING

DRAFTSMAN H.J. Turba 6-30-53 CHECKER C.V. Glenn 6-30-53 CERTIFIED N.C. Fiveley 7-8-53	CERTIFICATION DATA TYPE WRN-11 ROTARY AMPLIFIER VOLTAGE REGULATOR	WESTINGHOUSE ELECTRIC CORP EAST PITTSBURGH, PA., U.S.A. DWG. 30-B-7153 SUB. 5 NAVY DEPT. BUSHIPS	
BUSHIPS APPROVAL LETTER NOBS 61436(560G) SER. 560-79782A 12 APRIL 1954		BUSHIPS NO CVA60-S6102-1503122 SHEETS 3 OF 3	REV. B

BINDER 1789