PLAINTIFF'S EXHIBIT

WH-1103b

Westinghouse Electric Corporation
Industry & Defense Products

Hendy Avenue
Sunnyvale, Calif. 94[illegible]

NAVSHIPS 361-0026 CHANGE 1
INSTRUCTION BOOK 8236

JULY 1969

This change covers the modification made to the 1250-KW AC Turbine Generator Voltage Regulators on board USS ORISKANY (CVA-34). The change is effective on receipt.

Technical Manual IB 8236 NAVSHIPS 361-0026 is changed as follows:

1. Title Page: Insert after present Title Page.
2. Page 2A: Insert new page 2A after page 2.
3. Page 6A: Insert page 6A facing page 6.
4. Pages 7 and 8: Remove and replace with attached pages 7 and 8.
5. Pages 301A through 326A: Insert in manual following page 331.
6. Figs. R-1A through R-15A: Insert in manual following Figure R-10.
7. Insert this sheet immediately following front cover.
8. Destroy superseded pages in accordance with current Navy Department directives.

Lexington has changed
1. Woodward Gov
2. Lube Oil Pump
3. Volt Reg.

NAVSHIPS 361-0026

TYPE 1 EQUIPMENT MANUAL
for

1250 AND 1700-KW AC STEAM-TURBINE DRIVEN GENERATOR SETS (U)

DEPARTMENT OF THE NAVY
NAVAL SHIP SYSTEMS COMMAND

TECHNICAL MANUAL IB 8236

CHANGE 1
APRIL 1969

Serial No. 27

NAVSHIPS 361-0026

1250-Kw. Geared Turbine Generator

WESTINGHOUSE ELECTRIC

for

U. S. AIRCRAFT CARRIERS

CV31, CV33 to CV40 and CV45

NAVY CONTRACT NOs 93968

WESTINGHOUSE ORDER W.G-35060

YEAR OF CONSTRUCTION 1943-44

INSTRUCTION BOOK 8236

In the event that it becomes necessary to return any part of this equipment to the South Philadelphia Works, it should be tagged with the Sender's name and address and the serial number of the unit. Shipments by freight, express or parcel post should be addressed to:

Westinghouse Electric & Manufacturing Company
South Philadelphia Works
Essington, Pa., U.S.A.

Reprinted in U.S.A. (2-45)

SERIAL NUMBER ASSIGNMENT

ROTATING EQUIPMENT

VESSEL NUMBER AND NAME	UNIT No.	TURBINE Serial No.	GENERATOR* Serial No.	EXCITER* Serial No.
	1	2A-8277-___	___S-16P688	___S-16P689
	2	2A-8277-___	___S-16P688	___S-16P689
	3	2A-8277-___	___S-16P688	___S-16P689
	4	2A-8277-___	___S-16P688	___S-16P689
CV___ U.S.S.___________				
	1	2A-9440-___	___S-19P143	___S-19P145
	2	2A-9440-___	___S-19P143	___S-19P145
	3	2A-9440-___	___S-19P143	___S-19P145
	4	2A-9440-___	___S-19P143	___S-19P145

VOLTAGE-REGULATING EQUIPMENT

VOLTAGE REGULATOR ASSIGNMENT

Vessel No.	Regulator	Vessel No.	Regulator	Vessel No.	Regulator
CV31 . . .	BN-2	CV33 . . .	SRAN-4	CV40 . . .	SRAN-4
CV36 . . .	BN-2	CV34 . . .	SRAN-4	CV45 . . .	SRAN-4
CV38 . . .	BN-2	CV35 . . .	SRAN-4	....	......
CV39 . . .	BN-2	CV37 . . .	SRAN-4	....	......

STOCK ORDER IDENTIFICATION

M.S.O. 76-Y-441 - TYPE "BN-2" VOLTAGE REGULATOR EQUIPMENT

S.O. NO.	Quantity	Apparatus
94-Y-507	16	Motor-Operated Rheostats
94-Y-508	16	Contactor Panels
94-Y-509	32	Type "BN-2" Regulator Control Elements
76-Y-441	4	Sets of Spare Parts for Type "BN-2" Voltage Regulator Equipment
94-Y-514	16	Type "BN-2" Voltage-Adjusting Rheostats
94-Y-514	32	Type "VG-7" Neon Indicator Lamps
94-Y-514	32	Type "V-7" Lamp Sockets

M.S.O. - 76-Y-441 AND 1-Y-1321 - COMMON APPARATUS FOR TYPES "BN-2" AND "SRAN-4" VOLTAGE REGULATOR EQUIPMENTS

94-Y-509	32	Type "BN-2" Rectox Rectifiers
1-Y-1321	48	Type "BN-2" Rectox Rectifiers
76-Y-441	16	Cross-Current Compensators
1-Y-1321	24	Cross-Current Compensators
76-Y-441	32	Type "VN" 440/110-Volt Potential Transformers
1-Y-1321	48	Type "VN" 440/110-Volt Potential Transformers
76-Y-441	16	Type "UN" Modified 3000/5-Ampere Current Transformers
1-Y-1321	24	Type "UN" Modified 3000/5-Ampere Current Transformers

APPROVAL AND PROCUREMENT RECORD PAGE

APPROVAL DATA FOR: NAVSHIPS 361-0026, Change 1

TITLE OF MANUAL: Type I Equipment Manual for 1250 and 1700 KW Steam-Turbine Driven Generator Sets (U)

APPROVAL AUTHORITY: Commander, San Francisco Bay Naval Shipyard ltr Ser. H234C/H271A-125 dated 16 June 1969

Contract or Purchase Order	Ships Applicable	Quantity of Manuals	Building Yard
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7 July 1969

Certification: It is hereby certified that NAVSHIPS 361-0026, Change 1 provided under contract N00228-68C-1857 has been approved by the approval data shown above.

Lee W. Browne

Lee W. Browne
Westinghouse Electric Corporation
Marine Division
Sunnyvale, California 94088
Federal Code Number: 90099

SERIAL NUMBER ASSIGNMENT

VOLTAGE-REGULATING EQUIPMENT -- Continued

STOCK ORDER IDENTIFICATION

M.S.O. 1-Y-1321 - TYPE "SRAN-4" VOLTAGE REGULATOR EQUIPMENT

S.O. NO.	Quantity	Apparatus
1-Y-1321	40	Exciter Field Rheostats
5-Y-3824	80	Type "SRAN-4" Regulator Control Elements
1-Y-1321	80	Damping Transformers
1-Y-1321	80	Type "SRAN-4" Voltage-Adjusting Rheostats
1-Y-1321	40	Sets of Spare Parts for "SRAN-4" Voltage Regulator Equipment

TEMPERATURE-INDICATING EQUIPMENT

STOCK ORDER IDENTIFICATION

M.S.O. 76-Y-680 - TEMPERATURE INDICATING EQUIPMENT

S.O. NO.	Quantity	Apparatus
94-Y-515	40	Rectox Rectifiers
94-Y-516	40	Calibrating Rheostats
76-Y-680	40	Temperature Indicators
76-Y-680	40	Test Resistors

* The symbol "S" in generator and exciter serial stands for "Stator". Rotors have corresponding numbers with "R" in place of "S". Serial assignments were unknown at date of publication.

VALVE SETTINGS

(Clearance Between Valve-Lifting Bar and Valve Stem Adjusting Nuts)

CV____ U.S.S.____________

TURBINE SERIAL NUMBERS	VALVE NUMBER* No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
2A-8277-1	.049	.205	.195	.395	.475	.587
2A-8277-2	.047	.210	.200	.395	.490	.595
2A-8277-3	.045	.207	.243	.389	.459	.597
2A-8277-4	.045	.205	.242	.390	.490	.585
2A-8277-5	.045	.200	.235	.390	.490	.580
2A-8277-6	.045	.205	.240	.400	.497	.585
2A-8277-7	.048	.202	.234	.390	.496	.582
2A-8277-8	.042	.205	.241	.403	.542	.582
2A-8277-__	.___	.___	.___	.___	.___	.___
2A-8277-__	.___	.___	.___	.___	.___	.___
2A-8277-__	.___	.___	.___	.___	.___	.___
2A-8277-__	.___	.___	.___	.___	.___	.___
2A-9440-__	.___	.___	.___	.___	.___	.___
2A-9440-__	.___	.___	.___	.___	.___	.___
2A-9440-__	.___	.___	.___	.___	.___	.___
2A-9440-__	.___	.___	.___	.___	.___	.___

* Valve Settings for Turbines other than Serials 2A-8277-1 to 2A-8277-8 Inclusive, were unknown at Date of Publication.

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Bearing (Turbine Pinion and Gear Shaft) Details and Bill.	25-J-507	BB61-S61-58
Bearing (Thrust) Details and Bill	25-J-508	BB61-S61-21
Bed Plate Details and Bill.	25-J-572	BB61-S61-135
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Blading (Curtis) Baffle Details, Assembly and Bill.	25-J-511	BB61-S61-110
Blading (Rateau) Stages 1 to 8 inclusive Details and Bill.	25-J-512	BB61-S61-81
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Bridge Gage Details and Bill.	25-J-496	CV9-S6100-623
Coupling Details, Assembly and Bill.	25-J-518	BB61-S61-47
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† Drawing Number Unknown at Date of Publication

DRAWING LIST

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D-C. Exciter Uniform Specifications	35-J-487*	CV9-S6100-591
Manufacturer's Specifications Data	34-J-902*	CV9-S6100-577
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A-C. Generator Field Discharge Resistor	5-A-9347	CV9-S6100-612
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Auxiliary Equipment	37-J-652*	CV31-S6100-63276
Schematic Diagram	37-J-653*	CV31-S6100-63277
Type "BN-2" Main Control Element	35-J-960*	10-T-2568-L
Motor-Operated Rheostat	37-J-912*	CV31-S6100-63279
TYPE "SRAN-4" VOLTAGE REGULATOR EQUIPMENT		
Type "SRAN-4" Main Control Element, Uniform Specifications, Auxiliary Equipment and Spare Parts	46-J-245*	____________ †
Schematic Diagram	18-A-1517*	____________ †
TEMPERATURE INDICATING EQUIPMENT		
Temperature Indicating Equipment	37-J-654*	CV31-S6100-63278

*Included as Reduced - Size Illustration in this Instruction Book.

† Drawing Number Unknown at Date of Publication

PART I

TURBINE AND REDUCTION GEAR

PART I

(Section 1) GENERAL DESCRIPTION OF TURBINE

TURBINE AND REDUCTION GEAR CHARACTERISTICS

1. 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 Reduction Gear, which serves to reconcile the high speed required for efficiency in the turbine to the lower practicable generator speed. The turbine, gear and generators are mounted on a common bedplate, to which are secured also the oil cooler, etc. An outline arrangement plan of the unit is shown in Figure T-1.

2. Four identical units are supplied for each ship. The nominal rating of each unit is 1250 kw. on an 80% power factor, 3-phase, 60-cycle, 450 volt a-c. generator; including 16 kw. on a 120-volt, d-c. exciter.

3. The turbine is designed to operate on steam at a throttle pressure of 525 psi. gage with 825°F. total temperature or 575 psi. gage dry and saturated with an exhaust pressure of 1 psi. absolute. It will develop rated capacity with steam conditions of 420 psi. gage, 825°F. total temperature and 1 psi. gage absolute exhaust pressure. It is capable of operating with a maximum pressure of 618 psi. gage and 850°F. total temperature. The following steam consumptions are guaranteed when the units are operating under the designed steam conditions of 525 psi. gage throttle pressure, 825°F. total temperature and exhausting against 1 psi. absolute.

Kw. Load	625	937.5	1250	1562.5
Steam Consumption Pounds Per Hour Including Gland-Seal Steam	6980	9700	12660	15835

Gland steam to be supplied from a separate source at about 10 psi. gage. Expected amount about 25 pounds per hour.

4. The turbine exhausts into the auxiliary condenser at 1 psi. absolute exhaust pressure.

5. The normal operating speed of the turbine is 8050 rpm. and that of the generator 1200 rpm.

6. The turbine bearing pressures are 60 and 67 psi. of projected area for the thrust and coupling ends respectively and the turbine and pinion journal speed are 109 feet per second and 140 feet per second respectively. The gear journal velocity is 26.2 feet per second.

7. The pinion and gear are of double-helical type and the gear is designed to transmit a normal load of 1748 BHP. with the pinion operating at 8050 rpm. and the gear at 1200 rpm. Under these conditions the pinion bearing pressure is 155 psi. of projected area and the journal velocity is 140 feet per second. The gear bearing pressure is 73.5 psi. of projected area and the tooth pressure is 71.6 psi. face/in. P.C. diameter.

8. Oil System Capacity - At high level 104 gallons; normal 99 gallons, and at low level 94 gallons.

DESCRIPTION OF TURBINE AND GEAR

General Description

10. 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 Curtis stage is followed by eight Rateau stages.

11. 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.

12. The turbine cylinder is supported at the gear end by lugs on the cylinder base at the level of the turbine centerline, which rest on the gear housing and are restrained from axial movement relative to the housing by keys set half in the lug and half in the housing. The lugs can slide transversely on the keys thus allowing for differential expansion but transverse movement of the turbine as a whole is prevented by a vertical key on the end of the cylinder base, held between gibs on the gear housing. 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.

Cylinder

13. The turbine cylinder is made from cast alloy-steel and consists of a base and cover, bolted together on the horizontal flange, and each made in two pieces joined at a vertical joint between the second and third Rateau stages. This joint is made up permanently at initial assembly and the cover and base thenceforth treated each as one piece. The horizontal joint flanges are carefully machined to a full bearing surface and the metal-to-metal joints made tight.

14. The cylinder is protected from excessive steam pressure by a relief valve which is set at 5 psi. gage. This valve is shown in Figure T-3. The turbine cylinder is also protected by a back-pressure trip which will trip closed the throttle valve when the back pressure at the turbine casing reaches 10 psi. gage pressure.

15. The turbine rotor is machined from a solid alloy-steel forging. The overspeed trip body is screwed onto one end and the other end is coupled to the reduction gear pinion through a flexible coupling (shown in Figure T-11). After the blades are installed the entire rotating assembly is dynamically balanced.

Curtis Blading

16. The blading is shown in detail in Figure T-4. The Curtis element consists of one pressure stage with two velocity stages. After the steam has passed through the steam chest valves it enters the nozzle block. This block is made of stainless steel and is secured to the turbine cylinder, with wedges and screws. The steam is expanded through curved foil passages in the block to the pressure existing in the Curtis wheel chamber. The blades are milled from bar stock of stainless steel with integral shrouds which form a closed passage for the steam flow. Supplementary shrouds are provided, riveted over tenons on the ends of the blades, by means of which the blades are secured together in groups to raise their natural frequency of vibration as a protection against vibrational stresses.

17. The rotating blades are secured to the turbine rotor by a type of fastening consisting of a double T-root. 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. The row is completely filled with blades and the last blade at this starting point is secured by pins. The stationary blades are secured in straight-sided grooves by a series of short keys which fit in auxiliary grooves cut in the blade shank and in the side of the main groove.

18. 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 paths 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 any condensation to flow to drain.

Rateau Blading

19. The Curtis element is followed by eight Rateau stages divided from the former and from each other by interstage diaphragms. The nozzles for the Rateau stages are machined units welded into inner and outer rings to make complete diaphragm assembly. The latter are made in halves and extend completely around the rotor. The nozzles in the first three stages, however, occupy only a portion of the circumference, varying in area in succeeding stages in accordance with the increase in the volume of the progressively expanded steam. The blades are milled from bar stock of stainless steel and are provided with shrouds riveted over tenons on the ends of the blades, thus forming a closed passage for the steam flow.

20. The blades 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 sides of the 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. The row is completely filled with blades and the last blade as this starting point is secured by pins.

21. Steam leakage from stage to stage between stationary diaphragms and the rotating shaft is minimized by means of interstage labyrinth seals. These consist of labyrinth strips machined integrally in ring segments mounted in L-shaped grooves in the diaphragms and held in the position of minimum clearance by means of garter springs, as indicated in Figure T-5.

Curtis Wheel Chamber Labyrinth Seal

22. In order to minimize leakage of high-pressure steam from the Curtis wheel chamber, and to lighten the load on the turbine gland at the high pressure end, an integrally cast diaphragm or "dummy" is provided between the Curtis wheel chamber and the gland. This diaphragm is fitted with 12 rows of labyrinth seal packing, being thereby throttled to a much lower pressure, is carried away to a connection between the third and fourth Rateau stages and therefore gives up most of its available energy in the lower stages of the turbine blading before passing to the exhaust.

Bearings (Journal)

23. The rotating element consisting of the turbine rotor, flexible coupling and pinion is carried in four bearings which are similar in general

design. These bearings are illustrated in Figure T-6. They consist of steel shells made in halves, and lined with genuine tin-base babbitt. The two halves of each bearing are doweled together with pins and the bearing is prevented from rotating within the housing by a stop dowel which projects into a notch cut in the housing. Oil is admitted at the horizontal centerline, the babbitt being relieved on either side to provide ample space for the distribution of oil along the journal surface. At the end of the bearing nearest to the turbine, the shell is grooved and a slot is cut at the bottom of the vertical centerline to permit the oil which flows to this end of the bearing to flow freely to drain. This oil groove is not required in the pinion and gear bearings. The pinion bearings have a normal clearance of .010" to .012" with a maximum clearance before re-babbitting of .024". The turbine bearings have .007" to .009" clearance with a maximum of .015" before re-babbitting.

Oil-Seal Rings

24. The oil-seal rings, which are used to prevent the escape of oil along the shaft from the bearing housings, consist of bronze rings made in halves, and baffle plates also in halves. Any oil which creeps along the shaft is caught in the grooves in the oil ring and flows downward through a series of holes into the pocket in the lower half of the ring. Holes are drilled in the baffle which permit the oil to flow to drain. These holes are drilled at a sufficient height to maintain an oil level in the pocket, thus preventing the escape of oil vapor through the drain holes. The oil-seal rings may be seen in Figure T-2.

Turbine Glands

25. At the point where the turbine rotor shaft extends through the ends of the cylinder, leakage of steam from, or air into the cylinder is prevented by means of glands of the carbon-ring type. The coupling-end gland has a casing consisting of an outer and two inner sections, each divided in halves and the outer casing bolted against the cylinder. Each of the inner sections of the casing contains two carbon rings of three segments each, held together around the shaft by means of garter springs. The space between the two sections is connected to a source of sealing-steam supply. The glands are illustrated in Figure T-7.

26. The gland-ring casings have their halves held partly by the cylinder and partly by a separate outer casing bolted to the cylinder. The exhaust-end gland is of similar design, except its lower outer casing is integral with the cylinder base.

27. In order to remove the gland without lifting the cylinder cover, the outer casing half is first unbolted and removed. Then, the upper half of the first inner gland-ring casing may be removed, after which the carbon ring segments may be removed and the bottom half of the ring casing rolled around the shaft and removed. Then the second inner ring casing may be pulled along the shaft into the place of the outer casing and it then may be similarly removed. Replacement will be accomplished by performing the above operations in reverse order.

28. All the rings are fitted with a clearance around the shaft and remain stationary in the gland case. The rings are made in the shape of a frustrum of a cone and are held in by a retainer of corresponding shape, and garter spring. When the retainer is put under tension of the garter spring, the resulting compression acting on the conical surfaces of retainer, and carbon ring, presses the ring tight against the side of the groove thus preventing leakage between the ring and the groove wall.

29. This is an important feature of the design of these glands. It will be noted that in the exhaust end gland the tapers are not all in the

same direction. If the gland is dismantled, care must be taken to see that the rings are re-assembled in the same manner as found originally. The following instructions cover in detail the method of assembling the glands and the fitting and "running-in" of new rings.

ASSEMBLY OF NEW RINGS

30. When assembling new rings proceed as follows:

Step 1. The gland-ring casings and outer casing halves as well as the turbine shaft must be carefully cleaned.

Step 2. Slip the lower half of the inner casing into the cylinder base.

Step 3. Loop a garter spring on the shaft. Slip two segments under the garter spring and slide them around on the shaft into the lower half chamber, keeping enough tension on the spring to prevent the segments from parting company. Then assemble the remaining segment making sure that the locking pin comes at the joint. Repeat for the second ring.

Step 4. Put upper half of the ring case over assembled rings and push the inner case along the shaft into its proper place. For use in disassembling, a tool is provided for withdrawing the inner case (Figure T-30, Items 10 and 16).

Step 5. Repeat given assembly instructions with next two rings.

Step 6. Outer Casing Half

(a) Put outer casing half in place very carefully.
(b) Make sure that no dirt lies on the horizontal joint before bolting up the joints.

RUNNING-IN OF NEW RINGS

31. Be sure that sufficient steam is being supplied to the gland. It is practically impossible to determine off-hand the operating shaft temperatures along the shaft axis. Therefore, the "cold" ring clearances are determined by means of an empirical formula. It is, however, still possible, in fact very probable, that the ring clearances are either too large or too small.

I. Carbon Clearances Are Too Small

32. This can be determined by either of the two conditions.

(a) The turbine starts to vibrate. Vibrations get worse if speed and temperature are kept constant.

(b) The shaft overheats due to friction and starts to show heating colors.

Step 1. In either case the turbine speed must be lowered immediately. If the vibrations do not stop, or the shaft shows some additional heating colors, the turbine must be shut down.

Step 2. The packing must be disassembled. The inside surface of the rings will show spots and should be carefully scraped. After this the rings are installed again.

Step 3. If the clearances are only slightly too small, and this is usually the case, the carbon rings can be run in without having to take the packings apart. This, however, can only be done, if the opportunity exists of operating the turbine for some time at low speeds.

(a) Operate the turbine for 1 hour at each speed with the maximum steam temperature available for this speed. Start approximately at 1000 rpm.

(b) If vibration should start or heat-coloring of the shaft show, lower the speed immediately. Raise and lower the speed several times slowly, keeping the temperature constant. Afterward operate again at the speed where the vibrations started. In most cases the vibrations will not occur again.

(c) If the above described procedures will not eliminate the vibrations, the packing must be taken apart and scraped-in.

Step 4. If vibrations are caused by the packing, they will very quickly become more severe if speed and temperature are held constant. If, however, the vibrations start and stop without changing speed and temperature, they are not caused by the packing and must have another source.

II. Carbon Clearances Are Too Large

33. When carbon clearances are too large proceed as follows:

Step 1. If the packing is not tight, that is, if excessive steam leakage occurs at full speed and full load (maximum operating temperature) the carbon clearances are too large.

Step 2. The packings must be taken apart again and the rings taken up. This is done by filing off some carbon with a very smooth and fine file on one surface per joint. A fine emery cloth can also be used.

Step 3. Care must be taken that the joint surfaces stay flat and that the joint is tight after assembly of the rings.

Step 4. Do not remove large quantities of graphite. Approximately one thousandth of an inch per joint should be removed, if the packing leaks badly.

Step 5. Before assembling the rings again, they must be thoroughly cleaned.

34. Long life and good performance of the packings will more than compensate for the work involved in proper fitting or the time required in running-in the rings. In most cases not more than two fittings of the rings are required.

Steam, Gland and Drain Piping

35. 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 line and in part from the low-pressure valve steam leakoff, at approximately 10 psi. gage pressure and a valve and gage are furnished for controlling the pressure at each individual gland. Approximately 25 pounds per hour of steam will be required for this purpose. The steam pressure at the glands should be maintained at not more than 2 psi. gage. It will be noted that the main steam inlet line, the steam strainer body and the impulse chamber of the cylinder have drains controlled by globe valves. These valves should be opened during the starting periods in order

to remove the condensation resulting from heating the turbine parts. Further reference to these drains and Figure T-8 will be found under the subject "Operation".

Thrust Bearing

36. The end thrust on the rotor is transmitted to the stationary parts by means of a thrust bearing of the Kingsbury type, illustrated in Figure T-9. It is located on the exhaust end of the turbine shaft and is also shown in Figure T-2.

37. This bearing is of the double-thrust-type having babbitt thrust shoes on both sides of the collar which is a separate piece mounted on the shaft. Each side of the bearing is provided with six shoes.

38. The shoes "6" are supported on the leveling blocks (or "plates") "5" and "8", which by rocking upon each other allow the shoes to move relatively to one another so that the babbitt faces are all pressed against the collar with equal force. Hence each shoe takes an equal share of the load. The upper leveling plates "5" rest upon the lower leveling plates, "8", which in turn are carried in the base ring "4", made in halves.

39. As may be seen in Figure T-2 (longitudinal section through turbine and pinion) the base ring is supported in the housing. It is centered by the key "10" shown in Figure T-9. The thrust bearing is located by liners between it and the housing at each end.

40. The correct axial position of the thrust bearing, and hence the correct axial location of the rotor, is determined by the thickness of bearing liner (shown also in Figure T-2) the base ring "4" and the housing. The thickness of this liner must be such that with the rotor barred toward the exhaust end as far as it will go, the clearance between the nozzle block and the first row of Curtis blades is as shown on the clearance diagram, Figure T-26.

41. The actual internal clearance of the bearing should be between .009" and .015" in order to permit establishment of a proper oil film between the collar and the shoes. After the liner of correct thickness (as described above) has been installed, the proper running clearance is obtained by adjusting the thickness of the liner which is located between the thrust bearing outer end and the housing. This clearance should be checked by rolling the rotor and barring it from one extreme axial position to the other, measuring the end travel with a dial indicator.

42. If the bearing has been disassembled for cleaning or repair, the following notes will assist in simplifying reassembly.

43. First clean and inspect all parts carefully. Oil bearing surfaces when assembling.

44. All bearing parts are to be assembled radially with housing cover removed. See Figure T-9. With shaft in position first rotate lower half "1" of brass oil control ring into place under collar. Note that longer lug belongs on upward side of collar's rotation.

45. Put leveling plates "5" and "8", and six shoes in position on the split halves of base ring "4", and secure by screws "3". Rotate lower half of base ring into place on each side of collar, with parts attached, and follow with upper half and its key "10".

46. Bolt upper half "12" of oil-control ring to the lower half "1".

47. Turn base ring "4" to bring joint vertical, and test end-play by jacking shaft endwise and measuring movement with feelers. Adjust thickness of one or both end filler pieces, by shimming or machining, to make total end-play of shaft between .009" and .015". When found correct, turn base ring to bring key "10" to top center, and bolt housing cover down.

48. Do not force when assembling. If parts do not go together easily, something is out of place.

Rotor-Position Indicator

49. The rotor-position indicator which is bolted to the end of the thrust bearing housing is shown in Figure T-10. A reading is taken by pushing lightly on the pad "A" on the pointer "12" until the ball "6" makes contact with the end of the rotor. The indicator was set at the factory, but nevertheless immediately after installation the rotor should be barred toward the exhaust end (making sure that all clearance is taken up) and while in this position the pointer should be checked and, if necessary, adjusted to zero, loosening the clamp screw on the pointer to adjust it and then tightening up securely, and pinning. Thereafter when a reading is taken displacement of the pointer from zero will indicate an axial displacement of the rotor, one division on the graduated scale "16" representing a displacement of the rotor of .002". A small spring "8" holds the ball out of contact with the pinion when the indicator is not being used. It is obvious that readings should be taken either with the machine carrying load or with the rotor barred toward the exhaust end. Otherwise, the clearance in the thrust bearing may cause an erroneous reading.

Coupling

50. The turbine rotor and the reduction gear pinion are connected by means of a coupling of the "Fast" type, illustrated in Figure T-11.

51. As may be seen in the detail in the illustration the coupling is of the internal involute-toothed type. The coupling heads are pressed and keyed to the turbine and pinion shafts respectively and the two halves of the sleeve are bolted together to make the driving connection.

52. Lubrication is supplied by means of sprays of oil directed into the lip of the sleeve from nipples in the pinion bearing ends and a positive circulation of oil, to prevent sludging of the tooth clearances, is maintained by virtue of a number of outlet holes on the periphery of the lip at the turbine end. Further information will be found under "Installation" and under "Maintenance".

Throttle Valve

53. Steam is admitted to the turbine by a vertically disposed throttle valve which is shown in Figure T-12. This valve is manually operated by a handwheel, but is closed automatically by a compression spring when the trip release latch is tripped by the overspeed trip or by the back-pressure safety stop.

54. The valve shown in Figure T-12 consists of a single-seated disc operated by means of a handwheel which rotates a screw spindle in a sliding nut. The sliding nut is spring-loaded and arranged so that when the spring has been compressed, the sliding nut is held by the trip latch against the force of the spring. With the valve in the latched position, rotation of the handwheel will open the valve to admit steam to the turbine. With the valve open, it will be tripped closed automatically if the overspeed-trip mechanism functions. When the overspeed trip acts it rotates the shaft carrying the latch which holds the sliding nut against the operating-spring compression. This movement disengages the latch and releases the spring

force, so that the valve is driven instantly to its seat.

55. The valve is installed so that the steam enters above the seat, or in the direction indicated as the inlet by an arrow on the valve body. When the valve is closed full steam pressure acts over the total area of the disc, holding this to its seat. When the valve is being opened, the first movement of the stem lifts the pilot valve and releases the pressure acting on the disc, decreasing the pressure in the balancing cylinder to approximately the same pressure as that on the outlet side of the disc. Under these conditions the valve is practically balanced, the further movement of the valve stem opens the main disc without requiring excessive force.

TRIPPING AND RESETTING

56. In order to latch the valve, rotate the handwheel in the direction marked "RESET" on the handwheel. This causes the sliding nut to be raised, and rotation of the handwheel should continue until the sliding nut comes to a definite stop. Do not try to force rotation beyond this point.

ADJUSTING SCREW, FUNCTION AND USE

57. One very important feature is the controlled leak into the balancing cylinder, which is regulated by the adjusting screw in the valve cover.

58. All valves shipped from the factory, have the adjusting screw wide open, and this should be adjusted at installation to suit the actual operating conditions. If the valve is sluggish in operation, this may be due to excessive pressure in the balancing cylinder, and should be corrected by rotating the adjusting screw in a clockwise direction, to reduce the amount of steam flowing into the balancing cylinder.

59. If the adjusting screw is closed off too far, there may be a tendency for the main valve to jump when first moved off the seat. The adjusting screw should be backed off counter-clockwise until this jump is no longer felt. The jump is caused by the steam pressure acting on the seating area of the main disc as it is moved off its seat. This pressure force must be counter-acted by maintaining a sufficient pressure in the balancing cylinder. When the adjusting screw has once been set for actual operating conditions, no further adjustment will be necessary.

Steam Chest and Governor

STEAM CHEST

60. The steam chest and governor are shown in Figures T-13, T-14, and T-15, the first being a section of the steam chest and linkage, the second being a sectional view of the governor and the third a plan view showing the arrangement of the speed-changer. The steam chest body is an integral part of the turbine cylinder, and the cover serves also as the linkage support. The turbine is provided with six valves which are arranged in parallel within the steam chest; that is, all valves are surrounded with steam at approximately throttle pressure.

61. These valves are of the single-seated type. The seats are pressed into the steam chest body and can be replaced, if necessary. The governor servomotor raises and lowers the valve bar "20", keeping it perfectly horizontal at all times. The bar, in turn, lifts the valves by engaging the adjusting nuts "19". The adjusting nuts are threaded on the valves and hence the point at which each valve opens, and the amount of opening can be varied by means of these adjusting nuts. Of course, there is an unbalanced steam force tending to close the valves but, in addition, a positive closing force is obtained by the lower edge of the bar engaging the shoulder on each valve.

62. The valve bar stem packing consists of closely fitted bushings "16" and "17" with suitable leak-off openings. Two leak-offs are provided as shown in the Figures T-2 and T-13. The upper one is led to a point at atmospheric pressure and the lower one is led to the equilibrium pipe.

63. The operating lever is "V" shaped and mounted on a rock shaft, with the central arm connected to the governor and each of the two branch arms connected to a valve bar stem. Universal joints are used in the connecting links to insure correct alignment of the moving parts. The operating linkage is fulcrumed so that downward movement of the governor servomotor piston opens the valves and upward movement of the piston closes them.

64. The operating lever "4" is secured through universal links to the governor servomotor lever "10", which in turn is connected to the servomotor piston rod "51" of Figure T-14.

65. Since the governor servomotor piston spring "61" tends to move the valves in the closing direction it requires oil pressure above the piston to open the steam chest valves and with the unit at rest the relationship of the parts is such that the steam valves must be opened manually to get the unit into operation. For this purpose a hand lever, a cam and a jacking lever ("58", "55" and "54" of Figure T-14) are provided with which the linkage can be manually raised to open the valves. When steam is admitted and the unit comes up to speed, the movement of the linkage as the governor takes control releases the hand lever and the cam and lifting lever drop into the "OFF" position.

66. For establishing the proper lifts for the several steam chest valves a special fixture is provided, the application of which is illustrated in Figure T-16.

67. Referring to Figure T-16, in order to use this fixture first remove the valve linkage and the steam chest cover. Screw the valve-stem extension rods onto the valves, as indicated and assemble the valve-lifting bar and the valves with the reference bar and bolt the latter to the steam chest body in place of the steam chest cover. Before tightening the nuts on these bolts make sure that the reference bar is so located that the valves all seat properly and the extension rods slide freely through the bar.

68. Mount the measuring bar on the valve-lifting stems and make sure that it is parallel with the reference bar when all the valves are properly seated.

69. With a depth micrometer (the bearing-wear micrometer may be used for this purpose) measure accurately the distance from the top of each extension rod to the top of the measuring bar and record the readings.

70. Now raise the measuring bar until the spacer blocks provided can be set under the ends. Make sure that the measuring bar is down tight on the blocks and that the latter are standing squarely on the reference bar. Measure again from the top of the bar to the tops of the extension rods and record the readings.

71. The difference between the first and second readings on each valve will equal the clearance between the valve-adjusting nuts and the valve-lifting bar when all the valves are seated. The valve lifts (when recorded) from tests in the factory will be listed under "Valve Settings" at the front of this book and in the event of a complete dismantling of the steam chest the test lifts should be reproduced when the unit is reassembled.

GOVERNOR

72. The governor is of the vertical-shaft, fly-ball type, in which the revolving weights move radially in response to changes in centrifugal force, resulting from changes in speed.

73. The changes in centrifugal force of the weights are transmitted to a relay which controls the flow of high-pressure oil to and from the governor servomotor cylinder. Movements of the servomotor piston are transmitted by a lever to the steam chest linkage. The oil required to operate the servomotor piston is supplied by the main oil pump and is led to the high-pressure oil-inlet chamber of the relay through passages drilled in the governor housing.

74. Referring to Figure T-14, the governor hub which holds the weights is driven from the end of the gear wheel shaft by means of spiral gears. The governor weights are secured to a strap of spring steel mounted across the diameter of a ring held by the governor hub. The spring is formed into an inverted "U" at the center and the forces acting on the weights flex the strap, thus transmitting the forces through the spring seat to the cup valve. When the governor is at rest, the governor spring "18" holds the governor weights in their innermost position.

75. The complete rotating element is carried in two bearings. Each of these bearings is a combined radial and thrust bearing mounted in the bearing bracket. This bracket is centered in and bolted to the gear housing cover. The vertical clearance between the thrust faces can be adjusted by means of the liner "7" provided between the gear "8" and the spacer "3". This can be done by machining the liner. This clearance should be from .003" to .006".

76. The cup valve "64" rests on a ball "69" supported on the pin "75" in the center of the spring seat "70" which is secured to the governor weight strap.

77. The space beneath the relay piston "34", is supplied with high-pressure oil through drilled orifices in its periphery, and the cup valve, by determining the ratio of its area to the centrifugal force of the weights, controls the pressure acting under the relay "34".

78. The balance of forces in any given operating condition consists of the centrifugal force of the weights acting upward through the strap, ball and cup valve, opposed by the governor oil pressure acting downward on the cup valve. The valve of the governor oil pressure is determined by the area of the cup valve and the part of the centrifugal force of the weights not balanced by the spring forced, hence, every turbine speed (and consequent value of centrifugal force on the governor weights) determines a value of the governor oil pressure.

79. The relay is secured to the pin "37" which is subjected to the compression of the spring "40". Therefore, the oil pressure under the relay determines the degree of compression of springs "40" and hence the position of the relay in the ported bushing "36". This, in turn, controls the flow of oil to and from the servomotor cylinder.

80. The upper spring seat "43" of the spring "40" is connected through stem "41" and the follow-up linkage and lever "50" to the servomotor piston so that movement of the piston, consequent upon a change in the governing pressure under relay "34", is immediately followed by a corresponding change in the compression of spring "40", sufficient to balance the change in governor oil pressure and restore the relay to its neutral position.

81. The operation of the governor is as follows:- With the turbine at rest, the governor weights are held in their innermost position by the governor spring, and the governing valves are held closed by the servomotor piston which is held in its uppermost position by the spring "61" when no oil pressure is available. In order to start the unit it is necessary first to open the steam chest manually by means of the jacking handle "58" and the lever "54" (Figure T-14) which forces the servomotor piston down against the resistance of spring "61". When the turbine speed increases sufficiently for the oil pump to provide enough pressure to open the governing valves, the latter will open wide allowing the handle "58" to drop back to its original position. As the speed approaches normal the centrifugal force of the governor weights will overcome the force of the governor spring and the weights will begin to move outward. The unit then comes under the control of the governor.

82. If the load increases, the speed decreases and the centrifugal force acting on the weights is reduced. The governor spring-force being constant, the reduction in centrifugal force is balanced by a reduction in governor oil pressure. This results in a downward movement of the relay which opens the ports admitting high-pressure oil above the servomotor piston, and connects the space below the piston to drain. The piston therefore moves downward, opening the governing valves sufficiently to maintain the required speed. As the piston moves downward, the follow-up lever decreases the compression of spring "40" thus restoring the relay to its neutral position.

83. If the load decreases, the speed increases increasing the centrifugal force on the weights and this increase in force is balanced by an increase in oil pressure. The increase in oil pressure under the relay causes it to move upward, uncovering the ports which admit high-pressure oil below the servomotor piston and connecting the space above to drain. This piston therefore moves upward, closing the governing valves sufficiently to maintain the required speed. Upward movement of the piston, acting through the follow-up lever, compresses the spring "40" until the increased oil pressure is compensated for and balance has again been restored.

84. Thus it is seen that following any relay movement the resulting movement of the servomotor piston changes the spring compression so as to restore the relay to its neutral position where it remains until another change in speed (or load) occurs.

SPEED-CHANGER:

85. The hand or motor-operated speed-changer, by means of which the speed or load can be varied, is shown in Figures T-14 and T-15. As shown, it is in mid-position. The principal parts of the electrically operated portion are:- the motor, shaft, worm and worm wheel. The principal parts of the hand-operated portion are:- the handwheel and shaft. Both the electrically operated and hand-operated portions act to regulate the speed through the worm, "100" and worm wheel "23" (Section B-B, Figure T-14) which is threaded on the transformer housing "29".

86. Since the housing "29" is stationary, rotation of worm wheel "23" on it produces vertical motion of the worm wheel, which through ball bearings "22" supports the governor spring seat "21" and spring "18". Consequently, movement of worm wheel "23" changes compression of the governor spring "18" and hence the speed, or load, corresponding to a given governor weight position.

87. For hand-operation, rotation of the handwheel is transmitted directly through the shaft "92" to the worm "100" which meshes with the worm wheel "23", thereby moving the worm wheel upward or downward on the transformer housing "29". For motor-operation, the worm "108" (Section G-G,

Figure T-15) meshes with the worm wheel "98" (Section B-B, Figure T-14) and drives through the collars "91" and "95" and the handwheel, to the second worm and worm wheel. The collars "91" and "95", faced with clutch plates "93" and "94", form a friction-type clutch which is held in engagement by the spring "99". This clutch slips when the hand-operated feature is used and also serves as a safety device in the event of overtravel of the speed-changer motor.

Governor Disassembly and Adjustment

88. The governor is thoroughly tested and adjusted at the factory and should operate satisfactorily as received. However, from time to time during the life of the unit it will be expedient to completely disassemble the mechanism for examination, cleaning, or replacement of worn parts, and at such times when reassembling, it will be advisable to check the accuracy of the adjustment. At other times partial disassembly for examination of specific portions of the mechanism may be indicated, and on all such occasions, the following information should be noted:

89. TO DISASSEMBLE GOVERNOR

A. Complete Disassembly

Step 1. Disconnect steam-chest linkage from steam chest.

Step 2. Disconnect follow-up linkage.

Step 3. Remove cylinder cover bracket "47", together with servomotor piston "59".

Step 4. Remove servomotor spring "61".

Step 5. Remove governor cover "44" together with stem "41".

Step 6. Lift out spring seat "43" and spring "40".

Step 7. Lift out bushing "39". (This bushing serves as a stop to prevent overloading of the spring "40" and the follow-up linkage in case of excessive overspeed - for example, while testing overspeed trip. It serves also, incidentally, as a spigot to position the governor cover "44".)

Step 8. Lift out spring seat "38" and relay "34", using threaded rod screwed into a tapped hole provided for the purpose.

Step 9. Remove speed-changer handwheel "87".

Step 10. Unbolt and remove access plate "62". When this plate has been removed, the speed-changer worm shaft assembly may be withdrawn as a unit.

Step 11. If it is desired to completely disassemble the speed-changer mechanism, loosen the set screws securing the speed-changer clutch collars "91" and "95" and remove these collars. (The outer one will slip off while the inner "95" must be unscrewed from worm wheel "98".)

Step 12. Remove worm wheel "98" and bushing "89".

Step 13. Rotate the worm shaft "92" to screw the worm "100" out of mesh with worm wheel "23" and withdraw the worm shaft.

Step 14. Unbolt the bottom flange of the governor housing "73" and lift the housing straight up until the governor parts are cleared, and then swing the housing away. When the governor housing has been lifted clear of rest of the mechanism, make sure that the upper race of the ball bearing "22" has not been lifted with the housing. If it has, remove it immediately to avoid possibility of its dropping loose later and being damaged.

Step 15. Carefully remove the ball bearing "22".

Step 16. For access to governor weights, etc., remove governor casing "19".

Step 17. For access to the cup valve, etc., turn the governor housing upside down and remove the bolt "63" and the cap screws.

Step 18. Lift out the cup valve assembly.

Step 19. Turn the cup valve assembly right side up and remove the fillister head screws holding the cup valve seat. Remove the seat "31".

Step 20. Remove the cup valve "64".

B. Partial Disassembly

There are three partial disassembly sequences which may be required for access to specific portions of the governor mechanism. These are:

Group I. Access to cup-valve seat and cup valve for examination and cleaning.

Group II. Access to the governor weight assembly.

Group III. Access to the governor bearings and the axial clearance adjustment liner.

To make these three partial disassemblies, proceed as follows:

Group I. Follow steps 1 to 8 inclusive of "Complete Disassembly", Sequence A, described above.

Step 9. Lift out the governor spring seat "33" and the spring "32", using for the former the same threaded rod previously mentioned and for the latter, a hook-ended piece of wire.

Step 10. Unscrew the fillister head screws in the cup-valve seat "31" and remove the seat by means of the threaded rod screwed into a tapped hole provided for the purpose.

Step 11. Lift the cup-valve "64" using the same threaded rod.

Group II. Follow steps 1, 2, 14, 15 and 16 of "Complete Disassembly", Sequence A, described above.

Group III. Follow steps 1, 2, 14, and 15 of "Complete Disassembly", Sequence A.

Step 16. Remove the fillister head screws holding the brackets "9" to the gear-housing cover.

Step 17. Lift out the governor hub and bracket assembly straight up until clear of the housing. Remove this assembly to the work bench.

Step 18. On the work bench loosen the set screw "2" and remove sleeve nut "1".

Step 19. Stand the assembly on end, and by pushing down on the bracket, push the collar "3" off and remove the liner, Item 7.

TO ADJUST AND ASSEMBLE GOVERNOR

90. The governor is assembled by reversing the order of the steps given above. However, if the mechanism has been entirely disassembled, the adjustment should be checked before reassembly. In connection with the reassembly, remember that there is no gasket used between the governor housing and the gear-housing cover.

91. To Adjust the Governor Relay Mechanism

Step 1. Check the vertical clearance in the governor-spindle thrust bearing, that is, the clearance between the bearing and the spindle sleeve. This vertical clearance should be .003" to .006" and is obtained by replacing or machining the liner "7" as the case may require. The radial clearance in the governor-spindle bearing should be .003" to .006" on the diameter.

Step 2. When the governor hub and bracket assembly have been replaced in the gear-housing cover, remove the governor spring seat "21" and the governor spring "18".

Step 3. Place a scale across the top of the governor case "19" and measure the downward deflection of the governor weight strap "15" against the adjusting screw "12" by pressing down on the spring seat "70". This downward deflection should be 1/32". Readjust the position of adjusting screw "12", if necessary, bearing in mind that 1/4-turn of this screw produces a vertical motion of .015".

Step 4. When the governor housing has been reassembled on the gear-housing cover, remove all the liners "30" from under the flange of the cup-valve seat "31". This will permit the cup-valve seat to rest on the cup valve "64".

Step 5. Measure from the top of the cup-valve seat "31" to a scale laid across the top flange of the governor housing, being sure that the gasket "42" is not on the flange.

Step 6. Replace all of the liners under the cup-valve seat "31", and repeat this measurement. The difference between the two measurements should be 1/32". Change the liners if necessary, to obtain this figure.

Step 7. Set the governing valve lifts according to instructions given in the description of the steam chest.

Step 8. Adjust the length of the connection to the governor valve lever so that all the governing valves are closed tightly when the servomotor piston "59" is 1/4" away from its upper limit of travel.

Step 9. In reassembling the follow-up mechanism, be sure that the follow-up lever fulcrum pins "80" and "83" are placed in the same holes in which they were found originally, in order to maintain the same regulation.

Step 10. The speed-changer limit stop consists of lugs on the plate "27" and the ring "28". To set the limit stops, proceed as follows:

(a) Start-up the unit and hold the generator speed at 1240 rpm., without load, by means of the throttle valve. Turn the speed-changer in the "INCREASE" direction until all the governing valves are wide open. This will be determined by measuring the lifts and checking them against the figures given in the valve-lift tabulation. This represents the full-load position.

(b) Shut the machine down, and lock the limit stop in this position. To do this, remove the access plate "62". The ring "26" is saw-cut in the horizontal plane so that tightening the nut "63" locks the stop "28" securely. Since the upper and lower lugs on the stop ring "28" are a constant distance apart, the speed-changer range is fixed, and no further adjustment of the lower stop is possible.

92. The following data were used by the Manufacturer in making the governor adjustments. The values are approximate and are given as a guide in the event the governor requires readjustment.

<u>Step 1.</u> Locate follow - up lever fulcrum pin in hole No. 2.

<u>Step 2.</u> Set relief valve for 90 psi.

<u>Step 3.</u> With governor controlling speed in no-load position adjust servomotor spring to give secondary governing pressure of 40 psi.

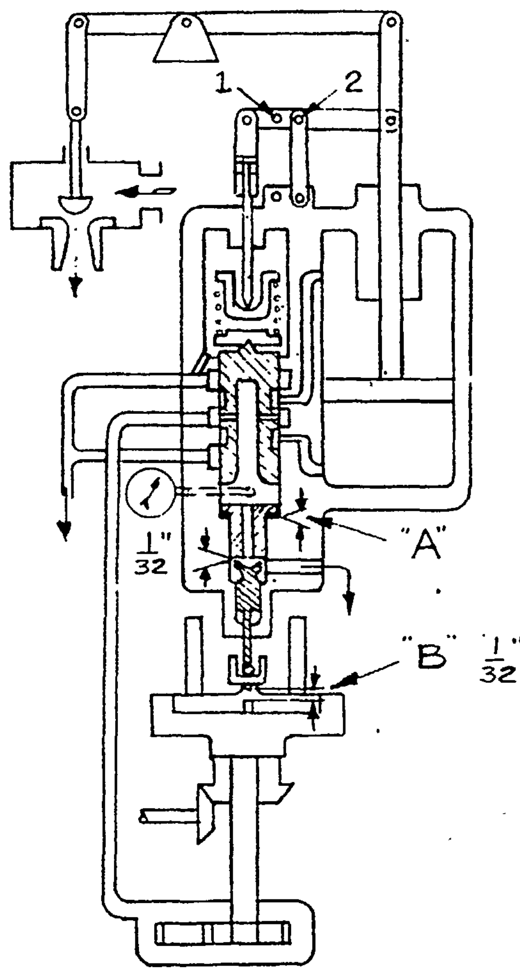
<u>Step 4.</u> Adjust the speed-changer to give 1200 rpm. and observe stability.

<u>Step 5.</u> Close the throttle valve till the governor is just wide open. The drop in speed should be 60 rpm. Speed variation 5%. The drop in secondary governing pressure should be 22 psi. ± 5%.

<u>Step 6.</u> Hold the speed at 1240 rpm. by means of the throttle valve and run the speed-changer in the opening direction until the governor is just wide open.

<u>Step 7.</u> Shut down and lock speed-changer limit stop in this position.

No Load to Full Load = (13/32" governor valve travel (3% speed changer



There is a 1/4" pipe tap for gage connection in the flange located on the side of the governor for obtaining secondary governing oil pressure.

"A" Shim to obtain 1/32" clearance between cup valve and seat.

"B" Set for 1/32" clearance when strap is clamped in place but with spring removed.

Extraction

93. As shipped from the factory, it is not intended that steam should be extracted from the blade path of the turbine. However, a nozzle is provided in the cylinder base at one side, from which steam could be extracted at some future date, if desired. This opening is blanked off at the factory. For the convenience of the operating personnel, should it be decided in the future to employ extraction, a curve is given in Figure T-32 showing the quantities of steam which could be extracted at various loads.

Reduction Gear

94. The longitudinal section through the pinion shaft is shown in Figure T-2 and the longitudinal section through the reduction gear is shown in Figure T-17. The gear wheel is pressed onto the gear shaft, and is further secured by set screws. The shaft is carried in the gear bearings (Figure T-17), the bearing on the turbine end acting also as the thrust bearing. Machined collars on the shaft act as the thrust bearing collars and liners are provided by means of which the axial location of the gear wheel may be adjusted. The gear wheel and generator rotor are dynamically balanced after being bolted together.

95. The gear housing base is mounted in the bedplate and forms the oil reservoir for the unit. An oil-level gage is provided to show the amount of oil in the reservoir. The main oil pump, which is driven by the bevel gears, takes its suction from the reservoir as shown.

96. A lug on the housing cover matches with a bracket on the base and the two are pinned together so that the cover may be swung open without the necessity of removing it completely. A support arm may be bolted to cover and base to hold the cover in the open position for inspection or work on the gear.

97. Between the generator-end gear bearing and the coupling there are two oil-thrower rings turned on the shaft and an oil ring, the labyrinths of which drain back into the gear housing. Also between the coupling and the generator there is a second double oil ring with a leak-off from between the sections so that the possibility of any vapor being drawn into the generator winding is eliminated.

98. The gear teeth are lubricated by means of pinion sprays which discharge oil between the pinion and gear teeth.

Gear Bearings

99. The pinion bearings, shown in Figure T-6, consist of steel shells, babbitt-lined, similar to the turbine bearings except that the pinion bearings, being enclosed by the gear housing do not require oil baffles, as do the turbine bearings. The pinion bearings have normal clearance of .010" - .012" with maximum of .024" before re-babbitting. The gear bearings shown in Figure T-18 have .008" - .010" normal clearance with maximum of .018" before re-babbitting. The turbine-end main gear bearing is provided with bolted-on thrust rings at either end. Shoulders on the gear shaft serve as thrust collars so that this bearing is a combined journal and thrust

bearing. Split liners between the bearing wheel and the thrust rings permit adjustment of the location of the main gear wheel in the housing and of the axial clearance of the bearing.

Alignment of Pinion and Gear

100. For proper operation of the unit the pinion and gear should be parallel. This condition exists when the pinion and gear-shaft centerlines lie in the same plane and are equidistant at both ends. For use in obtaining and checking this condition the gage and the fixture (Figure T-30), are provided.

101. The fixture is laid on the gear with the pads at the square end resting on the gear journals. If the pinion and gear are in the same plane the pads at the round end should simultaneously touch the pinion journals.

102. If this does not occur adjustment may be made by scraping the bearing lower half at the end which is touched, to bring the high end down so that both pads will touch. This scraping must be carefully done and should not in any case be carried to the extent of increasing the total bearing clearance beyond the maximum permitted. In such a case it would be necessary to re-babbitt or to install new bearings. However, the likelihood of such a condition occurring is most remote.

103. Parallelism is obtained when the gage "9" (Figure T-30) will just fit between the pinion and gear-aligning shoulders at both ends.

Main Oil Pump

104. The main oil pump, which is shown in the reduction gear assembly (Figure T-17), is located in the turbine end of the gear housing base. It is of the gear type and is driven from the governor body, which in turn is driven from the main gear shaft through spiral gears.

105. The pump body is bolted to an internal bracket in the gear housing base. The suction is taken from close to the bottom of the reservoir through a short intake pipe. The pump is driven by means of a vertical shaft splined at both ends. The upper end engages the governor body sleeve nut, which is secured to the governor body. The lower end engages splines in a hollow shaft or driving sleeve to which the pump gear (driver) is keyed and which rotates in the pump bearing bushings. A bushing pressed into the bore of the driving sleeve prevents the splined driving shaft from dropping down. The driven pump gear is keyed to a short idler shaft. The bushings which serve as bearings for the gears are made of tin-base babbitt.

106. The pump takes oil from the reservoir and discharges into a line leading through the gear housing to the duplex strainer and thence to the oil cooler.

OIL SYSTEM

Oil System

107. The arrangement of the oil system is shown diagrammatically in Figure T-19. This system consists essentially of a reservoir formed by the reduction gear housing, a main oil pump described above, a duplex strainer, a cooler, a hand-operated auxiliary pump for use when starting and stopping the unit, and the connecting piping.

108. The level of the oil in the reservoir is shown by the float-type of level gage which is located on the turbine end of the gear housing. The oil level should be maintained so that it is between the high and low-limit marks on the gage plate with the machine in operation.

109. In normal operation, the main pump discharges at approximately 90 psi. gage pressure. A part of this oil is led through cored passages to the governor mechanism to operate the steam chest valves. The remainder is led through external piping through the strainer and cooler to lubricate the bearing and reduction gear teeth. The maximum permissible temperature of oil leaving any bearing is 180° F. The temperature rise of oil passing through any bearing is not to exceed 50° F. The flow of the oil through the bearings is regulated by relief grooves cut at the horizontal joint of the bearing and by orifices.

110. A relief valve, connected to the bearing supply line, is set to discharge a part of the oil directly to the reservoir if the pressure at the bearings exceeds 10 psi. gage. Also the low-pressure-alarm contact-maker is connected to the system so as to sound an alarm if the pressure at the bearings drops to 4 psi. gage. A by-pass valve (Figure T-20), around the cooler is provided so that the cooler can be taken out for cleaning and repair while the unit is running. The cooler is preferably by-passed when starting the unit, until normal bearing operating temperatures have been established. When the cooler is put in service the water circulation should be carefully adjusted so as to prevent under-cooling of the oil.

Auxiliary Oil Pump

111. The hand-operated auxiliary pump takes its suction from the reservoir and discharges through a check valve into the strainer and thence to the lubricating system. This pump should be operated when starting the unit until the speed increases sufficiently for the main pump to supply the lubricating requirements. This pump should also be operated when slowing down the unit until the shaft is at rest.

112. The auxiliary oil pump is shown in Figure T-21,like the main pump it also is of the gear type, but is driven manually by turning the handle "9", which drives through the step-up gears "4" and "5". These gears have a 4:1 ratio. The pump driving shaft "12" passes through a stuffing box "15", "16" and "22" containing packing, which minimizes leakage of oil from the pump into the driving gear casing.

113. The pump gears "6" and "7" may be examined by taking off the gear housing cover "2" and removing the screws "21" which secure the driving gear housing to the pump body "3". The pump body "3" may then be removed, exposing the pump gears. If complete disassembly is required, the gear "5" must be removed from the shaft and the stuffing box loosened so that shaft may be withdrawn through it. Care must be used in removing pump body, to see that the pump gear (driven) "7" does not drop off the idler shaft "13".

114. The handle, items "9", "10" and "24", is hinged so it will drop out of the operator's way when the pump is not in use. The oil cup "17" is provided for priming the pump gears when starting.

Oil Strainer

115. The oil strainer is shown in Figure T-22. It is of the duplex type and is equipped with magnets for the removal of ferrous material from the oil. The basket, through which the oil must flow, is made with sides of wire mesh and perforated sheet, and contains the magnet assembly which consists of the magnets "24" and the rod "25".

116. The flow of oil to the strainers is controlled by the plug, which is so designed that when turned on its seat by means of the change-over lever, it will direct the oil to either strainer, but will prevent the oil from being completely cut-off during change-over. Lever points toward the side of the strainer which is in use. The stem of the strainer plug "18" is loose-coupled to a jackscrew "8" which is threaded through the top of the

bonnet "6" and carries a handle "13". Rotation of this handle in a counter-clockwise direction will pull the plug upward thus breaking its contact with the body and facilitating the change-over operation, while by turning it in a clockwise direction after the change-over has been made, the plug can be seated tightly in the body, thus eliminating leakage around the plug.

117. In order to clean a strainer it is only necessary to swing the change-over lever to the opposite side, back-off the handle "10", remove the cover "20" and lift out the strainer basket.

Oil Cooler

118. Figure T-23 shows the oil cooler with its pipe connections. The oil enters the cooler shell at the top left end (looking toward the unit) and passes around the outside of the tubes, being directed back and forth across them by the baffles and leaves the cooler by the outlet connection at the top of the other end. The water enters the water bonnet and passes through the tubes on one side to a reversing bonnet and back through the tubes on the other side to the outlet. The tubes are rolled into both tube sheets.

119. Provision is made in the shell by means of a double diaphragm structure, for relative expansion of the shell and tubes, the tube sheet being secured directly to the shell at each end.

120. The dry weight of the complete cooler is 835 pounds. Each cooler has 98 tubes and is designed to cool 55 gallons per minute of oil of a quality meeting Navy Symbol No. 2190 from 150° to 120° with 20 psi. pressure drop when supplied with 90 gallons per minute of water at 85° F. with 2 psi. water-pressure drop.

Lubricating Oil

121. Oil Navy Symbol No. 2190 having a viscosity of 185-205 S.S.U. at 130° F. should be used in the lubrication system.

DESCRIPTION OF SAFETY DEVICES

Overspeed Trip and Back-Pressure Safety Stop

122. The overspeed trip mechanism which trips the throttle valve and thus shuts down the turbine in case it overspeeds is shown in Figure T-24. The actuating device consists of a weight located transversely in a hole in the body which is screwed into the end of the turbine rotor. The weight is located with its center of mass slightly off the axis of rotation and is held in place by the spring and the retainer which is secured by the nut. As the speed of the rotor increases the centrifugal force of the eccentric weight becomes greater until at a predetermined speed (10 to 12% above normal full-load speed) the centrifugal force is sufficient to overcome the resistance of the spring, whereupon the weight moves outward radially until it comes into contact with the trip lever. This lever is struck sharply by the weight and the resulting movement disengages the latch from the reset handle, these latter pieces being held in engagement by hardened plates "37". When the reset handle is released the tension spring pulls the trip rod smartly toward the throttle valve trip lever to which one end of the spring is attached, and through which the trip rod end moves until the weight engages the lever with a hammer-blow effect which is sufficient to actuate the throttle valve tripping mechanism and close the valve as described in the section on throttle valve. The speed at which the auto-stop will function can be adjusted by means of liners "6" of Section A-A (Figure T-24). Increasing the thickness of the liners increases the tripping speed. Decreasing the thickness of the liners decreases the tripping speed.

123. When this mechanism has operated it must be reset by hand. This is accomplished by returning the reset handle to the vertical position when the latch plates will again be engaged. This resetting cannot be done until the turbine speed has decreased sufficiently to allow the overspeed trip weight to return to its normal position which will occur at slightly below normal turbine speed (approximately 1000 rpm. of generator).

124. A special jig is furnished as shown in Figure T-30 by means of which the overspeed trip spring may be compressed, thus making it easy to remove the retainer halves from the weight when making a change in the setting or overhauling these parts. As shown in Figure T-30, the two halves of the jig are inserted through the holes in the overspeed trip retainer, thus permitting the spring to be compressed sufficiently to clear the groove in the retainer. Then by spreading the jig halves apart the retainer halves can be freed from under the trip weight head, and the mechanism taken apart.

125. In putting the parts together again the jigs may be pressed down with one hand while pressing the retainer halves together with the other hand, so that as soon as the spring clears the retainer groove the retainer halves may be squeezed together under the trip head and the assembly locked by releasing the pressure on the jigs.

126. Figure T-24 also shows the back-pressure safety stop, which protects the turbine cylinder against excessive pressure by closing the throttle valve if the exhaust pressure exceeds 10 psi. gage. This mechanism operates through the same levers and trips the throttle valve in the same manner as described above. The diaphragm is clamped between the disc and the plate and is subject to the pressure existing in the turbine exhaust through the pipe connection as shown. If the exhaust pressure becomes high enough to overcome the compression of the spring, which holds the lever in position the rod is moved outward and the rod end strikes the pin and pulls the latch so as to disengage the latch plates and release the handle, which in turn trips the throttle valve and shuts down the turbine in the same manner as when tripped by the overspeed trip. The spring is set at the factory for pressure reported under the heading "Performance Data". It may be adjusted by means of lock nuts for any desired pressure.

Low Oil-Pressure-Alarm Contact-Maker

127. The contact-maker which closes the alarm bell circuit to warn the operator of dangerously low oil pressure is shown in Figure T-25. It is adjusted to operate if the bearing oil pressure falls to a predetermined minimum 4 pounds. The operation of this device is as follows:

128. The diaphragm "15", held between the base "16" and the case "12" is subjected to bearing oil pressure on its under face through one or the other of the oil connections indicated. The diaphragm, in turn, when flexed, actuates the pressure plate "14", which can move upward a small amount determined by the depth of the recess in the case into which it fits.

129. Upward motion of "14" opens the contact in the totally-enclosed switch unit "11" and thus opens the circuit. This is the normal condition and will exist as long as the bearing oil supply remains normal. If through casualty, sludging, or any other means the bearing oil pressure is reduced to the predetermined limit, the compression of the spring "8" overcomes the reduced oil pressure, forcing down the pressure plate "14" and closing the contact in the switch "11", which causes the alarm to ring. A condenser "4" prevents sparking and radio interference.

130. Adjustment of the spring pressure is accomplished by removing the lock screw "18" (Section B-B), thus exposing a screw driver slot in the adjusting screw "6". Rotation of the screw "6" moves the spring seat "17" up or down thus decreasing or increasing the spring compression.

131. Initial adjustment of the switch "11" is made by releasing the spring compression and pushing the pressure plate "14" into its uppermost position. Then, with the cap screws "20" loosened move the switch assembly "11" until the contact just "breaks"; tighten the screws "20" in that position.

Testing of Safety Devices

132. Overspeed may result from a variety of cause such as dirt or scale lodging under the steam valve, damage, to seats so that the leakage is more than the steam requirement at light loads, excessive friction in the governor parts due to foreign matter, or damage to working parts. Consequently, all parts should be kept in good condition at all times. Overspeed could also result from steam entering through the extraction opening (if this opening, which is normally blanked off, were being used) with no load on the unit and with high vacuum. Periodically, about once each month, the operation of the safety devices should be checked as follows: (with the generator disconnected from the line and meters)-

Test 1. The operation of the overspeed trip should be tested as follows:-

Referring to Figure T-13 (Steam Chest) disconnect the steam chest valve-lifting rod link from the lever and block the valves in the open position by inserting suitable blocks between the valve-lifting bar stem shoulders and the stem bushings. Then start the turbine and gradually increase the speed to the tripping point. The overspeed trip should function at 10 to 12% above normal speed (1320 to 1350 rpm.). The throttle valve should be opened very gradually. During this test, the speed of the unit should be watched continuously with a hand tachometer on the generator, and the operator should be ready to trip this valve instantly by hand in case the overspeed governor does not function at the proper speed.

Test 2. The low oil-pressure alarm may be checked when shutting down the unit by noting when the alarm sounds, and observing the reading of the bearing oil-pressure gage on the gage board. The alarm should ring when the bearing oil pressure reaches approximately 4 pounds gage.

Test 3. The back-pressure trip can be tested periodically with compressed air, followed by a test operating the unit at no-load and building up back pressure by cutting off the circulating water pump and air ejector. This trip should function at approximately 10 pounds gage.

PART I

(Section 2) TURBINE INSTALLATION

Alignment of Unit and Setting of Turbine Rotor

1. The bedplate of the unit is supported at six points on seating pads and is bolted down at these points only, as shown in the sketch at the upper left-hand corner of 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 proper alignment as established at the factory.

2. In the initial erection of the unit in the factory, the pinion and gear bearings were checked for plane and parallelism by using mandrels. The generator stator was set up and the generator outboard bearing was brought into alignment with the gear bearings. Next the turbine cylinder base was set up and the turbine bearing aligned with the pinion bearings, using liners under the turbine supports as necessary.

3. The turbine rotor was placed in the turbine cylinder cover and located axially in order to obtain the proper clearance dimension between the nozzle block and the first rotating row of impulse blades, as shown on the rotor clearance diagram Figure T-26. 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.

4. The rotor was next placed in the cylinder base and a liner of .100" thickness was installed in the thrust bearing as shown in Figures T-2, T-9 and T-26. The thrust bearing cover and the upper half of the turbine bearing (pinion end) and the bearing cover were assembled and bolted in place. After this the rotor was moved as necessary to obtain the 3/16" dimension between the coupling faces as shown in Figure T-26, and the cylinder base was adjusted in an axial direction, until the dimension from the end of the turbine rotor to the cylinder face was in agreement with that stamped on the cylinder base horizontal flange. The cylinder base was then doweled and keyed to the bedplate in this position.

5. The clearance in the thrust bearing was next measured and the thickness of the filler ring "14" shown in Figure T-9 was adjusted to the proper thickness, to provide this clearance. The gear and pinion were adjusted to drawing clearances by shifting the liners (See Figure T-17) in back of the gear bearing faces as necessary.

6. If it should become necessary to install a spare turbine rotor, the following procedure should be followed:-

7. With the new rotor placed in the cylinder cover, the dimension from the end of the rotor to the cylinder cover gland face should be determined as described above. Install the new rotor in the cylinder base and locate it axially to agree with the dimension from the gland face to the end of the rotor as found in the cylinder cover. Measure the axial clearance at the outboard end of the thrust bearing in order to obtain the proper thickness for the rotor locating liner, shown in Figure T-2. With this liner installed, the turbine rotor will be in its proper running position. Now measure the thrust bearing clearance and if this is not found to be within the prescribed limits, change the thickness of the liner "14" (Figure T-9) as described above to provide the proper clearance.

8. With the rotor in place, check the alignment as follows:

9. The method of checking the internal alignment of the reduction gear has been described under "Reduction Gear". To check the alignment of the pinion and the turbine rotor, disconnect the flexible coupling between them and check the angular alignment by taking feeler-gage readings between the faces of the coupling hubs at top, bottom and both sides. Also check the horizontal and vertical alignment of the coupling hubs at the periphery on top and at the sides. The pinion and turbine should be in line.

10. Check the alignment of the gear and generator. To do this, roll out the bottom half of the forward gear-shaft bearing and measure at the center of the bearing the amount that the gear-shaft journal drops when not supported. This drop should be .011". If it differs from this value the out-board generator pedestal should be adjusted upward or downward as necessary to produce the .011" drop required. As a cross check on this measurement the forward bearing may be replaced and the aft gear bearing rolled out instead. If this is done the journal should drop in the housing .007". Recheck these readings by rolling the gear shaft and generator rotor over 180° and repeating the operation.

Pipe Connections

11. The steam pipe connected to the turbine throttle valve must not be rigid because, if it were, it might move the unit out of alignment. It should be made with long radius bends and supported at a point near the turbine. In making this connection, the pipe should never be sprung into place. It should be made so that the joints match properly.

12. The exhaust line should have a flexible expansion joint close to the turbine, preferably at the turbine-exhaust flange. The exhaust pipe should be supported just beyond the expansion joint to prevent its weight from damaging the expansion joint or the turbine. The expansion joint should have enough flexibility to insure that no undue strain will be imposed on the turbine exhaust.

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

14. Wet steam is objectionable as it causes much more rapid erosion of the blades and nozzles than dry steam. It also reduces both 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, vibration and speed fluctuations or may trip the overspeed trip mechanism. If the pipe connections are such as to allow condensation to collect in the turbine or steam pipe, drains must be installed for use when starting up.

PART I

(Section 3) TURBINE OPERATION

To Start

1. To start up a turbine proceed as follows:-

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

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

Step 3. See that the throttle valve is in its closed position with the throttle valve trip latch in place. Make sure that the over-speed trip mechanism is in operating condition.

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

SPECIAL CAUTION: 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 reservoir and heated to at least 60° F. before unit is turned over.

When starting up with oil in reservoir between 60° F. and 100° F., the unit should be operated slowly until such time as the inlet oil to the bearing is 100° F. or until such time as there is a free flow of oil 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; lower temperatures require lower warming-up speeds.

Operating temperatures of 110° F. to 130° F. to the bearings should be obtained soon after full speed is reached.

Step 5. Drain the steam and exhaust piping.

Step 6. Open the drains from the throttle valve, steam strainer and cylinder. These drains are shown in Figure T-8.

Step 7. Open exhaust valve wide, or, if the unit is connected directly to its own condenser and no valve is fitted between them, start the circulating pump and condensate pump, recirculating condensate if necessary.

Step 8. Prime the lubricating system thoroughly with the auxiliary oil pump before attempting to run and continue to prime until main unit has reached sufficient speed to indicate pressure on main oil pump gage.

Step 9. Open the steam chest valves by means of the jacking lever under the governor operating-piston rod crosshead. Then open the throttle valve, starting the turbine rolling immediately so that the turbine rotor will be heated evenly.

Step 10. As soon as the rotor is rolling turn steam on the glands, using not more than 3 pounds pressure.

Step 11. Start the air ejector and establish vacuum in the condenser.

Step 12. Trip the hand trip to check the operation of the tripping mechanism. Then rotate throttle valve handwheel in the closing direction and reset the trip latch.

Step 13. Bring the turbine speed up slowly, as the vacuum rises, coming up to normal speed in 5 to 10 minutes. Be sure that the governor acts to control the speed. When this takes place the jacking handle (item 58 of Figure T-14) will drop to the "OFF" position and then the governor linkage will move in the closing direction as the governor partly closes the steam valves to hold the unit at no-load speed.

Step 14. See that the bearing oil pressure is maintained between 5 and 10 pounds.

Step 15. Close all drain lines.

Step 16. Circulate water through the oil cooler.

Step 17. Adjust the rheostat for normal voltage of the generator.

Step 18. Connect the generator to the line and put on load.

To Parallel

2. To put one machine on the line when the other unit is in operation:

Step 1. Bring the unit up to normal no-load speed, as described above.

Step 2. With the speed-changer, bring the speed down 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. Readjust the speed-changer until each unit takes its share of the load at the proper speed.

3. 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 line voltage, depending upon local conditions.

To Shut Down

4. To shut down machine when operation is no longer required:

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

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

Step 3. Close the turbine throttle valve. This can be done by striking the overspeed trip latch tip "39" or pulling on the back-pressure safety stop trip rod end "46" in Figure T-24.

Step 4. Break vacuum by means of vacuum breaker.

Step 5. Operate the auxiliary oil pump when slowing down until the shaft is at rest.

Step 6. Shut off the water to the oil cooler.

Step 7. Shut off the steam to glands.

Step 8. Shut down condensate and circulating pumps.

Step 9. Clean the machine and put it in readiness for the next run.

Precautions

5. The following operating precautions should be carefully observed:

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

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

Point 3. Periodically (about once each month) inspect the overspeed trip weight to see that it works freely in the body. Also test all safety devices to see that each one functions properly.

Point 4. Keep the throttle stem and the steam-chest valve-lifting rods clean and free of corrosion. (Do not paint these stems.)

Point 5. Keep bearing oil pressure between five pounds and ten pounds gage.

Point 6. Keep the oil level in the reservoir between the limits indicated on the "Oil Level Gage".

Point 7. Keep the oil strainer clean.

Point 8. Keep the oil cooler clean.

Point 9. Leave all switches open when machine is not running.

Point 10. At the least sign of trouble, stop machine immediately. Investigate and correct the trouble before starting the machine again.

(Section 4) TURBINE CARE AND MAINTENANCE

Inspection

1. 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 raised 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.

2. 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.

Weights

3. The weights of the principal parts of the unit, which may require handling are as given in the table below:

One Unit (Assembled Complete) - Actual Weight.	27480 lbs.
A-C. Generator and Exciter (Complete)	13335 lbs.
Turbine (Complete)	7620 lbs.
Turbine Rotor (Bladed)	1250 lbs.
Cylinder Cover	2320 lbs.
Gear and Bedplate.	7850 lbs.
Gear Case Cover.	760 lbs.
Gear Wheel and Shaft	1162 lbs.
Generator Rotor	5075 lbs.
Generator Stator	6725 lbs.
Governor	365 lbs.
Throttle Valve and Strainer.	685 lbs.
Oil Cooler	835 lbs.
Oil Strainer	135 lbs.
Generator Air Cooler	790 lbs.

4. The weight of one complete set of turbine gear and generator spare parts (without boxes) and one set of tools is approximately 8990 pounds.

5. For the assistance of the operator in checking the condition of the unit and in performing such repairs as may become necessary, the following information and materials are furnished.

Rotor Clearance Diagram

6. Figure T-26 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.

Bridge Gages

7. In order that the operator may have warning of any undue wear in the bearings of the unit, a set of three bridge gages is provided as shown on Figure T-27. One of these is for the turbine bearings, one for the pinion bearings, and one for the gear bearings. Each gage bears a

a plate which is stamped with the turbine serial numbers and the clearances that were found at the initial assembly. Holes are provided in the horizontal joint flanges in order that the bridge gages may be located by the pins "2"and "4". Each gage is provided with two finished surfaces as shown in the elevation view, and the clearances between these finished surfaces and the journal are measured with feeler gages. Any deviation from the clearances originally established indicates lateral displacement of the shaft or wear of the bearing as the case may be.

Rotor-Lifting Gear and Guides

8. Figure T-28 shows the arrangement of the rotor-lifting gear and guides. The guides are bolted to the turbine cylinder base, one at either side at the coupling end, the bearing pedestal covers, auto-stop cover and spindle-position indicator first having been removed. 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 pipe and plate. 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.

Rotor-Lifting Device for Removing Bearing Shells

9. 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-29. 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 jack support for the exhaust end is supported from two of the bearing housing-flange studs on either side and that for the coupling end from the two end studs of the gear housing flange, as shown in the illustration. Care should be taken when using these jacks 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.

Tools and Wrenches

10. Figure T-30 is shown for the purpose of enabling the operator to familiarize himself with the special wrenches and tools and the purposes for which they are intended. Those tools, the use of which is not immediately obvious, are referred to at appropriate points in the foregoing text.

Cylinder-Joint Sealing Grooves

11. While the turbine horizontal and vertical joint flanges are carefully machined to a full bearing surface and the metal-to-metal joints made tight, in addition, the joint-flange surfaces are grooved and pipe-tapped holes are provided, so that the grooves may be pumped full of sealing compound if a leak should develop while the machine is in service. A pressure pumping gun for filling these grooves is supplied with the tools.

12. The arrangement of the sealing grooves and their filling connections is shown in Figure T-31. For the horizontal joints, tapped and plugged holes are provided in the cylinder cover flange, five on each side. The figure shows one half of the cylinder cover the other half being symmetrical with the view shown. As will be noted by the arrows, three holes have been designated as inlet holes, and the other as outlet holes.

13. To fill the grooves, start at Hole 1, leaving Holes 2 and 3 open. Apply the pressure pumping gun and pump in compound until it flows

out of Holes 2 and 3. Then transfer the gun to Hole 3 and pump until compound flows out of Holes 2 and 4. Then proceed to Hole 5 and pump until compound flows out of Hole 4.

14. For the vertical flange, six openings are provided and the method of filling is similar to that described above.

15. Note that care should be exercised to see that no air pockets remain in the groove. For example, after pumping at Hole 1 until compound has flowed out of Hole 2 when the gun is then put on Hole 3, compound may shortly flow out of Hole 2 and the operator may believe that he has filled the groove between Holes 3 and 2. However, the first compound that appears out of Hole 2 when pumping in Hole 3 is probably some that was pumped past when pumping into Hole 1. Therefore, the operator should disregard the first compound that comes out of Hole 2 when pumping into Hole 3 and make sure that he has expelled all of the air between Holes 3 and 2.

Repair Parts

16. The lists which face the several turbine (T-) illustrations in the rear of Part I of this instruction book have been compiled to facilitate ordering spare or renewal parts by name and number. Whenever parts are ordered, it is of utmost importance to give the serial number of the turbine or gear on which the parts are to be used.

17. A complete list of spare parts as supplied with the original equipment will be found in Pages 501 to 510 of Part V of this instruction book.

PART II

SHIP'S SERVICE A-C. GENERATOR

PART II

SHIP'S SERVICE A-C. GENERATOR

1250 Kw. (1562-Kv-a.)—450 Volts—1200 Rpm.

(Section 1) DESCRIPTION OF A-C. GENERATOR

GENERAL INFORMATION

Purpose

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

Machine Identification and Data

RATING - DRAWING 34-J-902 (FIGURE G-5)

2. These generators are rated 1250 kw. (1562 kv-a.), 80% power factor, 450 volts, 2005 amperes, 3 phase, 60 cycles, 1200 rpm. Excitation 120 volts, 115.3 amperes d-c.; temperature rise per Table #1 (Appendix 1), Method #2 for rotor, Method #3 for stator. These generators are also designed to carry 125% load for 2 hours or 150% load for 5 minutes.

3. The complete rating table from Westinghouse Drawing 34-J-902 is as follows:

A-C. GENERATOR RATING								D-C. EXCITER RATING		
Voltage (B-9) 450, 3 Phase (B-11), 60 Cycle (B-10)								Voltage 120		
Load and Time Rating (B-8 & D-8)	Kw. (B-6)	P. F. (B-7)	Kv-a.	Amps.	Guar-anteed Effi-ciency (D-12d)	D-C. Exci-tation Required * Kw.	D-C. Exci-tation Required * Amps.	Kw.	Amps.	Effi-ciency
50% Cont.	625	.8	781	1003	93.0	10.5	87.4	8	67	Incl.
75% Cont.	938	.8	1172	1504	94.9	12.2	101.3	12	100	in
100% Cont.	1250	.8	1562	2005	95.5	13.9	115.3	16	133	A-C
125% 2 Hr.	1562	.8	1952	2506	....	15.9	132.	20	167	Gen.
150% 5 Min.	1170	.5	2340	3008	....	19.8	165.	..	...	Effi-
150% 5 Min.	....	.8	....	3007	....	....	155.	18.6	155	ciency

* Including Rheostat Losses

4. GENERATOR CLASSIFICATION - DRAWING 34-J-902 (FIGURE G-5)

(a) Reference ambient temperature (B-3) 50° C.
(b) Method of Measuring Temperature Rise.......... Rotor by Resistance; Stator by Embedded Detector
(c) Class of Insulation.......... (B-4) Class A
(d) Degree of Enclosure.......... (B-5) Enclosed
(e) Method of Cooling............ (B-5) Water-cooled
(f) Manufacturer's Type & Design. Special 6- 44-1/2 x 22-1/2 S.O. 16-P-688 or S.O. 19-P-143
(g) Means of Excitation.......... Direct-Connected D-C. Exciter
(h) Prime Mover.................. (B-2) Steam turbine with reduction gear. Prime mover built by Westinghouse Electric & Manufacturing Company.

GENERATOR TEST DATA

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

6. NAME PLATE DATA

1250 Kw. (1562 Kv-a.)	120 Exciting Volts
450 Volts	115.3 Exciting Amperes (Calculated)
80% Power Factor	Stator Serials {1S- to 20S-16P688 and
3 Phase	1S- to 20S-19P143
60 Cycles	Rotor Serials {1R- to 20R-16P688 and
1200 Rpm	1R- to 20R-19P143

7. It is recommended that the name-plate 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.

8. **Always Refer to the Serial Number** stamped on the name plate of the machine when corresponding with the manufacturer, for this is the number which identifies the machine.

DESCRIPTION OF APPARATUS

Illustrations

9. Reference to the three drawings, Figures G-4, G-5, and G-6, will be found useful in supplementing the following description.

General Arrangement - Dwg. 34-J-901 (Fig. G-4)

10. The a-c. generator and d-c. exciter stators and the common pedestal bearing are separately mounted on the turbine bedplate.

Frame and End Bells - Dwg. 34-J-901 (Fig. G-4)

11. The enclosed box-type frame is fabricated from rolled-steel sheets and plates. The punchings of the armature core are stacked in the machine against the collector-end frame ring. Keys secure the punchings to the transverse ribs which extend between the frame rings. After the punchings are stacked in the machine, they are compressed to the proper core length in the machine. A removable end plate, keyed to the turbine-end frame ring, holds the armature core firmly in the frame.

12. A split, double-enclosing end bell is bolted to each end of the frame to direct the ventilating air and to protect the armature windings. The cooler housing is bolted to the top of the frame and end bells.

13. Two heavy steel eyebolts are provided for lifting the frame. They may be threaded into holes in the top of the frame, but they must be removed before the cooler is installed.

14. Heavy steel-slab feet, welded to the lower portion of the frame rings, insure rigid attachment of the generator to the turbine bedplate. These feet are machined parallel to the shaft and are drilled for foundation bolts, dowels, and jackscrews.

Air Cooler - Harrison Radiator Co. Dwg. A-8507960 (Fig. G-10)

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

21. A .005" thick shellacked-paper strip extends depthwise between the two rows of strands in the straight part of each coil. Each straight side of the coil embedded in the slot is insulated with 1-1/2 turns of a .012" thick fishpaper and mica wrapper. The end portions of the coils are insulated by hand-taping with one layer of half-overlapped .010" thick treated cloth. Coils are finished all over with one half-overlapped layer of .007" thick cotton tape. Finished coils are impregnated by the vacuum-and-pressure method with heat-reactive varnish, Navy Approval Letter EN8/L5-2-2528. A .007" thick fishpaper cell separates the coils from the iron in the stator slots. Micarta wedges are used to hold the coils in place in the slots. The coils are roped to two insulated steel rings on each end of the winding to prevent distortion in case of short-circuit. The assembled stator is treated twice in moisture- and oil-resistant varnish, Navy Specification 52V13.

Shaft and Spider - Dwg. 34-J-901 (Fig. G-4)

22. The a-c. generator shaft is machined from a steel forging. One end of the shaft is provided with a flange and a machined female fit for connection to the gear coupling. The other end is provided with a flange and a machined female fit for connection to the exciter shaft. The spider 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 - Dwg. 34-J-901 (Fig. G-4)

23. 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 dovetail is prevented from buckling by a weld extending the full length of the pole at the bottom of the dovetail.

24. Five round copper damper bars extend axially just beneath the face of each pole. At each end, the bars pass through the cast-bronze upper coil support which is bolted to the pole. The bars at the end of each pole are brazed to a length of curved copper angle which is separated from the upper coil support by short spacers of brass tubing surrounding each damper bar. A steel damper end ring, bolted to these copper damper segments at each end of the machine, connects the damper windings between poles.

Field (Rotor) Winding - Dwg. 34-J-903 (Fig. G-6)

25. The field coils are constructed of copper strap wound on edge. The upper part of each coil consists of 82 turns of .032" x 2" copper strap. In the open coils, the lower part consists of 29 turns of .047" x 2" copper strap; but in the crossed coils, the number of these turns is 28. The sides of each coil are machined off at an angle in the lower portion to prevent interference between the sides of coils on adjacent poles. At the ends of the coil, every fourth turn is wound so as to extend 1/2" beyond the other turns in order to provide additional surface on the coils for cooling.

26. After the copper strap is bent to shape, the bulges at the corners due to bending are removed by pressing or filing. The formed coil is then dipped in shellac and allowed to dry in air. Insulation is next applied between the turns. Between the .032" thick copper straps are inserted two layers of .007" thick shellac-treated asbestos paper. This insulation compresses to .009" thick. Between the .047" thick copper straps is inserted a sandwich of one layer of .005" thick mica between two layers of .007" thick shellac-treated asbestos paper. This insulation compresses to .012" thick. The coil is heated by current circulated through it until the shellac ceases to flow. The coil is then pressed to size. The ground

Harrison Radiator Company. Separate instructions are provided for the cooler.

Bearing and Pedestal - Dwgs. 34-J-901 (Fig. G-4) and 34-J-903 (Fig. G-6)

16. The a-c. generator bearing, which supports the front half of the a-c. generator rotor and the rear half of the d-c. exciter armature, is carried by a pedestal mounted between the generator and exciter on an extension of the turbine bedplate. The bearing is of the split type, having an upper and lower cast-steel bearing shell lined with babbitt. The bearing is connected to the forced-feed lubrication system of the prime mover which furnishes oil at a pressure of approximately 10 psi. A fixed orifice at the bearing inlet adjusts the oil flow to 1/2 gallon per minute.

17. In addition to oil throwers machined on the shaft, front and rear labyrinth oil seals are provided to prevent leakage of oil from the bearing. Each seal consists of two semi-circular steel castings surrounding the shaft and bolted to the pedestal. Thin semi-circular copper seal strips are calked into a series of circular grooves machined into the bore of each half of the seal. The small clearance between the shaft and the inner periphery of the seal strips prevents leakage of oil along the shaft away from the bearing. An additional seal on each side of the bearing consists of two semi-circular rings of thin brass with close clearance around the shaft. These rings are bolted to cast-steel bearing seals.

17-A. Rotor to Paragraph 42, "Spare Parts", for alterations required before the spare bearings are installed.

Core - Dwg. 34-J-901 (Fig. G-4)

18. The core of the machine is built up of circular segmental laminations of silicon steel stacked on twelve machined transverse ribs to which the punchings are keyed. Each circular lamination consists of six identical segments. Ventilating spaces are formed between the end plates and the ends of the core by finger-plate spacers, and between the packages of punchings by vent-plate spacers at thirteen 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. The stator punchings have 72 slots, each having a finished size, after stacking, of 0.525" wide by 2.325" deep.

Terminals - Dwg. 34-J-901 (Fig. G-4)

19. The a-c. leads are brought out at the bottom of the generator frame, and the exciter leads are brought out at the bottom of the exciter frame. The terminal data are given on Drawing 34-J-901.

Armature (Stator) Winding - Dwg. 34-J-903 (Fig. G-6)

TABULATION OF WINDING

Coil Grouping: 4 Coils per Group per Phase
1 Group per Pole per Phase - 18 Groups Total 72 Coils
Throw of Coils: Slots 1 to 12
6 Poles - 3 Phase - 6 Parallels

20. The stationary armature has a bore of 31" 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 two conductors, each 2 strands wide by 5 strands deep of .081" x .204" double-cotton-covered wire (insulated size .096" x .217"). Two coil sides lie in each slot.

insulation is applied next. It consists of a U-shaped cell of .005" thick Kraft paper built up to 1/16" thick, over which is put another U-shaped cell of .034" thick fishpaper. These cells are applied to the four sides of each coil. Finally, the coils are machined as previously described.

27. Each field coil is assembled on its pole between the top and bottom Micarta washers. The coil is secured in position by the upper and lower coil supports and the coil braces. The upper coil support is made of cast bronze and is bolted to the pole. The lower coil support is made from steel channel and bar and is bolted to the spider at the centerline of the pole. The coils are wedged between poles by coil braces consisting of tapered Micarta blocks fastened to the spider by long bolts extending radially between the field coils. The lower machined parts of adjacent coils are separated and held in position by Micarta spacers between the radial bolts.

Blowers - Dwg. 34-J-901 (Fig. G-4)

28. On each end of the spider, six blower blades provide ventilation in addition to that induced by the blowing action of the rotor poles. The blades are of the flat, radial type and are bolted to the lower coil supports on the centerlines of the poles.

Collector - Dwg. 34-J-901 (Fig. G-4)

29. The collector assembly is shrunk onto the shaft between the spider and the journal. It consists of a steel bushing over which is pressed a split-steel ring covered with mica on which the two steel collector rings have been shrunk. Two insulated copper connectors, one brazed to each ring, connect the rings to their respective field leads. The surface of each collector ring is machined with a spiral groove to improve brush performance.

Brush Rigging and Brushes - Dwg. 34-J-901 (Fig. G-4)

30. Each machine requires a total of eight brushes, each 1-1/4" thick by 3/4" wide by 2" long. For replacement brushes, order Westinghouse Style No. 1240018. The four brushes for each collector ring are held in individual cast-bronze brushholders mounted on a curved steel bracket. These two brackets are separated from each other and mounted on the end of the bearing pedestal by three insulated studs.

Space Heaters - Dwg. 34-J-903 (Fig. G-6)

31. Four space heaters are located on the lower part of the frame inside the end bells. The heaters are connected for parallel operation from a 115-volt source.

Temperature Detectors - Dwg. 34-J-903 (Fig. G-6)

32. A resistance coil is embedded between the upper and lower armature coil sides in each of six slots equally spaced around the armature core. The connections for these temperature detectors are shown on Drawing 34-J-903.

Air Seals - Dwg. 34-J-901 (Fig. G-4)

33. On the coupling end of the generator, an air seal is provided around the shaft flange to prevent the mingling of the outside air with the cooling air of the machine's recirculating ventilating system. The construction of the seal is similar to that used for the labyrinth oil seals previously described in connection with the bearings. Two air-seal pipes apply the generator blower pressure to the seal on the shaft flange to prevent leakage of oil into the generator.

34. At the collector end of the machine, the ventilating air is sealed off from the outside air by the small clearance between the seal ring mounted on the rotating collector bushing and a split Micarta ring bolted to the front end bell.

Mechanical Rotation - Dwg. 34-J-901 (Fig. G-4)

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

Phase Rotation - Dwg. 34-J-903 (Fig. G-6)

36. When the mechanical rotation is clockwise as viewed from the exciter end, the emfs. induced in the phases will reach positive maximum values in the following order: $T_1 - T_2 - T_3$.

Short Circuit Currents - Dwg. 34-J-902 (Fig. G-5)

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

(1) With the regulator in operation: 7750 amperes.
(2) Without the regulator in operation and with full load excitation: 4220 amperes.

38. The symmetrical R.M.S. short-circuit current is calculated to be approximately 16,500 amperes for the first half-cycle.

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

Parallel Operation

40. The generators of this rating on each ship are designed for parallel operation.

Spare Parts - Dwg. 34-J-902 (Fig. G-5)

41. The spare parts furnished for the a-c. generators are given on the List of Spare Parts and Tools, Sheets 1 and 2, which appear as part of Drawing 34-J-902. These lists are also included at the close of these instructions (Pages 511 and 512), and they indicate whether the items are to be stored on shipboard or ashore.

CAUTION when using SPARE BEARINGS!

42. Before installing the spare bearing, an error in manufacture must be corrected. If this is not done, the oil flow will be excessive, and the oil reservoir in the bearing pedestal will overflow.

43. Refer to the end sectional view of the bearing on Figure G6, Drawing 34-J-903 (Bureau No. CV31-S6100- 414994). At the horizontal split in the bearing, four 3/16" holes are indicated as being drilled at an angle of 45 degrees below the horizontal centerline. The holes extend from the "relief", or groove, at the split, to the outside of the bearing shell. These holes are unnecessary and must be plugged before the bearing is used.

44. To plug the holes, tap the outside ends of the holes by hand with a No. 12-28 tap, and plug the holes with short No. 12-28 set screws. Do not tap the full length of the holes. The set screw must not extend outside the bearing casting, and it must be locked in place by peening over the threads. If a No. 12-28 tap and set screw are not available, the outer ends of the holes can be drilled oversize with a No. 7 drill for a 1/4"-20 tap and set screw.

Ordering Renewal Parts

45. When ordering renewal parts, give the name of the part and the nameplate reading of the machine, including the serial number. The serial number will be found stamped on the name plate and on the metal under the name plate.

PART II

(Section 2) INSTALLATION OF A-C. GENERATOR

Storage

1. 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.

2. 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 Unpacking

3. 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.

4. 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.

5. Lifting the parts of the generator set should be done with the greatest possible care. The a-c. generator, the d-c. exciter, and the bearing pedestal are equipped with eyes in which the crane hook should be inserted when each piece is lifted. Each of the stationary pieces and the rotor must be lifted separately, for the generator and exciter set is not designed to be lifted as a unit. The generator and exciter rotors may be lifted together if necessary.

6. 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.

Foundations and Supports

7. The principal external dimensions of the generator set and the provisions for mounting the set on the turbine bedplate are shown on "Outline and Section", Drawing 34-J-901 which appears as Figure G-4 of these instructions.

INSTALLATION AND ERECTION OF A-C. GENERATOR

Examination of Bearing and Journal

8. Before the machine is installed, the surfaces of the bearings and journals 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.

Alignment of Equipment

9. The alignment of the generator with the gear unit affects the performance of the gear. Therefore it is essential that the alignment procedure outlined in the erection manual for the gear unit be followed.

10. The following conditions must be met in the erection of the generator parts to insure trouble-free operation.

Step 1. Set the generator pedestal as required by the gear erection instructions, making certain that proper axial clearance exists at the journal oil throwers.

Step 2. After the generator pedestal is set, a final check on the coupling "truth" should be made with a dial indicator. The presence of burrs, nicks, or other results of poor handling will show in this check. The coupling outage should be less than .001".

Step 3. After the generator pedestal is located, the generator stator should be set in the proper axial position. Determine this position by measuring the extension of the pole tips beyond the stator iron on each end of the generator. Make the extensions at both ends as nearly equal as possible.

Step 4. Obtain equal air gaps around the periphery by adjusting the stator position. The gaps should be equal around the bore within 1/64".

(a) 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 this purpose should extend to the center of the core. They are furnished with the d-c. exciter spares.

(b) 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.

(c) 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.

Step 5. Couple on the exciter shaft, and tighten the exciter coupling bolts as nearly uniformly as possible. Check the truth of the exciter shaft and coupling. Measure the outage of the exciter shaft journal (bearing removed), by using a dial indicator. This outage should be less than .002".

Step 6. The exciter is a single-bearing, bracket-type unit, and its air gap, bearing, and coupling alignment depend upon the proper location of the stator. Allow the coupling end of the exciter shaft to hang on the coupling spigot with the bolts loose, the coupling faces slightly separated, and the commutator end supported by the exciter bearing. Adjust the exciter stator to obtain the proper axial clearance at the bearing oil thrower on the exciter shaft. Using the jackscrews in the exciter frame feet, adjust the vertical and lateral positions of the frame, as well as its alignment with the shaft, so as to obtain parallel coupling faces (as measured by feeler gages) and uniform air gaps around the bore. Using feeler gages, check the alignment of the journal with the exciter bearing by working through the end of the bracket and extending the feelers along the top and the sides of the bearing. If this check shows misalignment of the bearing with the journal, the cause should be found and eliminated. Place shims as needed beneath the frame, and tighten the bolts in the frame feet. After tightening the bolts in the frame feet, make certain that the proper alignment is obtained by rechecking the parallelism of the coupling face, the alignment of the bearing, and the equality of the air gaps.

Step 7. Tighten the coupling bolts as uniformly as possible and lock them in position.

Step 8. After the proper alignment of all parts is obtained, drill and ream dowel holes, and install all dowels.

Brush Adjustment

11. 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 holders. 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 cut and "Grade 0" 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.

12. An initial brush pressure of 2 psi. is recommended. Once the machine is in service, the pressure may be altered as necessary.

Insulation Resistance

13. The insulation resistance of windings is usually measured with an instrument called a megger. It is necessary to connect one terminal of the instrument to ground and the other to the conductor whose insulation resistance is to be measured. When the "generator" in the instrument is rotated, the insulation resistance may be read directly on the scale of the megger. This measurement gives an indication of the condition of the insulation, particularly with regard to moisture and dirt. The actual value of resistance varies greatly among different machines, depending upon the size and voltage. Therefore, the chief value of the measurements comes from a comparison of the values of resistance observed at various times on the same machine. During a drying-out run, for example, the insulation resistance rises as the winding dries out, although it may fall slightly at first. When measurements are made at regular intervals as part of the maintenance routine, it is thus possible to detect an abnormal condition of the insulation and take steps to remedy it before a failure occurs.

14. The following rule is given to indicate the order of magnitude of stator insulation resistance which is satisfactory for a clean dry machine at approximately 75° C., but considerably higher values are often obtained.

$$\text{Insulation resistance (in megohms)} = \frac{\text{Machine Voltage x 3}}{\text{Rated Kv-a.} + 1000}$$

Example: 1250-Kw., 1562-Kv-a., 450-Volt A-C. Generator.

$$\text{Ins. res.} = \frac{450 \times 3}{1562 + 1000} = 0.527 \text{ megohm}$$

Drying-Out Machine

15. If there is reason to believe that the windings have been exposed to moisture during shipment or erection, it is well to subject them to a drying process before putting the machine into regular operation. The windings can be dried by passing current through them or by using external heat.

16. One method of circulating current through the windings without subjecting them to full voltage is to drive the machine with the armature short-circuited and with the proper value of excitation applied to the field to give less than rated armature current. A second method of circulating current through the windings is to apply direct current to the armature.

17. It is essential that the heat be brought up gradually at first, the aim being to allow the water vapor to find its way out through the natural pores in the material. Too rapid heating is likely to develop such steam pressure in local portions that new passages are forced through the insulation, thus injuring it permanently. It is generally desirable to consume 15 to 20 hours in bringing the temperature up to the value required. This depends to some extent on the method of heating and measuring temperature, but a maximum temperature of 75°C. as measured on the external portions of the insulation is considered good practice. It must be remembered that the temperature of the insulation in the internal parts of the machine near the copper itself may be at a considerably higher temperature than that measured on the external surface of the coil.

18. This external temperature of 75°C. should be as uniform as possible throughout the machine so that moisture driven from one portion will not condense on another. Sufficient thermometers must be used to assure that no part reaches an excessive temperature. After the temperature has risen to the maximum value specified, it must be held practically constant until the insulation resistance reaches the desired value. Measurements of insulation resistance must be taken at regular intervals, and it is desirable to plot the values in the form of a curve of resistance vs. time. The drying-out process should be continued until the resistance remains approximately constant at a high value.

19. During and after the process, the external temperature of the coils should not be allowed to drop below that of the surrounding air. Moisture will thereby be prevented from condensing on the coil surfaces and nullifying the effect of previous drying.

20. When the heat for drying-out the machine is to be obtained from an external source, the machine should be covered and the heat supplied preferably by electric space heaters. The space heaters provided with the machine are intended only to prevent moisture from condensing on the machine and they are not of large enough capacity for use in drying-out the machine. The aim is to obtain a uniform temperature of 75°C. throughout the machine. The covering over the machine may be either a fairly close-fitting wooden box or a tarpaulin. It is preferable for the heaters to be located at the bottom of the enclosure, and the clearance between the machine and the enclosure should be small enough to cause most of the heated air to pass through the ventilating spaces of the machine. The machine should be

protected against direct radiation from the heaters, and inflammable material should be kept away from the heaters. If a wooden box is used, it is advisable to line the lower part with asbestos.

21. Readings of insulation resistance should be taken periodically during the drying-out process in order to determine the length of time required for the process. This has been explained more fully for the other method of heating.

Temperature and Ventilation

22. The generator is ventilated by the combined blowing actions of the rotor poles and the blower blades. The blades are located at each end of the rotor and are shrouded by the inner end bells. Air is drawn in past the field coils from the outer end bells. The air divides and passes either through the openings between the end windings of the armature coils or through the vent ducts in the stator core. All the air is discharged into the frame outside the core where it is directed into the air cooler through an opening at the top of the frame. From the cooler, the air is returned to the outer end bells through ducts.

23. For the generator to meet its temperature guarantees, the air cooler must be furnished with the proper quantity of cooling water. Fifty gallons per minute of water are required at a maximum pressure of 75 psi. A temperature relay sounds an alarm if the temperature of the air leaving the cooler reaches 60°C. (140°F.).

Power Connections (Armature Leads) - Dwg. 34-J-901 (Fig. G-4)

24. The main generator terminals are brought out at the bottom of the generator frame. Terminal information is tabulated in Drawing 34-J-901. No conduit box is provided to house the generator armature leads.

Control Wiring (Field Leads) - Dwg. 34-J-901 (Fig. G-4)

25. The terminals for the generator field are attached directly to the bottom of the brushholder brackets which are fastened to the generator side of the bearing pedestal. Terminal information is tabulated in Drawing 34-J-901. No conduit box is provided to house the generator field leads.

Auxiliary Wiring - Dwgs. 34-J-901 (Fig. G-4) and 34-J-903 (Fig. G-6)

26. Space heater and temperature detector leads are brought to individual terminal boards located on the lower part of the generator frame on the right-hand side as viewed from the exciter end. Access to these terminals may be had through an opening in the frame cover. Terminal information is tabulated in Drawing 34-J-901.

27. The temperature relay, which warns of excessive temperature of the air being discharged from the cooler, is mounted on the upper part of the rear end bell. Connections for the alarm leads are made at the relay itself, where conduit connections are provided.

Lubrication

28. The bearing is connected to the forced-feed lubrication system of the prime mover which furnishes oil at a pressure of approximately 10 psi. An orifice at the bearing inlet reduces the oil pressure at the bearing to a value which permits a flow of 1/2 gallon per minute.

PART II

(Section 3) DISMANTLING GENERATOR AND EXCITER

Removal of Exciter Bearing

1. To remove the exciter bearing, first disconnect the oil inlet and drain and the brushholder cross-connections. Lift the brushes clear of the commutator. Unbolt and remove the bracket. Unbolt and remove the bearing seals. Remove the plug in the top of the bracket. Loosen the set screw, and slide the bearing out of the bracket.

Removal of Exciter Stator

2. To remove the exciter stator, first disconnect the exciter leads, oil inlet, oil drain, collector cover, and exciter air shield. Lift the brushes clear of the commutator. Unbolt the exciter frame feet, and slide the stator out until the end of the frame clears the shaft. Lift out the exciter stator.

Removal of Exciter Rotor

3. To remove the exciter rotor, first remove the bracket and collector cover. Shim the air gap. Place slings over the ends of the shaft. Unbolt the exciter coupling, break the pilot fit, and move the exciter shaft out until the end of the shaft flange clears the end of the frame. Lift out the exciter rotor.

Removal of Generator Bearing

4. To remove the generator bearing, unbolt and remove the collector cover, bearing seals, bearing cap, and the top half of the bearing. Jack the rotor off the bearing, and roll out the bottom half of the bearing.

Removal of Pedestal

5. To remove the pedestal, first remove the complete exciter. Remove the generator bearing, and disconnect the generator field leads, oil inlet, and oil drain. Lift the brushes clear of the collector rings. Unbolt the pedestal feet, and slide the pedestal toward the exciter until the brush rig clears the end of the shaft. Lift out the pedestal.

Removal of Generator Rotor

6. To remove the generator rotor, first remove the complete exciter. Unbolt and remove the front and rear end bells. Shim the air gap. Remove the generator pedestal and bearing. Place slings over the ends of the shaft. Unbolt the gear coupling, break the pilot fit, and move the rotor out until its centerline clears the stator coils on the exciter end. Place a sling around the center of the rotor, and move the rotor out until the shaft flange clears the stator coils. Lift out the rotor.

PART II

(Section 4) OPERATION AND MAINTENANCE OF A-C. GENERATOR

STARTING OPERATION OF A-C. GENERATOR

Final Check Before Starting

1. Before the unit is started, the following points should be checked:

Point 1. Complete all necessary work of installation and alignment. The air gap should be uniform around the periphery of the machine. The gap should be free of all foreign matter which may become jammed between the armature core and the field poles. Bolts, tools, small pieces of iron, etc., should be kept away from the machine so as not to be drawn into it by magnetic forces.

Point 2. Be sure windings are free from dirt and moisture. Dry out the machine if the insulation test indicates that the windings are not dry enough.

Point 3. Check all electrical connections to be sure they are tight. Be sure that the proper clearances exist between conductors. Do not allow the brush shunts to touch each other.

Point 4. Check the provisions for lubricating the bearing to be sure that proper oil flow will be obtained. Once the machine is started, check the flow at an appropriate sight-flow indicator in the oil piping.

Single Generator Unit

2. The generator should not be started from rest unless the a-c. line circuit breakers are open, the field switch is open, the voltage regulator is in the position for manual control, and the a-c. and d-c. generator field rheostats are in the extreme "LOWER" position (the position for minimum field current). After the unit has been brought up to the desired speed (as indicated by a tachometer), the field rheostat of the d-c. generator should be adjusted to provide the rated d-c. excitation voltage (normally 120 volts).

3. In order to place the a-c. generator in service, first close the field switch. The unit may now be brought up to the desired speed by adjusting the governor. The frequency is indicated by the frequency meter on the a-c. generator panel. The a-c. voltage may be raised to the desired value (normally 450 volts) by adjusting the a-c. generator field rheostat. It may be necessary to readjust the d-c. generator voltage in order to compensate for the changes made in the speed of the unit.

4. If desired, the a-c. generator may be placed under automatic voltage regulation by balancing the regulator to the generator voltage and putting the regulator in control. The a-c. generator may now be connected to the bus. If desired, the voltage regulator may be placed in control after the generator is connected to the bus. In general, it is advisable to put the regulator into service or take it out of service only under conditions of steady load or no load.

5. For a discussion of the effect of changes in excitation, see the section on "Operation" following.

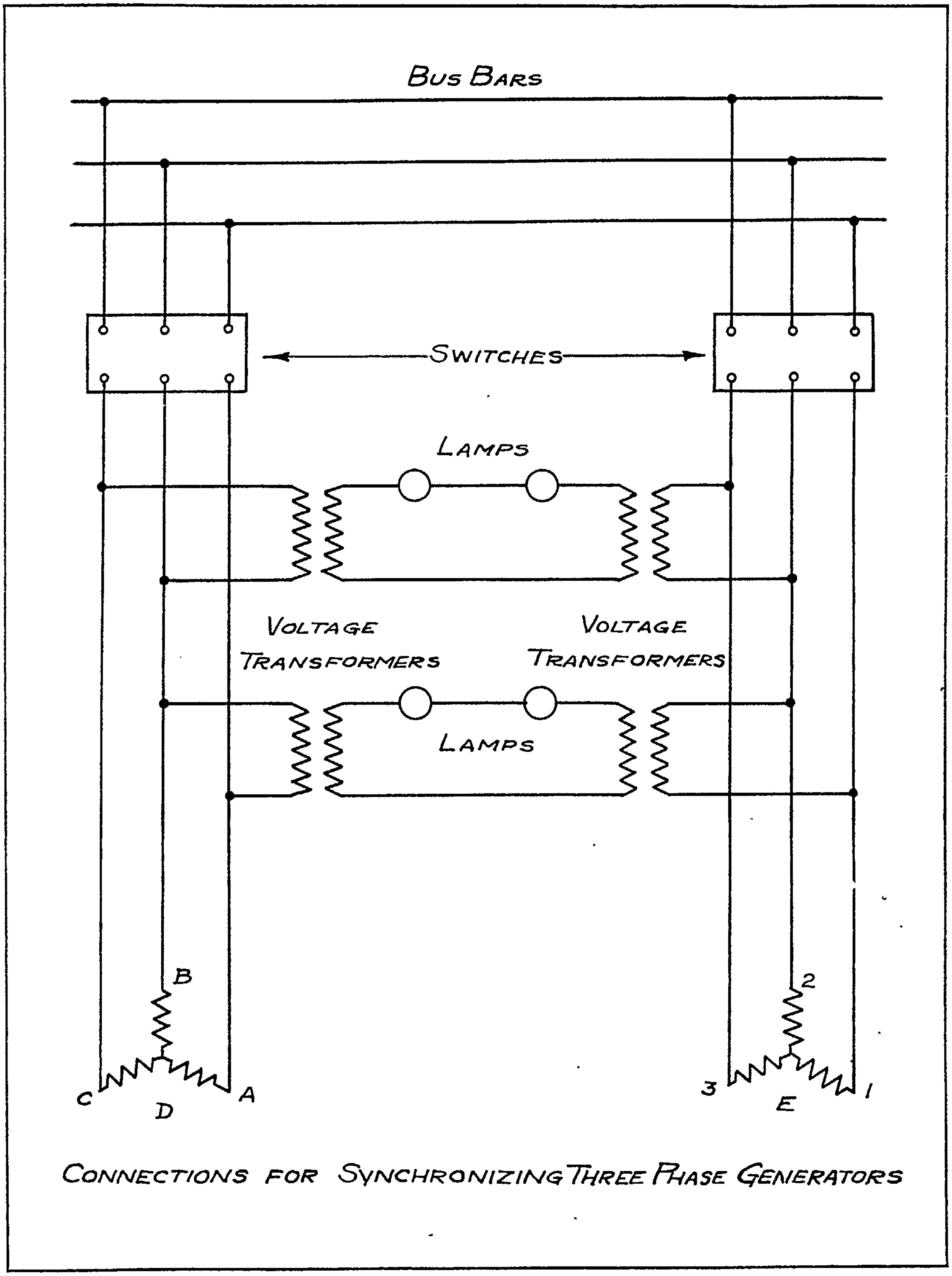


Fig. G-1 -- Typical Diagram of Connections and Apparatus Required for Paralleling of A-C. Generators (Westinghouse ED. Sketch 187003)

Paralleled Generator Unit

GENERAL

6. When 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.

7. In order that synchronous apparatus 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 frequencies be the same and that the two voltages be equal, both in magnitude and in phase position.

EXPLANATION OF SYNCHRONIZING LAMP CIRCUIT

8. The following method can be used to determine when the incoming generator and the system are at the same frequency and when their voltages are in phase. This method requires the use of lamps connected between the leads which are to be paralleled. 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. E.D. Sketch 187003 (Figure G-1) shows such connections between two of the phases of two three-phase generators. One generator may be considered as representing the system which is already in operation. A recommended check on the transformer connections is given in paragraph 11 following.

9. 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 difference between the frequency of the incoming generator and that of the system, the lamps will increase in brilliancy until the voltage of the machine and that of the system are in exact phase-opposition. From this condition, the lamps will decrease in brilliancy until they are completely dark, indicating that the voltages are again in phase. The rate of pulsation of the lamps is proportional to the difference between the frequency of the incoming generator and that of the system.

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

11. When voltage transformers are required because of the high line voltages, it is possible for the transformer connections to have been made in such a manner that the lamps will burn with maximum brilliancy when the two voltages in question are in phase. It is preferable to **use dark lamps to indicate synchronism.**

12. 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 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 should be dark if the transformer connections are correct. If the lamps burn brightly under these conditions, the connection to one of the

primaries or to one of the secondaries of the voltage transformers should be reversed.

DETERMINING PROPER PHASE SEQUENCE

13. 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 E.D. Sketch 187003 (Figure G-1), 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.

14. 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, the phase rotation of the generator is the same as that of the system.

15. 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 A SYNCHROSCOPE

16. 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. 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.

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

18. 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" (counter-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" (clockwise) direction, indicating that the generator is running too slowly.

19. 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 different from the system frequency.

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

Point 1. 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.

Point 2. The frequency of the generator is equal to the frequency of the system. When this condition exists, the pointer of the synchroscope remains stationary.

Point 3. 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.

21. 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.

SYNCHRONIZING GENERATORS WITH LAMPS

22. 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 the corresponding 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 a definite and accurate indication of synchronism. Nevertheless, they may be used satisfactorily if proper care is exercised. 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.

OPERATION OF A-C. GENERATOR

Single Generator

23. When a synchronous generator operates alone, without being 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 by hand, but it is preferable for this to be done by a voltage regulator which can 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, for the power factor is determined entirely by the characteristics of the load.

Paralleled Generator

REQUIREMENTS FOR SUCCESSFUL PARALLEL OPERATION

24. The following list gives the general requirements for successful parallel operation of synchronous generators.

Point 1. The speed regulation of the prime movers should be alike. That is, the per cent drop in speed for a given per cent increase in load should be the same for both, or all, units. The drop in speed from no-load to full-load may be only 2 per cent 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.

Point 2. 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 voltages.

Point 3. Engine-driven machines should have sufficient flywheel effect to prevent wide fluctuations in speed which arise from the regular pulsations in torque inherent in reciprocating engines.

Point 4. The wave-form of the generators should be alike. If this condition is not fulfilled, there will be harmonics in the current wave which will cause additional losses in the machines. In modern machines, the wave-forms are usually close enough to sine waves to prevent any trouble from this source.

LOAD DIVISION AND POWER FACTOR CONTROL

25. 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.

26. In the following discussion, let it be assumed that the total load is to be divided between two generators of equal rating. In addition, it will be assumed that the generators are under manual control. 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 wattmeter readings will be equal. This redivision of load may be effected 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.

27. After the load is balanced, the power factor and line current of the two generators may be equalized by setting the a-c. generator field rheostats properly. This may be accomplished without appreciable change in the ship's service voltage (normally 450 volts) by slight alternate adjustments of the field rheostats of the two a-c. generators.

28. When the kilowatt-load is divided equally between the two generators, the machine operating at the lower lagging power factor has the higher line-current ammeter reading. If the field rheostat of this generator is turned slightly to "LOWER" (in order to decrease its excitation), the power factor of this machine will increase, and the line-current ammeter reading for this machine will decrease.

29. In an extreme condition of improper rheostat settings, 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 generator will be considerably higher than that of the other machine. This is due to the fact that this machine is carrying all of the reactive-load, whereas the other machine is carrying only its share of the kilowatt-load.

30. When automatic voltage regulator control is being used during the power-factor adjustments, the same equalization of current may be obtained. In this case, it is necessary to vary the voltage-adjusting rheostats instead of the a-c. generator field rheostats. The voltage regulators will continue to maintain the proper division of reactive load by means of cross-current compensators, regardless of changes in load.

SHUTTING DOWN OF A-C. GENERATOR

Removing Generator Unit from Service

31. 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 regulator may then be taken out of control by turning the regulator switch to the "MANUAL" position. The a-c. generator field rheostat should then be run to the "LOWER" position to reduce the excitation. The field switch may then be opened.

Precautions

32. When the generator unit is to be shut down, the detailed instructions furnished with the prime mover should be followed.

33. Whenever the generator unit is shut down, it should be kept warm and dry. If the machine is to be shut down for a considerable period of time, more extensive provisions should be made to protect the machine from dirt, moisture, rust, and corrosive fumes. Particular attention should be given to the collector rings, as noted in another paragraph.

34. It is important that all line switches and breakers be open when the machine is not running, in order that the machine may be isolated from the external circuits.

MAINTENANCE OF A-C. GENERATOR

Causes of Insufficient Voltages

35. Insufficient voltage may be attributed to any of a number of causes. The regulator may be set for too low a voltage; part of the armature or field winding may be short-circuited or improperly connected; or the power factor may be too low. It is possible that the switchboard instruments may be incorrect so that the voltage or current may actually be greater than that shown by the readings.

Routine Inspection and Care During Operation

MACHINE TEMPERATURE

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

37. The temperature of the bearing, as indicated by the temperature of the oil draining from the bearings, should not exceed 85°C. Temperature detectors in the armature slots provide a means of checking the temperature of the stator winding.

Collector Rings and Brushes

38. Sparking, when it occurs in regular operation, is in general caused by imperfect contact between brush and collector ring. This may be due to any of the following causes:

<u>Cause 1</u>. The presence, between the brush and the ring, of dirt or particles broken from the edge of the brush.

<u>Cause 2</u>. Lack of free movement of the brush in the holder because of either too tight a fit or cramping due to too loose a fit. Brushes may stick in the holders because of the collection of dust between the brush and holder. This dust may conduct sufficient current to fuse the dust to the brush and the brush to the holder.

<u>Cause 3</u>. Sluggish springs which fail to keep the brush in contact with the ring when there is any vibration.

<u>Cause 4</u>. Rough, untrue, or rusty collector rings which cause momentary separation between the brush and the ring.

<u>Cause 5</u>. Vibration of collector rings, brushes, or brush supports which also cause momentary separation.

<u>Cause 6</u>. Incorrect alignment of brushes and rings which results in the overhanging of a thin edge of the brush which chips and breaks off.

<u>Cause 7</u>. Excessive current densities due to overloads. The mechanical contact is never perfect, and high current density will cause sparking with brush fits that would be accurate enough for normal densities.

<u>Cause 8</u>. Insufficient spring tension. Blackening and cutting of the ring is an indication of bad brush service. When sufficient graphite is present for good lubrication, the brush on the ring which has the highest polish may be considered to be giving the best service.

<u>Cause 9</u>. Occasionally, ring trouble will arise from a ring's not being of uniform hardness. Uneven wear results from this, and such a ring should be replaced.

<u>Cause 10</u>. Brush "chatter" accompanied by sparking frequently results from a long period of operation with an unusually low value of field current, as when a standby generator is kept running without load. If this occurs, the load should be carried alternately by all the generators of this rating on the ship.

39. If all the ship's service generators are not in continuous operation, it is recommended that the load be transferred from one machine to another on alternate days so that no machine will remain idle continually. By this means, the surface of the collector will be kept in the proper condition. Whether or not the machine assumes all or part of the load on various days, it should be brought up to speed daily and run for a few minutes at least. If this is not possible, the collector rings should be protected from rust and corrosive fumes by the application of a little paraffin to the rings while they are still warm and while the machine is coming to a stop.

40. In general, to stop sparking it is necessary to get good contact between the brush and the ring, and the causes of sparking previously

listed should be removed. It often happens that one brush is carrying more than its share of the current. The pressure on such a brush should be relieved temporarily, and the pressure on the other brushes on the ring should be adjusted until each brush carries its proper share of the current. Excessive pressure should be avoided because of the resulting mechanical wear.

Frequent Periodic Inspection and Care at Shutdown

CARE OF COLLECTOR RINGS AND BRUSHES

41. As the brushes become shorter from wear, the springs should be tightened so that the proper brush pressure is maintained.

42. Collector rings and brushes always tend to gather dust. If this dust is allowed to accumulate, it may break down the insulation of various parts of the machine. It will also cause sticking of the brushes in the holders.

43. For this reason, the brushholder and collector parts should be kept clean. Best results will be obtained if all brushes are removed from the holders frequently and thoroughly wiped off and the insides of the brush boxes given a thorough cleaning. A piece of canvas dipped in a grease solvent is recommended for cleaning the brush rigging and collector parts.

44. Since there is always an electrolytic action at the surface of the collector rings, their operation is improved by occasionally reversing the polarity of the rings. It is recommended that this be done once a week if the machine can be shut down long enough to make the change. Sometimes trouble will occur on one ring only, and by reversing the polarity every day or so, the trouble will disappear entirely.

45. Any black spots that appear on the surface of the collector should be removed by rubbing 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.

46. Sometimes an imprint of the brushes will be found on the rings. This can be due to the action of acid fumes or rust on unprotected collector rings during an extended shutdown. The fumes or rust attack the rings except for the parts covered by the brushes; so a high spot remains under each brush. When the machine is again brought into service, the brushes jump slightly as the high spots pass beneath the brushes, and the resulting arc burns the imprint of a brush behind each high spot. As noted in paragraph 39, the application of paraffin in the rings as the machine comes to a stop will protect the rings during an extended shutdown.

47. Another cause of brush imprint on the rings is a slight unbalance in the rotor or eccentricity in the collector rings which causes a jerking or movement of the rings once every revolution. This causes the brush to jump and produces a small arc which in time burns the imprint of the brush on the ring.

48. The location of brush imprints due to acid fumes or rust will depend upon where the machine happens to stop, but the imprints caused by rotor unbalance or eccentric rings will always occur in the same location relative to the rotor.

49. Regular inspection should be made to see that the collector rings are perfectly cylindrical and running true. If they are not, it may be necessary to turn down the surface of the rings. This should be attempted only when the collector assembly is tight.

INSULATION RESISTANCE OF STATOR AND ROTOR

50. It is recommended that the insulation resistance of the stator and rotor windings be read once every two weeks, and no less frequently than once a month. As noted under the general heading of "Installation and Erection", the values of resistance of the insulation are useful chiefly in showing a trend. A trend toward lower insulation resistance can be a warning of impending failure of the insulation; so the readings obtained at any particular time should be compared with the previous readings in order to be of maximum significance.

Occasional Inspection at Shutdown

GENERAL

51. It is advisable to give the machine a thorough inspection occasionally; and in doing so, the end bells should be removed.

ALIGNMENT

52. Once the generator has been properly installed, there should be little need for further adjustment of the alignment. However, it is important that such adjustments be made if necessary; so an occasional check on the alignment is recommended.

53. The air gap between the stator and rotor should be checked for uniformity around the periphery. The top half of the generator bearing should be removed and a check made to see that the journal is properly centered in the bearing. A similar check on the axial alignment should be made at the exciter bearing by removing the cover over the outboard end of the exciter shaft.

54. More complete directions for gaging the air gap are given in a preceding section entitled "Alignment of Equipment".

COILS AND CONNECTORS

55. A check should be made for loose field coils, armature coils, and connections. All coils and connectors should be tight and free from oil and moisture.

Cleaning the Windings

GENERAL

56. Occasionally the accumulated dust on all parts of the windings should be blown out by means of compressed air. The pressure used in such service should not exceed 25 psi. When the available compressed air is at a higher pressure, a throttling valve should be used. Before turning the air blast on the machine, any accumulation of water in the air pipes should be blown out, for the damage which would be caused by spraying water on the windings would outweigh the benefits derived from removing the dirt. The air should be directed through the vent ducts in the stator core, as well as toward the windings, for an accumulation of dirt in the vent ducts impedes the free flow of cooling air.

57. Cleaning with air pressure should be followed by a thorough wiping with a cloth. The dirt which clings to the field coil washers should be removed carefully, for it may accumulate and form a conducting path from the coil to ground.

58. In some marine installations, the windings of electrical apparatus become covered with oil or grease due to the presence of oil vapor,

or even direct leakage of oil from bearings, etc. Although windings which are to be subjected to this kind of service are treated with an oil-resisting varnish, the prolonged presence of oil may prove harmful, due to the fact that it will collect current-conducting dirt and carry this dirt to all parts of the winding. For this reason, it is desirable to clean any accumulation of oil or grease from the windings of such apparatus at fairly regular intervals. The maximum time interval between cleanings depends upon the rate at which dirt and grease accumulate on a given generator. The windings of this enclosed machine should remain reasonably clean over an extended period of time.

59. There are three types of grease solvents which may be used for cleaning the insulated windings of electrical apparatus. These are benzine or gasoline, carbon tetrachloride, and a mixture of benzine or gasoline with carbon tetrachloride. The characteristics of these grease solvents are the following:

BENZINE OR GASOLINE

60. Either benzine or gasoline is very inflammable, and their vapors mixed with the proper percentage of air are quite explosive. If this type of solvent is used, there should be good ventilation, and every care taken to avoid fire risk. Care should be taken also to see that the workers' clothing does not become saturated with the solvent. Clothing which does become saturated with the solvent should be removed before the workers leave the job.

61. Of the three types of solvent, benzine and/or gasoline has the least corrosive action on the insulation varnish and should therefore be used in preference to the other solvents where conditions permit.

CARBON TETRACHLORIDE

62. Carbon tetrachloride is non-inflammable and non-explosive. It has a slight toxic effect, but this is not accumulative.

63. This solvent is much more corrosive in its action than either benzine or gasoline. Because it is a solvent of rubber, it should not be used on the leads and any other parts where rubber insulation is used. Care must be taken to protect adjacent parts also from corrosion. With these precautions, carbon tetrachloride, which evaporates quickly, may be used for cleaning the windings with small risk of damage. It should be used where proper ventilation is not obtainable or where fire risk is high.

MIXTURE

64. A mixture of 50% carbon tetrachloride and 50% benzine, or 60% carbon tetrachloride and 40% gasoline, is non-inflammable; but the vapors mixed with the proper amount of air are explosive. There should be fair ventilation so that the explosive fumes will not accumulate. There is no particular danger from spilling these mixtures on the clothing. This solvent may therefore be used where there is fire risk, but only where the ventilation is sufficient to prevent the accumulation of an explosive mixture of fumes.

OPERATION OF CLEANING THE WINDINGS

65. Waste, or a dry cloth, should be used to wipe as much of the oil or grease from the winding as possible. Then waste, or a cloth, moistened with one of the recommended solvents should be used for cleaning the windings. Inaccessible parts of the machine may be reached with a swab moistened with the solvent, or in some cases a spray of the solvent may be directed at the winding with sufficient force to wash away the oil.

66. Whenever possible, the parts which have been cleaned should be dried with clean waste or rags in order that the insulating varnish may not become soft from prolonged exposure to the solvent. If the varnish coating of the windings shows considerable deterioration, the windings should be retreated with a varnish furnished by the manufacturer. In any case, the machine should be given an opportunity to dry out thoroughly before being placed in service.

Emergency Repair Measures

REBABBITTING OLD BEARINGS

67. 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 bearings are 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.

68. Only a good tin base babbitt such as N.D. Specification 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 become quite hard.

69. 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.

REPLACING BEARING SEAL STRIPS

70. To replace the bearing-seal strips, first remove the collector cover and bearing seals. The old seal strips and lock strips may then be removed from the seal. The new seal strips "77" and lock strips "78" (Figure G-5) are then inserted, and the lock strips are caulked into place with a round-nosed tool. The strips are then machined at the splits and bored to a diameter of from 6.264" to 6.265". The seals may then be reassembled.

REPLACING AIR SEAL STRIPS

71. To replace the air-seal strips, first unbolt the rear end bell from the air seal. Disconnect the air-seal piping, remove a quarter-section of the end bell, and remove the air seal. The procedure for actually replacing the strips is the same as for replacing the bearing labyrinth seal strips. Seal strips "52" and lock strips "53" (Figure G-5) are used. The splits are machined, and the assembly is bored to a diameter of from 11.264" to 11.265". The seal may then be reassembled.

PART II

(Section 5) A-C. GENERATOR AIR COOLER

1. Installation

(a) Ports are provided on the inlet and outlet cover for connections to sea-water line. The upper ports may be used for inlet and the lower ports for outlet, or vice versa.

(b) 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" screen openings.

(c) Strainers or filters are essential if liquids circulated through the cooler contain foreign matter larger than specified.

(d) 5/16" - 18 tapped holes are provided in the angle frames for attachment of the cooler in the air duct.

(e) The 1/8" pipe plugs which are inserted in the tell-tale holes before shipment should be removed before the cooler is put in operation.

2. Operation

Step 1. Open water valves fully.

Step 2. Manipulate handwheels until desired air temperature regulation is secured.

Step 3. No other operating instructions are necessary.

3. Maintenance

Step 1. Clean strainers in sea-water inlet line as frequently as required to provide unrestricted flow.

Step 2. The inside of the tubes should be cleaned as frequently as necessary to provide unrestricted flow of sea water. The unit should be inspected at long intervals to see if the fins on the outside of the tubes require cleaning from deposits of oil and grease from leaky bearings, or carbon from brush wear.

Step 3. Coolers are provided with zinc electrodes to centralize electrolysis. The electrodes should be examined 30 days after installation, and checked every 30 days thereafter.

Step 4. Observe notations on applicable Assembly Drawings.

4. Cleaning

Step 1. Close valves in pipe connections to and from cooler; disconnect air ducts, and remove the unit from the piping.

Step 2. Disconnect inlet and rear covers to expose inside of tubes.

Step 3. Clean inside of tubes by application of steam jet and use of rods where necessary.

Step 4. Clean outside of tubes by use of steam jet, drying with compressed air.

Step 5. Clean any foreign matter from inside of inlet and rear covers.

Step 6. Reassemble, using new gaskets when necessary.

Step 7. Reinstate operation by following instructions under Paragraph 1.

5. Reference Drawing

See Harrison Radiator Division Drawing A-8507960 (Figure G-10).

PART II

(Section 6) DESCRIPTION OF D-C. EXCITER
(16-Kw.—120 Volts—1200 Rpm.)

Rating

1. The exciter is rated at 16 kw., 120 Volts, 1200 rpm. Stabilized shunt wound - Class A insulation - Continuous duty at 40°C. rise good for 25 per cent overload for two hours at 55°C. rise. Exciter built on S.O. 16-P-689 or 19-P-145. Frame Size 6-103.35 SK.

Classification

Prime Mover - Steam Turbine
Degree of Enclosure - Drip-proof, Open
Class of Insulation - A
Method of Cooling - Natural
Type of Winding (Fields) - Stabilized Shunt Wound
Ambient Temperature of Reference - 50°C.
Specifications - Bu. Ships 17-G-7 (INT.) of 15 August 1941.

General Description (Reference Dwg. 34-J-901, and Fig. G-4, and 35-J-487, Fig. G-7)

3. The exciter is direct-connected to the ships service a-c. generator. The armature is supported by a bearing at the commutator end and by a flange shaft solidly bolting to the a-c. generator shaft at the rear end. The frame is supported from an extension of the main bedplate.

Frame

4. The frame is of fabricated-steel construction. The magnetic section is made from rolled steel carefully butt-welded. The feet are welded to this ring. Spacer bars are used to form the support for the front bracket and a suitable drip-proof cover is added to the overall unit. Access covers are provided at the commutator end for servicing the commutator and brushes. The terminal board is mounted in the area between the feet just below the commutator.

End Bracket

5. An end bracket is provided in the front end to support the brushes and brushholders and to carry the sleeve bearing. The bearing is lubricated from the pressure system of the turbine and suitable inlet and outlet pipes are provided.

Armature

6. The armature is built to be removable from the shaft. It is held to the shaft by a tight press fit. It is prevented from turning on the shaft by keys. The steel punchings making up the core are riveted together between solid end plates. The commutator is made of hard-drawn copper bars held in V-shaped grooves by steel bushings and rings.

Fields

7. The field winding and brushes and brushholders are adequately described on Drawing 35-J-487 (Bu. Number CV9-S6100-591). (See Figure G-7.)

Spare Parts

8. The spare parts were supplied in accordance with the tabulation on Drawing 35-J-487 (Bu. Number CV9-S6100-591). (Figure G-7). Also see Page 513.

PART II

(Section 7) INSTALLATION, OPERATION AND MAINTENANCE OF D-C. EXCITER

General

1. To obtain long satisfactory service from direct-current generating equipment it is necessary to properly install, operate and maintain such equipment. The following gives the simple precautions and instructions for such care. Properly maintained 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.

INSTALLATION OF D-C. EXCITER

Unpacking

2. When unpacking be sure and protect any exposed windings from damage. Coil insulation is very 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 quill. Keep it free from bumping which will cause burrs and interfere with the fit on the shaft of the main generator as this will cause misalignment.

Inspection

3. As soon as the exciter 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 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

4. Electrical equipment is easily damaged when dismantled. If the exciter is dismantled and the windings are exposed, care is necessary to properly 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 steel punchings or by a wooden or steel bar through the armature quill. Use a spreader to keep the ropes from pressing against the coil ends or commutator. Never support it 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 instruments on any coils as the insulation can be easily punctured.

Connections

5. Connect the exciter in accordance with the diagrams supplied with the regulating equipment.

OPERATION OF D-C. EXCITER

Before Starting

6. 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 two psi. 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. See also instructions on the regulator.

Starting

7. On initial starting proceed slowly and note especially any evidence of rubbing.

8. See instructions under the "Regulator" for proper adjustments to be made and method of controlling voltage.

9. After load is applied look for evidence of sparking at the commutator. The exciter should carry rated load with little sparking. If severe sparking occurs see comments under "Maintenance".

MAINTENANCE OF D-C. EXCITER

Insulation

10. Keep exciter 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 (generally marked on label inside the instrument cover) is known.

11. The method of making a resistance measurement with the voltmeter is to first read the voltage of the line, 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 voltmeter in ohms
R = Resistance of insulation in ohms

12. 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.

13. 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

$$\frac{3\,(\text{rated voltage})}{\text{Kw.} + 1000} \text{ (in ohms)}$$

14. If the resistance is low the generator should be dried out before it is started into regular service. It can be done by,

(a) Using a separate heater (such as a lamp bulb) inside the generator.

(Do not place too near the coils and in general the machine should be enclosed for best results),

(b) Circulating current through the windings, or

(c) Dismantling and removing the armature and coils and baking them in an oven (at not over 105°C.). This should be done in extreme cases.

15. If the second method is used run the generator with a low-voltage output, adjusting the load to a current value which will raise the temperature to approximately 70°C. This temperature should be maintained during the drying process by raising or lowering the current as required.

16. Careful attention should be given to the machine during this drying-out process. There is always danger of overheating the windings when drying them with current. The inner parts which cannot quickly dissipate the heat generated in them may get dangerously hot, while the exposed and more easily cooled portions are still at a comparatively moderate temperature. Therefore, the temperature of the hottest part accessible should always be observed during the drying-out process, and should not be allowed to exceed 80°C. total temperature.

17. If it is found that the generator is in a very damp condition, it may require several hours or even days to dry it out because the insulation is more easily injured when damp than when it is comparatively dry. In such extreme cases, it will be better to bring up the temperature slowly at first, not allowing the maximum temperature to be reached until part of the dampness is expelled.

Brush Position

18. The correct brush position has been located at the factory and the rocker ring is locked to the magnet frame to prevent any movement. The brushholder should be adjusted to be approximately 1/16" from the face of the commutator.

Brushes

19. The ends of all brushes should be fitted to the commutator so that they make good contact over their 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 Out and "Grade 0" for the final fit. (See Figure G-3.)

20 Make frequent inspection to see that:

(a) Brushes are not sticking in holders.
(b) Shunts are properly attached to brushes and holders.
(c) Tension is changed as brush wears. Maintain approximately 2 psi.
(d) Worn out brushes are replaced before they reach their limit of travel and break contact with the commutator.
(e) Remove any free copper picked up by the face of the brush.

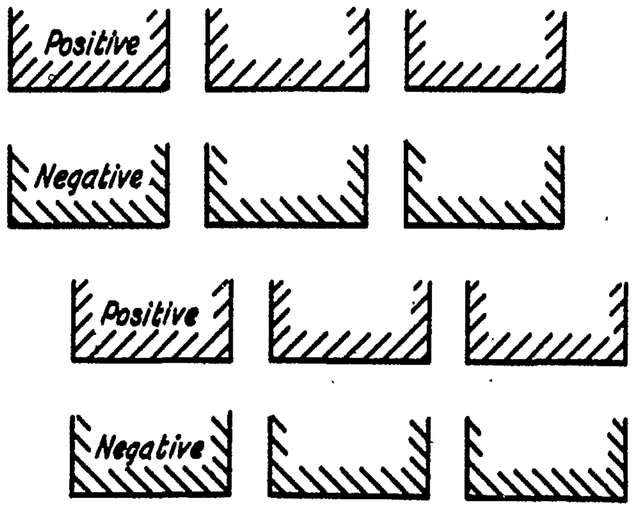


Fig. G-2 -- Correct Method of Staggering Brushes
(Westinghouse Drawing T-75040)

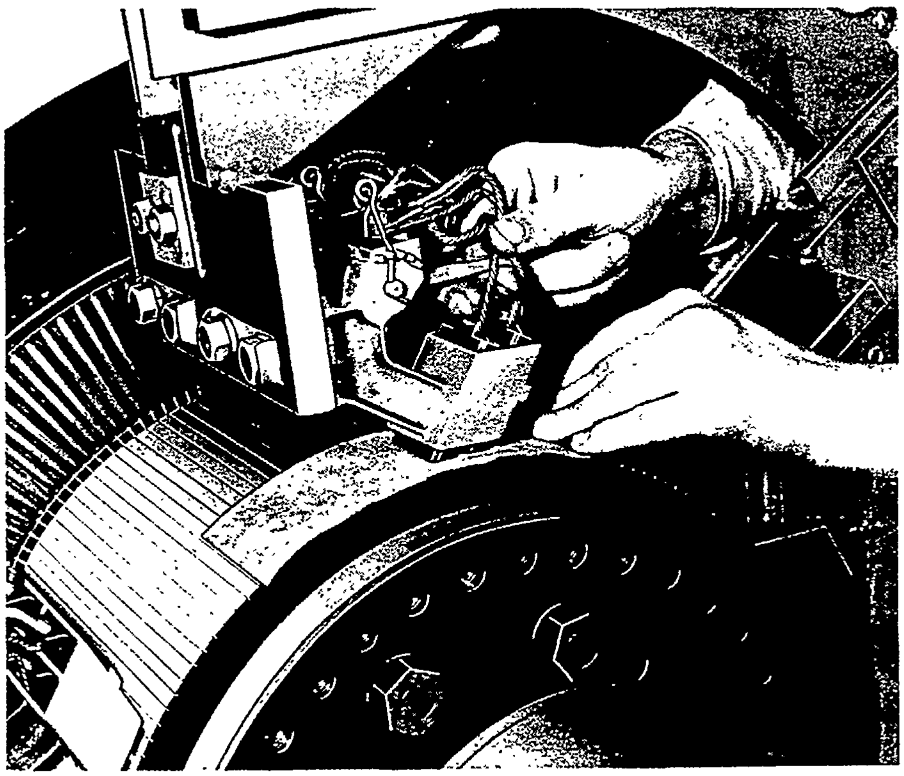


Fig. G-3 -- Proper Method of Grinding Carbon Brushes
(Westinghouse Photo 283841)

Commutator

21. The commutator is perhaps the most important part of the whole exciter because it is most sensitive to abuse. Under normal conditions, it should require very little attention beyond frequent inspection. The surface should always be kept smooth. If through extreme carelessness, neglect or accident, it becomes badly roughened, the armature should be removed and the commutator turned down in an engine lathe.

22. Sometimes a little sandpapering is all that is necessary. Emery cloth or paper should never be used for this purpose because of the continued abrasive action of the emery which becomes embedded in the copper bars and brushes. Even when sandpaper is used the brushes should be raised and the commutator wiped clean with a piece of canvas. Cotton waste should never be used.

23. All commutators are thoroughly baked and tightened before leaving the factory, but if a bar should work loose it should be attended to promptly. The same may be said of flat spots or "flats" which will sometimes occur, due to a loose bar, unusually soft copper or even to severe flash or short-circuit.

24. Under normal conditions the commutator should become dark and highly polished after a few weeks' operation, and so remain unchanged for years; there should never by any lubricant used on the commutator.

25. Trouble is sometimes experienced from the burning out of mica insulation between segments. This is most commonly caused by allowing the mica to become oil-soaked or by the bars loosening between them. It is rarely, if ever, definitely traced to excessive voltage between bars. When this burning does occur it may be effectively stopped by scraping out the burned mica and filling the space with a solution of sodium silicate (water glass) or other suitable insulating cement.

26. Even with the most careful workmanship, high mica will sometimes develop and start sparking, which burns away the copper and aggravates the difficulty. By prompt action serious damage can be prevented by cutting away the mica to a depth of one sixteenth of an inch below the adjacent copper.

Sparking at the Brushes

27. Sparking at the brushes may be due to any of the following causes:

(a) Machines may be overloaded.

(b) Brush may not be set exactly on neutral.

(c) Brushes may be wedged in the holders or have reached the end of their travel.

(d) Brushes may not be fitted to the circumference of the commutator.

(e) Brushes may not bear on the commutator with sufficient pressure.

(f) Brushes may be burned on the ends.

(g) Commutator may be rough; if so, it should be smoothed off.

(h) A commutator bar may be loose, or may project above the others.

(i) Commutator may be dirty, oily or worn out.

(j) Carbon brushes may be of an unsuitable grade.

(k) Brushes may not be equally spaced around the periphery of the commutator.

(l) Some brushes may have extra pressure and may be taking more than their share of the current.

(m) High mica.

(n) Vibration of the brushes.

(o) Incorrect brush angle.

28. These are the more common causes, but sparking may be due to an open-circuit or loose connection in the armature. This trouble is indicated by a bright spark which appears to pass completely around the commutator and may be recognized by the scarring of the commutator at the point of open circuit. If a lead from the armature winding to the commutator becomes loose or broken it will draw a bright spark as the break passes the brush position. This trouble can readily be located, as the insulation on each side of the disconnected bar will be more or less pitted.

Flashover

29. 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:

(a) Rough or dirty commutator.

(b) A drop of water on the commutator from leaky steam pipes or other source.

(c) Short-circuits on the line producing excessive overload.

Causes of Insufficient Voltage

30. The following causes may prevent exciters from developing their normal voltage:

NOTE: Usually the exciter does not need to develop its name-plate voltage in order to obtain rated voltage on the main generator. In general, disregard the exciter voltage and be concerned only with the ability of the exciter and regulator to produce normal voltage on the main generator.

(a) The speed of the exciter may be below normal.

(b) The switchboard instruments may be incorrect and the voltage may be different from that indicated, or the current may be different from that shown by the readings.

(c) Part of the shunt field may be reversed or short-circuited.

(d) The brushes may be incorrectly set.

(e) A part of the field rheostat or other unnecessary resistance may be in the field circuit.

(f) The regulator may not be functioning properly.

Heating of Field Coils

31. Heating of field coils may develop from any of the following causes:

(a) Operating at too low a speed, requiring more than normal field current.

(b) Too high voltage.

(c) Partial short-circuit of one coil.

(d) Overload.

Heating of Armature

32. Heating of the armature may develop from any of the following causes:

(a) Too great a load.

(b) A partial short-circuit of two coils with heating of the two particular coils affected.

(c) Short-circuits or grounds on armature or commutator.

Heating of Commutator

33. Heating of commutator may develop from any of the following causes:

(a) Overload.

(b) Sparking at the brushes.

(c) Too high brush pressure.

(d) Lack of inherent lubrication of brushes.

Cleanliness

34. Particular care should be exercised towards keeping all parts of the exciter reasonably clean. High rotative speed draws air into the armatures and other parts with a velocity sufficient to carry with it particles of dirt or oil vapor that may be in the air. The rotating part must be cleaned periodically or the exciter will ultimately short-circuit between commutator necks or break down to ground over insulation surfaces. Stationary windings should be well-cleaned for the same reason.

35. In extreme cases clean machine using carbon-tetrachloride on a rag. Use sparingly and in a well-ventilated place as the fumes are nauseating. (See "Cleaning the Windings", Page 224. Do not scrape coils with any instrument.

36. After several years of operation it is good practice to coat all coils with a good coat of insulating varnish. If possible a baking varnish should be used and coils removed to an oven for such operation. A baking varnish is much superior to any air-drying varnish.

PART III

VOLTAGE-REGULATING AND TEMPERATURE-INDICATING EQUIPMENT

PART III

VOLTAGE-REGULATING AND TEMPERATURE-INDICATING EQUIPMENT

(Section 1) TYPE "SRAN-4" VOLTAGE REGULATOR EQUIPMENT

GENERAL INFORMATION

Purpose

1. Careful reading of these instructions will provide information for the proper care and handling of the generator voltage-regulating equipment and avoid damage to the equipment which may impair its performance when placed in operation.

DESCRIPTION OF "SRAN-4" GENERATOR VOLTAGE REGULATING EQUIPMENT

2. On this installation the a-c. generators are rated 1250-kw., 450 volts 3-phase, 60 cycles, using the "SRAN-4" type of voltage regulator.

3. The purpose of the automatic voltage regulator is to maintain the terminal voltage of the a-c. generators at, or very close to 450 volts, regardless of load variations.

4. The voltage regulator controls the voltage of the a-c. generator by varying the resistance in the exciter field circuit. This regulating action is semi-static in nature. The regulator operates only when a correction in voltage is necessary. Since the regulator acts directly on the exciter field resistance, no intermediate contactors, levers or linkages are necessary.

5. This "SRAN-4" type of voltage regulator has four regulating resistance plates connected in series-parallel and these in turn are connected directly in the exciter field circuit.

6. This resistance is varied by the value of the current in the coil circuit. Normal operating range of the coil current varies from .145 to .165 ampere d-c. from the rectifier.

7. With this value of coil current in the regulator circuit, proper voltage regulation will be obtained.

Voltage Regulator Control Element (See Fig. R-1)

8. The regulator coil is wound with 3000 turns of No. 25 enameled-copper wire with a resistance of 65 ohms. It is identified by Westinghouse Style No. 1173224.

9. An adjustable resistor tube is connected in series with the coil of the voltage regulator to set the range covered by the voltage-adjusting rheostat, so that rated generator voltage is obtained with the voltage adjusting rheostat in the mid-position. This internally mounted resistor is a 750-ohm tube identified by Westinghouse Style No. 1115103.

10. The spring-mounted moving arm of the regulator is supported so that the armature passes within the fixed air gap in the magnetic circuit. The pusher pins are located at the outer end of the moving arm and arranged to press against the silver buttons which are mounted at the free end of the leaf springs made of conducting material.

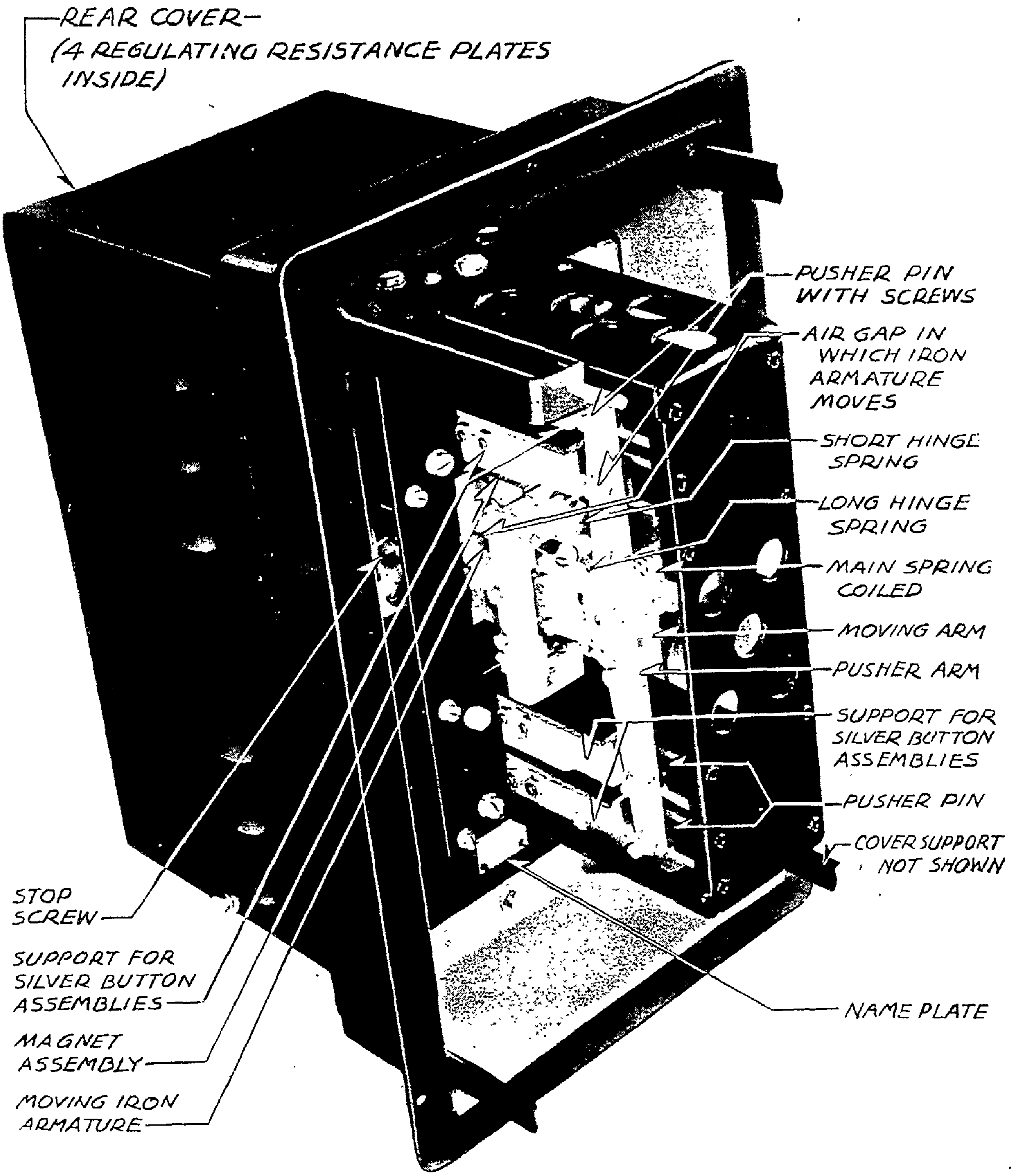


Fig. R-1 -- Westinghouse Type "SRAN-4" SILVERSTAT Voltage Regulator
(With Front Cover Removed)
(Photo 292530)

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VOLTAGE-REGULATING AND TEMPERATURE-INDICATING EQUIPMENT

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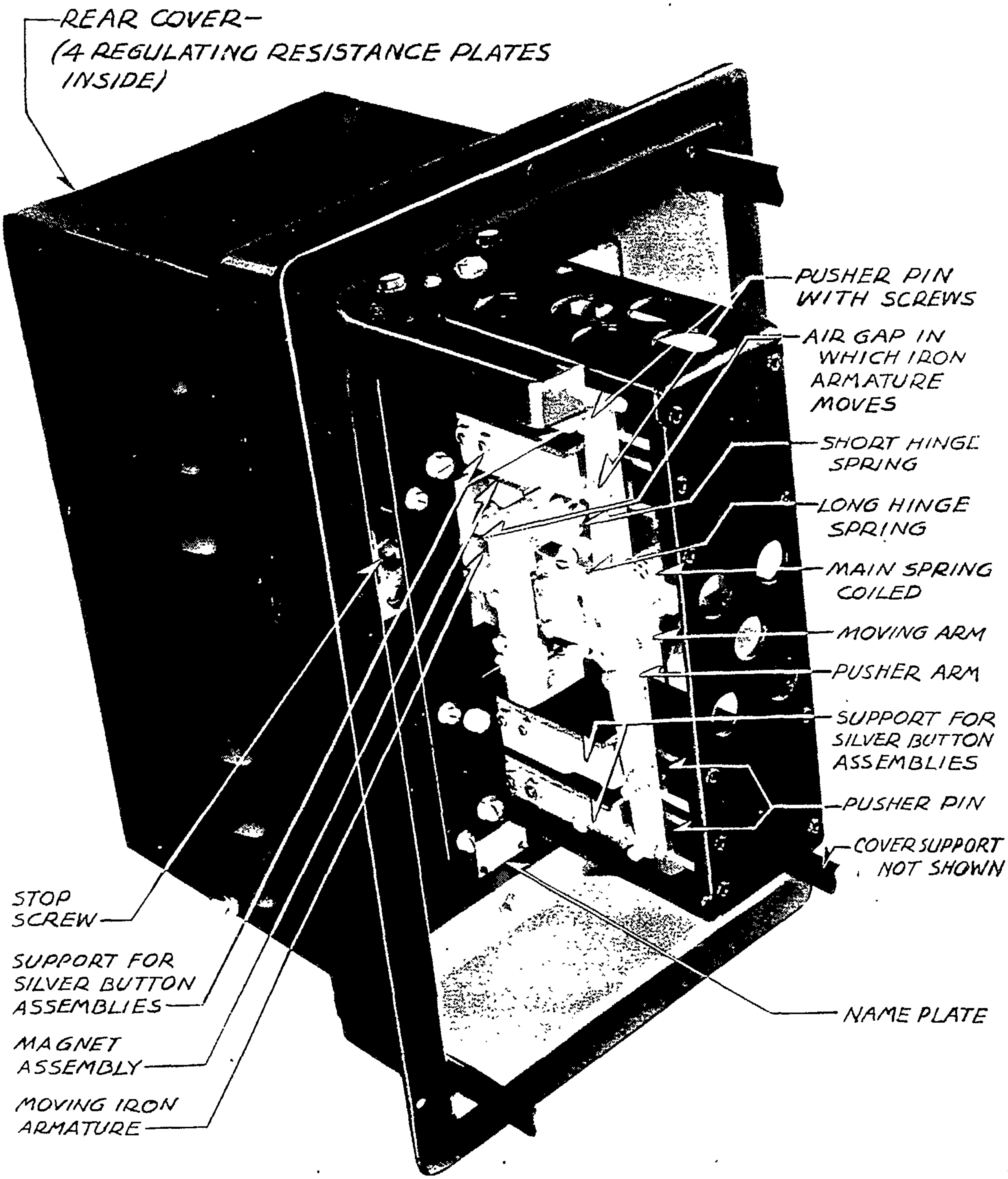


Fig. R-1 -- Westinghouse Type "SRAN-4" SILVERSTAT Voltage Regulator
(With Front Cover Removed)
(Photo 292530)

11. The fixed end of each silver-button leaf-type spring is attached to consecutive steps of the regulating resistance plates. These plates have resistive wire embedded in vitreous enamel. Each regulator has one plate per silver-button assembly mounted in the rear of the regulator unit. These plates are then connected in the exciter field circuit.

12. The coil spring is fastened to the outer end of the moving arm and pulls against the force on the armature caused by the coil and its magnetic circuit.

13. The voltage from the a-c. generator potential transformers is applied to a three-phase full-wave Rectox rectifier. The d-c. output of the rectifier is applied to the series connection consisting of regulator coil, adjustable resistor, the secondary of the damping transformer, and the voltage-adjusting rheostat.

14. The flow of this direct-current through the coil sets up a flux in the magnetic circuit. The iron armature on the non-magnetic moving arm is attracted by this magnetic field, the amount of attraction depending on the intensity of the magnetic field. The strength of this field depends on the current through the regulator coil and in turn the current depends on the generator voltage. Therefore, the magnetic pull on the armature is proportional to the voltage.

15. When the arm moves in response to the magnetic pull on the armature, it pivots on the mounting springs and stretches the coiled spring attached to one end. The insulating pusher pins, also mounted on the same end of the moving arm, directly control the closing or opening in succession of the series of silver buttons. These silver buttons are individually mounted on leaf-type springs, insulated from each other, and wired to consecutive taps on the stationary regulating resistance plates.

16. At one end of the travel of the moving arm (the magnetic pull of the coil having overcome the mechanical pull of the spring), all of the silver buttons are apart from each other placing maximum resistance in the field circuit. At the other end of travel (the mechanical pull of the spring having overcome the magnetic pull of the coil) all of the silver buttons are closed thus shorting out the resistance in the field circuit through a silver contact path which reduces the resistance to a negligible value. Therefore, as the moving arm operates through its travel, depending on the direction of its motion, it successively opens or closes the silver buttons to increase or decrease the resistance in the exciter field circuit. Since the moving arm has a short travel all resistance can be inserted or cut out quickly, or it can be varied gradually depending upon the change in excitation required.

17. Although the operation of these buttons in sequence apparently cuts small amounts of resistance in or out of the field circuit in a definite step by step manner, this is not actually the case. When the moving arm operates the silver buttons in sequence there is a progressive change in pressure between the faces of the buttons due to the action of the moving arm in deflecting the leaf springs on which the buttons are mounted. Since the effective resistance between silver surfaces is dependent upon the pressure, this effect is combined with the small value of resistance per step to provide a large number of steps from practically zero resistance to the maximum thus assuring smooth changes in the regulating resistance.

Damping Transformer

18. The damping transformer is an anti-hunting device which consists of two windings (primary and secondary) on the middle leg of a B-shaped laminated core. The secondary consists of 3600 turns of No. 23 enameled-copper wire with a resistance of 70 ohms, and is connected in series with

the regulator coil. The primary is wound over the secondary and consists of 6500 turns of No. 29 enameled-copper wire of 700 ohms resistance and is connected across the exciter armature.

19. On a change in exciter voltage, the induced transfer of energy from the primary to the secondary, and, therefore, to the coil, acts to dampen the movement of the armature to prevent excessive voltage and hunting. When the a-c. voltage rises, the regulator operates, due to increasing coil pull, to insert resistance in the exciter field circuit and thereby decrease the exciter field current and armature voltage. The primary of the damping transformer is subject to this change, and induces a voltage in the secondary which causes a momentary reduction in the normal regulator coil current. Thus, the coil pull is reduced by this impulse from the damping transformer, and the regulator voltage correction is not excessive. Conversely, when the a-c. voltage falls and the regulator operates, due to decreasing coil pull to short out resistance in the exciter field circuit, the impulse from the damping transformer aids the normal coil current. Thus the regulated voltage is not increased excessively.

20. The complete damping transformer is identified as Westinghouse Style No. 1313987.

Rectox Rectifier

21. The three-phase a-c. voltage is rectified by the three-phase full-wave Rectox rectifier, Westinghouse Style No. 1257681, to provide d-c. current for the main coil of the voltage regulator control element. The basic element of the Rectox rectifier is a copper disc, on one side of which a layer of cuprous oxide has been formed. This disc allows current to pass freely in the oxide-to-copper direction but with difficulty in the opposite direction. In this installation the discs are assembled on six separate supporting studs. The six stacks of discs, each identified by Westinghouse Style No. 1253324, are connected so that all positive half-waves of the impressed a-c. energy will send current to the regulator coil in one direction through one half of the rectifier stacks; all negative half-waves will return to the potential transformer through the other half-stack which previously opposed passage of the positive half-waves. The result is a d-c. output from the rectifier to the control element coil. This output depends on the average of the three-phase voltages.

Voltage-Adjusting Rheostat

22. Turning the handle of this rheostat raises or lowers the value at which the regulator holds the generator voltage. Changing the resistance varies the current in the coil circuit of the regulator which changes the position of the regulator moving arm and results in a change in resistance in the exciter field circuit. Hence the regulated value of generator voltage can be adjusted by the position of this rheostat. This Type "RC" Rheostat has 43 equal steps of resistance, one plate, and 200 ohms total resistance. The rheostat is identified by Westinghouse Style No. 1354205.

Potential Transformers

23. Two, Westinghouse Style No. 1294692, Type "VN", Potential Transformers are used to step down from 450 volts a-c. generator voltage to 112.5 volts, which is applied to the regulating equipment.

24. The potential transformers are connected as follows:

<u>Primary</u> - Connected open-delta, receives three-phase, three-wire, 60-cycle, 450-volt alternating current.
<u>Secondary</u> - Connected open-delta, gives three-phase, three-wire, 60-cycle, 112.5-volt alternating current.

Current Transformers

25. One current transformer is supplied with each a-c. generator that operates in parallel with other generators. It is connected in line "B" of the generator and its energy is supplied to the cross-current compensator. The ratio of this current transformer depends upon the rating of the generator. For this application one Type "UN", (Modified) Current Transformer, ratio 3000/5 amperes, is used.

Cross-Current Compensator

26. This piece of apparatus consists of an adjustable auto-transformer connected across a resistor-reactor combination. Two insulating transformers transmit energy in proper phase relation to the potential circuit of the regulator. This causes the regulator to droop the regulated voltage in proportion to the magnitude and phase angle of the reactive-load current. The compensator is identified by Westinghouse Style No. 1257682.

Regulator Control Switch (Supplied By Switchboard Manufacturer)

27. The regulator control switch is of the rotary type. In the "MANUAL" position the generator voltage is controlled by the operator by use of the exciter field rheostat. In the "AUTOMATIC" position the generator is under full control of the regulator and it will adjust the voltage to a value predetermined by the position of the voltage-adjusting rheostat.

Regulator Transfer Switch (Supplied By Switchboard Manufacturer)

28. The regulator transfer switch is of the rotary type. In the "NORMAL" position the "Normal Control Element" and its associated auxiliary equipment control the generator and in the "STANDBY" position the "Standby Control Element" and its associated auxiliary equipment control the generator.

INSTALLATION OF "SRAN-4" VOLTAGE REGULATOR

Storage

29. The regulator is packed for shipment with the object of providing protection during the necessary handling and storage. The unit will withstand reasonable atmospheric and temperature conditions. A metal case encloses the moving element of the regulator to afford protection against dirt and dust.

Handling And Unpacking

30. Care should be taken not to kink or bend the hinge-spring assembly. The moving arm assembly should not be forced in any direction otherwise the performance of the regulator is likely to be unsatisfactory.

Installation And Erection

31. When the regulator is placed in position prior to the installation of other large apparatus nearby, the electrical equipment should be protected by box or crate parts, or sections of plywood.

Temperature And Ventilation

32. Provision for cooling has been made by leaving the resistor plates exposed to the atmosphere and yet protected from harm by the use of a metal shield. These resistor plates are vertically mounted which assures

Section 2. DESCRIPTION

2.1 GENERAL

After initial startup, the field of the ac generator is self-excited; that is, all energy applied to the generator field is derived from generator output terminals. Field excitation is provided through separate circuits. See Fig. R-1.

Most excitation energy is delivered by a circuit composed of three linear reactors, L1, L2, L3, three vector summing transformers, T1, T2, T3, (Figs. R-11 and R-12) and power rectifier assembly, X1. The secondaries of vector summing transformers are connected in wye; the wye is connected directly to ac side of power rectifier assembly terminals, AC1, AC2, and AC3. DC output of power rectifier assembly is delivered through terminals POS and NEG to generator field. The primary circuit of the vector summing transformers has two isolated windings. One of these forms a portion of the phase bus that connects generator output terminals to line breakers; the other is connected in series with a linear reactor across each phase in a wye configuration. The rest of the generator field excitation is delivered by the regulator circuits. See Figs. R5 and R6.

All auxiliary power, 120 vac, 3 phase, 60 Hz, required for energizing regulator circuits is derived from generator line through breaker 90-41 and three delta connected stepdown transformers (450/120 volts).

Voltage regulator unit receives its intelligence from three delta connected 450/112.5-volt potential transformers, Fig. R-10 and one 3000/5-ampere current transformer. Voltage adjusting rheostat, P1, Fig. R-13, which connects to voltage regulator unit terminals R1, R2, and R3 sets reference for regulating system. Voltage regulator unit compares difference between reference and actual generator output voltage, and delivers the error signal to the first stage of amplification.

Output of voltage regulating circuit is applied to preamplifier circuit; output of preamplifier circuit appears at regulator unit terminals COM-O2. The bias supply unit contains circuitry that converts 120-vac, 3-phase, 60-Hz power (terminals X-Y-Z) to a dc bias voltage (terminals B1-COM-B2) used to bias circuits of regulator unit and firing circuit unit. Half of this dc voltage is also applied across potentiometers R19 and R20 and manual control rheostat, P2. During operation in manual mode, manual control rheostat setting determines magnitude of signal delivered to firing circuit input.

For operation in automatic mode, regulator output signal is connected to firing circuit input terminals COM-I2 through contacts 7-8 of regulator control switch 90-CS. Firing circuit converts this input signal, which is proportional to regulator error, into phase controlled pulses delivered through firing circuit terminals G1X-C1X, G1Y-C1Y and G1Z-C1Z, to gates of controlled thyristors contained in thyristor amplifier assembly, X5.

2.1.1 Thyristor Amplifier. Firing circuit output pulses are applied to thyristor amplifier assembly X5 at terminals G1-G2-G3 and returned on terminal (+). Output of amplifier assembly is ultimately delivered to the generator field through terminals (+) and (-). The current flowing through terminal (+) must go through rectifier assembly X4 before getting to the generator field. Diode assembly X4 isolates the power amplifier from higher voltage transients occuring on the field side of the circuit. Rectifier X4 also prevents the amplifier from being reversed biased off by voltages on the field side of the circuit. During this

Step 6. Check the direction of rotation of the exciter and make sure that the brush setting is correct for the direction of rotation.

Step 7. Turn the exciter field rheostat gradually in the direction to "RAISE" the voltage observing at the same time the a-c. generator voltmeter. Stop turning when the a-c. generator voltmeter reads rated a-c. generator volts and mark this position of the rheostat. This position should later be rechecked and marked for hot fields. The operator will find it useful to have the exciter field rheostat positions marked for loads ranging from the no-load marked position to loads up to full-load rated a-c. generator amperes. Then, prior to turning the regulator cutout switch from "AUTOMATIC" to "MANUAL" position, the correct exciter rheostat position can be determined and set for the existing a-c. generator load.

Step 8. To give control of the a-c. voltage to the regulator turn the regulator control switch to the "AUTOMATIC" position. Then turn the voltage-adjusting rheostat until the a-c. generator voltage reaches the rated value. After this condition has been obtained, the regulator moving arm should settle promptly after a load or voltage change. Should the arm swing back and forth continuously, check the circuit and polarity to the damping transformer terminals EXC. (+) and EXC. (-). Open-circuit or wrong polarity will cause violent swinging.

Step 9. When the generator voltage is approximately at rated value the generator breaker may be closed if the generator is operating alone. When the generator is to be connected to an already hot bus the circuit breaker may be closed only when the two voltages are in synchronism. The second machine may be connected to the line with the voltage either under manual or regulator control.

Step 10. As soon as two generators are operating in parallel, readjust the governor motor (speed-changer) control switch until each unit takes its share of the loads.

Compensator Adjustments

39. After the generator breaker has been closed with the generators operating in parallel, it becomes necessary to divide the reactive load between generators by use of the cross-current compensator as follows:

Step 1. Set compensator dial switches at zero compensation.

Step 2. By governor adjustment, pick-up approximately 1/2-load on the generator.

Step 3. Increase the lagging reactive kv-a. on the a-c. generator, by turning the voltage-adjusting rheostat in the direction to raise voltage.

Step 4. Increase compensation by moving dial switches on the compensator to the maximum setting. The regulator should act to lower the exciter voltage as the per cent compensation is increased. This also lowers the reactive (lagging) kv-a. on the generator, the power factor of the load on the generator improving at the same time. If the exciter voltage increases instead of decreases, the compensation effect needs to be reversed. This is done by interchanging the current-tranformer connections at the rapid removal of heat from the unit. Free movement of air around the unit should be permitted for proper dissipation of the heat developed in the resistance plates.

Control Connections

33. Each piece of apparatus has clearly marked terminal blocks or studs for connections. Leads should be connected as shown in the schematic and wiring diagram. Due regard should be given to the polarity of the damping transformer, otherwise the moving armature of the magnet will swing violently.

Adjusting And Testing

34. The regulator has been carefully adjusted and tested at the factory and no further readjustment should be required other than voltage adjustment by means of the voltage-adjusting rheostat.

35. The following precautions are desirable before actually operating the unit. Check for the free operation of the moving armature. The clearances are approximately .013 ± .002 of an inch on each side of the moving armature. This armature must be exactly centered for all its travel in the air gap of the magnet. Sufficient clearance in the hinge-spring holes permits centering the armature. If the armature should be out of center, thus causing a binding or rubbing against the bumpers, it is necessary only to loosen the hinge-spring screws, center the armature with a feeler gage to insure proper clearance and then tighten the hinge-spring screw thus locking the armature in position. Check to see that there are no bent or kinked hinge springs, as this will cause the armature to shift out of position. The leaf springs should under no condition be loose or bent.

36. The limit of travel for the moving arm should be just sufficient to permit all silver buttons to open and close. This travel can be adjusted by loosening the stop screws at the bottom of the moving arm, adjusting to permit all buttons to open and close and then retightening the locknuts.

Lubrication

37. Positively no form of oil or lubricating substances are required on this regulator. There are no bearings as all movement is accomplished through springs.

OPERATION AND MAINTENANCE OF "SRAN-4" VOLTAGE REGULATOR

Starting Up An A-C. Generator

38. The following steps should be taken when voltage is placed on a regulator for the first time.

Step 1. The generator line circuit breaker should be open.

Step 2. Turn the regulator control switch to the "MANUAL" position.

Step 3. Turn the exciter field rheostat to the "ALL-IN" position. (Turn in the direction to "LOWER" voltage.)

Step 4. Turn the voltage-adjusting rheostat to a position midway between "LOWER" and "RAISE" ends of its travel.

Step 5. See that no load is connected to the a-c. generator and then bring the a-c. generator and exciter up to normal speed.

by the governor of its prime mover. Thus the division of the kw. load is practically independent of the excitation. However, changes in the field excitation of paralleled a-c. generators do affect the reactive kv-a. or wattless component of the output. Since the voltage regulator acts directly on the field excitation, it will be seen that although the division of kw. load between generators is unaffected by the voltage regulator, the division of wattless current is directly affected by the operation of the regulator.

48. Thus, when a-c. generators are operated in parallel, each under control of an individual regulator, wattless current will not be shared between the a-c. generators unless some provision is made to cause each generator to shirk wattless current. To secure stability in parallel operation it is, therefore, necessary to give the regulated voltage of each generator a droop with increase in the wattless component of the generator current. This is obtained by giving the regulator a drooping characteristic from a cross-current compensator energized from a current transformer.

49. One compensator and one current transformer are used for each a-c. generator and its regulator as shown on the schematic diagram. The compensator is designed to supply compensating voltages in two legs of the three-phase regulator potential circuit. This insures applying a balanced three-phase voltage to the regulator element.

50. Two dial switches are provided on each compensator. One of these switches gives a coarse adjustment and the other a fine adjustment of the compensation. A total of 24 steps are available on the two switches, thus the 12% compensator gives a 1/2% change in compensation per step. The 12% compensation is on basis of 4 amperes from the current transformer. Should the current-transformer ratio give some other value of secondary current the compensation settings will be affected proportionally. 5% Compensation is ample for the usual application.

Shutting Down

51. To remove the regulator from control make certain that the exciter field rheostat is in the marked position, corresponding to the load on the a-c. generator. It is desirable to have a number of marked positions corresponding to various loads. Turn the regulator control switch to the "MANUAL" position. The a-c. generator voltage is now under control of the exciter field rheostat.

52. To shut-down the generator completely, the preferred method is as follows:

53. Unload the a-c. generator by governor adjustment and by turning the voltage-adjusting rheostat in a direction to reduce voltage. As the load approaches zero, the generator breaker may be opened.

Maintenance

54. Dust should be blown out from the regulating resistance at regular intervals. The front cover should also be removed from the regulator and the dust carefully blown out. Any excessive amount of dirt in the air gap of the magnetic circuit should be removed by means of a thin piece of steel which has been magnetized.

compensator terminals C and CO.

CAUTION: Avoid opening the secondary of an energized current transformer.

Step 5. After the proper connections of all current transformers have been checked independently, the correct value of compensation will be determined by operating conditions. For the usual application, 5% compensation is ample. A smaller amount may be used, provided satisfactory division of reactive kv-a. between machines is secured. Once the proper connections and setting of the compensator have been made, no further readjustment is required.

Step 6. Should it be necessary to operate generators at different power factors, this adjustment is accomplished by means of the voltage adjusting rheostat.

Example Of Operation

(A) NON-PARALLEL

40: An example of the regulator corrective action can best be explained by reference to the schematic diagram.

41. Assuming the generator breaker to be closed and the generators operating with the control switch in the "Automatic" position, the corrective action is as follows:

42. Should additional load be placed on the machine whose voltage is being regulated, the voltage will drop, and an increase in exciter field current is required to bring the voltage back to normal.

43. This decrease in voltage is transmitted through the potential transformers and through the Rectox rectifier thus decreasing the magnetizing effect of the regulator coil and reducing the flux in the air gap of its magnetic circuit.

44. This in turn decreases the magnetizing pull on the iron armature that is attached to the moving arm, and allows the coil spring to move the arm in a direction to begin closing in sequence more of the silver buttons. This action shorts out in small steps additional portions of the regulating resistance which being connected in the exciter field circuit, causes the exciter field current to be increased and the a-c. voltage raised back to its normal value. When the voltage is restored to its normal value the moving arm of the regulator is again in a balanced state. The moving arm, however, has changed its position to correspond to the change in load on the machine.

45. In case some load is removed and the voltage rises, the action of the regulator is just the reverse of the previous operation and again will restore the voltage to its desired value.

46. From the above description, it becomes apparent that the Silverstat regulator can increase the excitation to the ceiling voltage of the exciter. Also the excitation can be quickly reduced to the lowest value required. As the total travel of the moving arm is only a fraction of an inch, the regulating resistance can be varied from maximum to practically zero depending on the requirements of operating conditions.

(B) PARALLEL

47. The division of the kw. load among paralleled a-c. generators is dependent upon the power supply to each generator and is controlled

PART III

(Section 2) TYPE "BN-2" VOLTAGE REGULATOR EQUIPMENT

GENERAL INFORMATION

Purpose

1. Careful reading of these instructions will provide information for proper care and handling of the generator voltage regulating equipment and avoid damage to the equipment which may impair its performance when placed in operation.

DESCRIPTION OF "BN-2" GENERATOR VOLTAGE REGULATING EQUIPMENT

2. On this installation there are a-c. generators, rated 1250-kw., 450 volts, 3 phase, 60 cycles using the "BN-2" type voltage regulator.

3. The purpose of the automatic voltage regulator is to maintain the terminal voltage of the a-c. generators at, or very close to, 450 volts regardless of load variations.

4. Reference should be made to the schematic diagram and the wiring diagram supplied with the generator voltage regulator or switchboard equipment. In each installation one regulator controls one generator. For the first trials the generator line circuit breaker should be opened, the main exciter field circuit closed and the exciter voltage at normal rated value.

5. The type "BN-2" generator rheostat voltage regulator controls the voltage of the a-c. generator by varying the resistance in the generator field circuit by means of a motor-operated rheostat. When the a-c. voltage is normal all parts of the regulator are stationary. For small deviations from normal voltage the regulator operates to change the position of the generator field rheostat thus effecting the required change in field current to bring the generator voltage back to normal. For large deviations from normal voltage, the regulator operates by means of high-speed contactors to insert or short-circuit suitable blocks of resistance in the generator field circuit, thus effecting a relatively large change in field current, at the same time turning the rheostat to a new position.

6. The important parts of the main control element are a torque motor which carries a spring-mounted moving arm, and two anti-hunt devices. The torque motor is made up of a stationary coil mounted on an iron magnetic circuit in the shape of a square "C". The moving arm, which is non-magnetic carries a small iron armature supported on the arm so that it can move in the fixed air gap of the magnetic circuit. The magnetic pull on the iron armature is balanced by a coiled spring.

7. The coil receives its energy from a 3-phase full-wave Rectox rectifier, the a-c. side of which is fed by potential transformers connected to the a-c. generator voltage. The regulator therefore responds to a d-c. voltage which is proportional to the average of the 3-phase a-c. voltage. The regulator adjusts the generator field rheostat to whatever position is required in order to maintain normal voltage, by means of the rheostat motor control relays and the high-speed field-forcing contactor.

8. The voltage-adjusting rheostat is used to raise or lower the value of the regulated voltage. This is done by changing the value of the resistance in the d-c. coil circuit of the regulator.

WHAT TO DO IN CASE OF TROUBLE

a - Regulator Not Working. Look for:

- a-1 - Open circuit.
- a-2 - Short-circuit across terminals "RR1" and "RR2" of regulator.
- a-3 - Obstruction in air gap of regulator magnetic circuit.
- a-11 - No a-c. voltage on rectifier terminals.
- a-12 - Damping transformer secondary open between transformer and regulator ("DT2" and "N" wires).
- a-13 - Exciter connections to damping transformer open.
- a-14 - Circuit open between exciter field and regulating resistance.

b - A-C. Voltage erratic or Swings Violently. Look for:

- b-1 - Loose or poor connection.
- b-2 - Exciter circuit to damping transformer open.
- b-3 - Wrong polarity on damping transformer primary "EXC-" and "EXC+"

c - A-C. Voltage Droops Badly when Generator is Loaded. Look for:

- c-1 - Exciter speed below normal.

d - Sparking at Silver Buttons. Look for:

- d-1 - Excessive dust or dirt between buttons.
- d-2 - Open-circuit or poor connection between resistance and buttons.
- d-3 - Open-circuit in regulating resistance.

e - NOTE: When the wiring to the regulator and damping transformer is correct and the regulator is properly adjusted the moving arm settles promptly after a load or voltage change. Should the arm swing back and forth continuously, check the circuit and polarity to the damping transformer terminals "EXC+" and "EXC-." Open circuit, loose connection or wrong polarity will cause swinging. If swinging persists without dying out when wiring and polarity are correct, the tension on the main coiled spring in the regulator should be decreased slightly by readjustment of the slotted-end screw by one or two turns. Leave spring hook free in groove of pin in moving arm, and lock nut on adjusting screw tight.

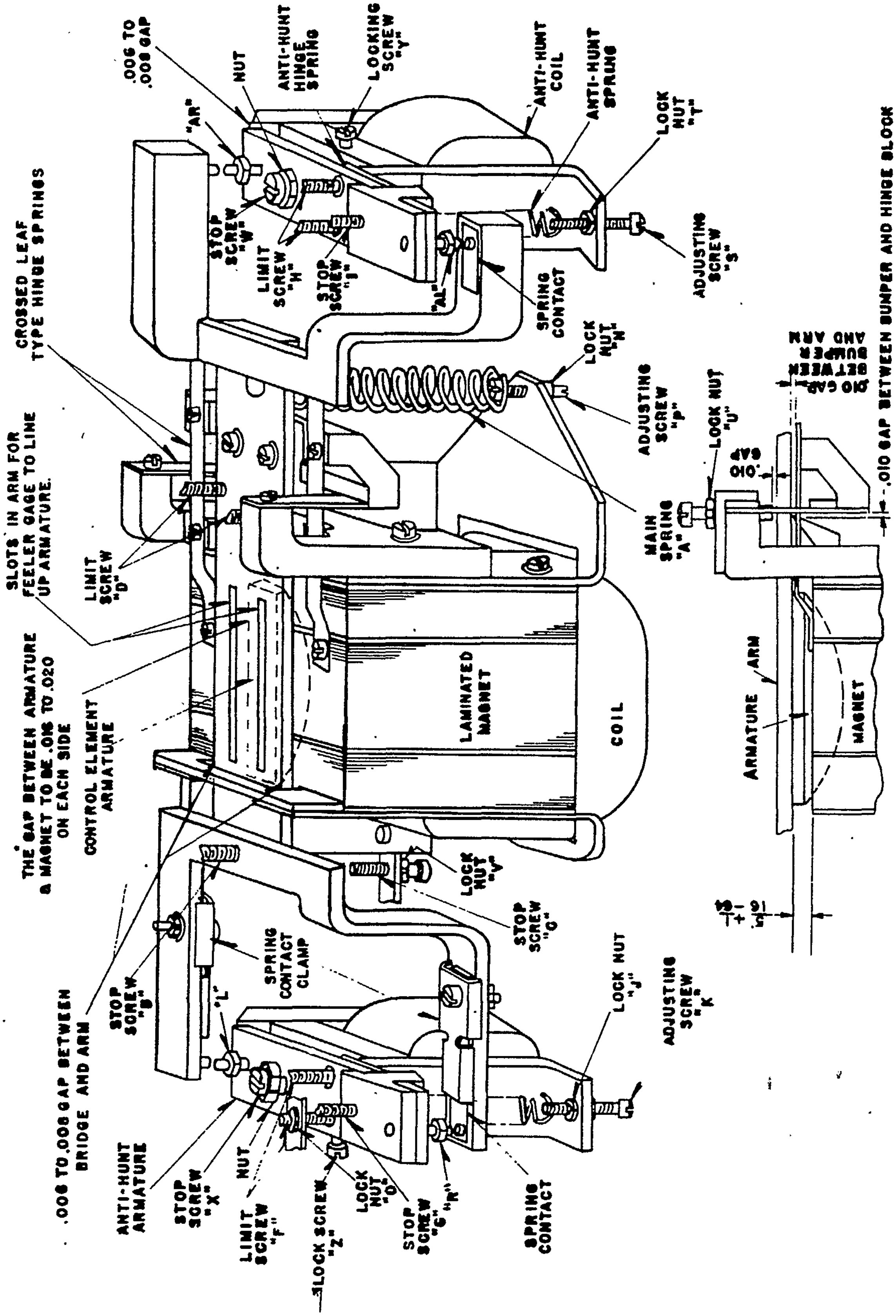


Fig. R-3 -- Westinghouse Type "BN-2" Voltage Regulator -- Pictorial View of Control Element Showing Adjustment Details
(Drawing 7-D-6187-3)

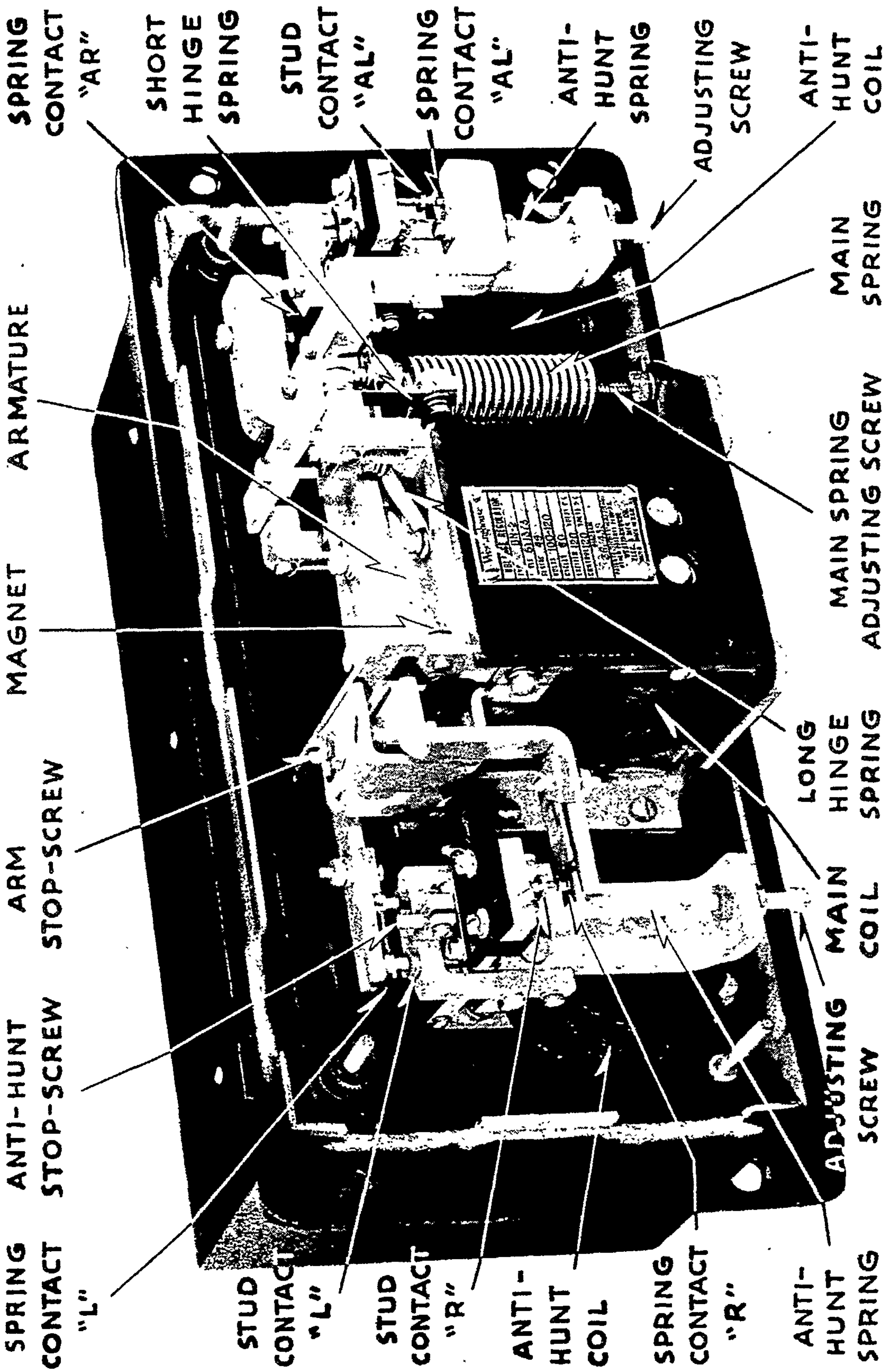


Fig. R-2 -- Westinghouse Type "BN-2" Voltage Regulator Control Element
(With Front Cover Removed)
(Photo 296281)

Motor-Operated Generator Field Rheostat and Contactor Panel

17. This unit is sometimes built into the switchboard, or may be located apart from the switchboard. The motor-operated rheostat provides the means for changing resistance in the a-c. generator field circuit either by manual control, or under the control of the voltage regulator element. The contactor panel includes two small contactors, one "RAISE" and the other "LOWER" for energizing the rheostat motor in either the forward or the reverse direction, under the control of the voltage regulator. Heavy-duty, high-speed, field-forcing contactors are also located on this panel, one for field-forcing-up and the other for field-forcing-down, for the purpose of restoring the voltage more quickly to normal in case of relatively large load changes.

18. The resistor tubes mounted on the contactor panel are identified by the following ratings and Westinghouse Style Numbers.

R-8	6500 ohms	S# 1250 276
R-9	168 ohms	S# 1250 277
R-10	6500 ohms	S# 1250 276
R-11	24000 ohms	S# 1250 278
R-12	24000 ohms	S# 1250 278

Potential Transformer

19. Two potential transformers are used to step down from a-c. generator voltage to the usual value of 112 volts which is applied to the regulating equipment. The voltage transformers are located back of the switchboard panel.

20. The potential transformers are Westinghouse Type "VN" and are connected as follows:

<u>Primary</u> - Two transformers connected open-delta receive 3-phase, 3-wire, 60-cycle, rated generator voltage.

<u>Secondary</u> - Two transformers connected open-delta give 3-phase, 3-wire, 60-cycle, 112.5 volts.

Current Transformer

21. One current transformer is supplied with each a-c. generator that operates in parallel with other generators. It is connected in line "B" of the generator and its energy is supplied to the cross-current compensator. The ratio of this transformer depends upon the rating of the generator. For this application one Type "UN" (Modified) Current Transformer, ratio 3000/5 amperes, is used.

Cross-Current Compensator

22. When a multiplicity of regulator-controlled a-c. generators operate in parallel on the same bus, it is necessary to droop the regulated voltage with respect to wattless generator current. For this purpose an inductive compensator is used, and this is energized from a current transformer. The manner in which this compensator is connected and operates is explained under "Cross-Current Compensation".

Regulator Control Switch (Supplied By Switchboard Manufacturer)

23. The regulator control switch is of the rotary type. In the "MANUAL" position the generator voltage is controlled by the operator by use of the generator field rheostat. In the "AUTOMATIC" position the generator voltage is controlled by the voltage regulator and its associated equipment.

Voltage Regulator Control Element (See Fig. R-2)

9. This element is located on the switchboard. The moving arm carries two sets of contacts "Normal-Response" (R & L) and "Quick-Response" (AR & AL). The former controls the motor-operated rheostat and adjusts the generator voltage automatically when necessary on account of relatively small changes in load on the a-c. generator. The "quick-response" contacts control the quick-response field-forcing contactors to restore the a-c. generator voltage to normal in case of relatively large changes in load on the a-c. generator. The regulator element includes anti-hunting devices which change the spacing of the regulator contacts temporarily as required in order to prevent hunting or over-shooting of the generator voltage.

10. The regulator main control coil is rated 65 ohms, 0.2 ampere and identified as Westinghouse Style No. 1087427. The coil is wound with 3000 turns of No. 25 enameled wire.

11. The anti-hunt coils are rated 7000 ohms, 0.25 ampere and identified as Westinghouse Style No. 1247173. The coil is wound with 30,000 turns of No. 38 enameled copper wire.

Rectox Rectifier

12. The 3-phase a-c. voltage is rectified by the 3-phase, full-wave Rectox rectifier in order to provide d-c. current for the main coil of the voltage regulator control element. The rectifier unit is located back of the switchboard panel. When a-c. generators operate in parallel a compensator is used for the purpose of making the generators share proportionally the reactive load. A current transformer connected in one phase of the a-c. generator between the generator terminals and the bus provides energy to the compensator. The output potential terminals of the compensator are connected in the a-c. potential leads between the potential transformer and the rectifier terminals.

Voltage-Adjusting Rheostat

13. This is mounted on the switchboard. Turning the handle of this rheostat raises or lowers the value at which the regulator holds the generator voltage.

14. The rheostat is Ward-Leonard Type "RC" having 100 ohms, 43 steps and identified as Westinghouse Style No. 1250157.

15. An adjustable fixed resistor having 750 ohms is mounted on the rear of the voltage-adjusting rheostat and identified as Westinghouse Style No. 1115103. This resistor is shown on the schematic diagram as R-1 and is connected in series with the voltage-adjusting rheostat R-2.

Indicating Lamps

16. Two approved Navy type "VG-7" indicating lamps are used to enable the operator to adjust properly the regulator control element when it is transferred in and out of service. These lamps indicate when the excitation is correct to make such a transfer and safeguard against transfers during periods of excitation change. When the a-c. voltage is normal, both lights burn brightly. When the regulator is changing the position of the motor-operated field rheostat, either the "RAISE" or the "LOWER" lamp is short-circuited, which not only indicates that a change is taking place but also indicates the direction of the change.

diagram supplied with the equipment. Should it be necessary to check polarity of the Rectox rectifier, this may be done by using low-voltage d-c. circuits (6 to 12 volts) with lamps (6 to 12 volts) in series, testing a stack of discs, section by section. With current flow in the normal direction, the lamp will glow. With the same d-c. voltage circuit connected to the Rectox in the reverse direction, the lamp will not glow.

C. CONTROL ELEMENT, INTERNAL ADJUSTMENT -- SEE DWGS. 7-D-6187 (FIG. R-3) AND 6-D-9196 (FIG. R-4)

33. After the regulator is mounted on the switchboard panel, and ready for service, the cover should be removed, and the element inspected internally to see that there is no dust or dirt present, and that parts appear to be intact and in place. The left-hand end of the moving arm should be free to move through about 1/8 inch of travel without interference or friction. Since the moving arm is supported by crossed leaf-type springs, there are no pivots or bearings to wear or require adjustment.

34. The armature which is fastened to the moving arm and which moves in the air gap of the magnetic circuit should be centered in this air gap. Close inspection should be made to see that there is no foreign matter in the air gap.

35. Should adjustment of the element become necessary, the following procedure is given:

36. Voltmeter Method For Contact Adjustment

Step 1. A portable a-c. voltmeter should be used, connected to the a-c. input terminals on the Rectox rectifier. This is recommended in place of using the switchboard-mounted voltmeters since all the regulators on the ship should be checked and calibrated against a common standard instrument.

Step 2. Place the regulator transfer switch in the "TEST" position. Allow the element to warm up for about 10 minutes.

Step 3. Note that the regulator "normal-response" contacts (left-hand end of regulator) can operate the "NR" and "NL" contactors when the transfer switch is on either the "TEST" or "AUTOMATIC" positions. The rheostat motor however is energized only when the transfer switch is in the "AUTOMATIC" position. The "RAISE" contacts "R" are at the front, and the "LOWER" contacts "L", at the rear.

Step 4. The quick-response "AR" and "AL" contacts are on the right-hand side ("AL" at the front and "AR" at the back). These contacts energize the quick-raise and the quick-lowering contactors only when the transfer switch is in the "AUTOMATIC" position.

Step 5. To check the setting of the regulator contacts proceed as follows:-

(a) Adjust the voltage with the manual rheostat handwheel to 455 volts. Turn the voltage-adjusting rheostat gradually until the "LOWER" light just starts to blink. Lower the a-c. voltage with the handwheel until the "RAISE" light just starts to blink. This should be about 445 volts. The quick-response contacts "AR-AL" should "make" about the same time or a little after the indicating light for the corresponding normal-response contacts "R or L" ceases to blink and goes completely out.

Rheostat Motor Control Switch (Supplied By Switchboard Manufacturer)

24. The rheostat motor control switch is of the rotary type. In the "RAISE" position the rheostat is operated through the electric motors to raise the generator voltage. In the "LOWER" position the rheostat is operated to lower the generator voltage.

Regulator Transfer Switch (Supplied By Switchboard Manufacturer)

25. The regulator transfer switch is of the rotary type. In the "NORMAL" position the normal control element and its associated equipment control the generator and in the "STANDBY" position the standby control element and its associated equipment control the generator.

INSTALLATION OF "BN-2" VOLTAGE REGULATOR

Storage

26. The generator voltage regulating equipment should be stored where it will not be subject to excessive moisture or damage to containers which will permit entrance of dust and dirt. The apparatus is designed to operate under relatively clean atmospheric conditions and if allowed to accumulate too much foreign matter, failure of equipment may result or performance be impaired when placed in service.

Unpacking

27. Small packages should be opened only when the apparatus can be promptly placed in its final position on switchboard panel or other location.

Installation

28. When equipment such as the motor-operated rheostat or contactor panel is placed in position prior to the installation of other large apparatus nearby, the electrical equipment should be covered with wrapping paper or canvas and protected by box or crate parts, or sections of plywood paneling.

Temperature And Ventilation

29. Resistor elements such as rheostats, should have sufficient opening around the apparatus so as to provide for a normal flow of air to secure proper ventilation.

Adjusting And Testing

30. More detailed adjustments may be necessary and can be accomplished according to the following:

A. VOLTAGE-ADJUSTING RHEOSTAT

31. This rheostat provides for adjustment of the regulating voltage through a range of 18 volts on the potential transformer secondary terminals. Should it be desired to raise or lower this range, it may be done by readjustment of the slider on the resistor tube mounted on the back of the voltage-adjusting rheostat. Initial trials should be made with the factory setting.

B. POTENTIAL TRANSFORMER AND RECTIFIER CIRCUITS

32. Two potential transformers of standard 100-volt-ampere capacity are used, connections being made to the regulating element as shown on the

Step 7. Decrease coil current to .192 ampere and adjust the "AR" or rear (quick-response) contact screw on right-hand anti-hunt device so that contact just "makes).

Adjustments (Steps 6 and 7) give the regulator element a sensitivity of ± 4% for the quick-response contacts. Satisfactory performance should be obtained when this adjustment is of the order of 3% to 5%.

D. ANTI-HUNTING DEVICE

38. Two duplicate anti-hunting devices are used, the normal-response contacts "R" and "L" being carried by the device on the left-hand side of the element (front view) and the quick-response contacts "AR" and "AL" on the right-hand device. The purpose of the anti-hunt device is to separate the regulator contacts shortly after they have closed due to a small deviation from normal regulated voltage, and to provide a predetermined length of time for the motor-operated rheostat to make a correction in the excitation, prior to the contacts of the anti-hunt device returning to their normal position. When the coil of the anti-hunt device is energized, the moving armature of the device acts to pull its contact away from engagement with the corresponding contact on the regulator moving arm. The action of the anti-hunt armature in separating the contacts is fast but the return of the armature to its normal position is relatively slow, depending upon the adjustment of the anti-hunt device coiled spring. The time of return of the contacts to their normal position is adjustable from approximately .25 second to 4.0 seconds.

39. The anti-hunt device can be set to separate the regulator element contacts either a large or a small amount. Normally the maximum opening (normal-response or quick-response contacts) should not exceed about 1/8 inch. Decreasing this amount will cause the motor-operated rheostat to operate more frequently than is necessary. Increasing this amount will cause the motor-operated rheostat to operate less frequently, and will provide somewhat longer time between successive correction (notching action) of the rheostat.

40. By slowly turning the voltage-adjusting rheostat the exact point where the "R" contacts or the "L" contacts close may be determined by observing the corresponding indicating lamp. By slowly turning the voltage-adjusting rheostat a little further, in the same direction, the limit of the contact-spreading action of the anti-hunt device may be determined. For the normal-response contacts, this limit should be approximately 3%. For the quick-response contacts this limit should be about 8%. The spread of the contacts (with the anti-hunt coil energized) should in general not be disturbed from the factory setting.

41. The anti-hunt device is set to take approximately 3 seconds to return the contacts from the fully-spread position to the normal position, provided the factory adjustment of the coiled spring has not been disturbed. See that there is no dirt or obstruction in the air gap at the rear end of the anti-hunt device armature.

E. RHEOSTAT MOTOR CONTROL RELAYS

42. Check the "NR" and "NL" rheostat motor control contactors to see that main and auxiliary contacts have normal spacing in the open position (about 1/4 inch) and make positive contact in the closed position. The auxiliary contacts on the "NR" and "NL" relays should close at about the same time as the main contacts. An adjustable-capacity condenser is connected in parallel with the coil on each of these contactors and this arrangement causes them to operate as definite-time-delay devices. The time setting may be changed to suit the individual installation by changing the amount of condenser

Step 6. The action of the quick-response contacts should be checked as follows:-

(a) With the transfer switch still on the "TEST" position, adjust the a-c. voltage by means of the handwheel until the indicating light just goes completely out. Turn the transfer switch to the "AUTOMATIC" position, and note if the quick-response contacts "make", by watching for the quick change in the a-c. voltage. The voltage change required to cause the contacts to close can be determined by repeating this test, changing the voltage by hand control, to the point where the quick-response contacts just close when the transfer switch is changed from the "TEST" to the "AUTOMATIC" position.

Step 7. The normal-response contacts should close at ± 1% of normal a-c. voltage. The quick-response contacts should close at ± 4.4% of normal a-c. voltage. In case the quick-response "AR" and "AL" contacts close on a voltage change of less than 4.4%, the hexagon head contact screw on the anti-hunt device should be backed off carefully, only a small part of one complete turn at a time, until the proper adjustment is secured. The clutch screw which holds the threads tight against the contact stud, should not be loosened unless the contact stud is found to turn too hard.

37. Ammeter Method For Contact Adjustment

Step 1. This method is recommended when maximum accuracy of adjustment is required.

Step 2. Set the main coil current at .2 ampere d-c. An accurate d-c. ammeter with full scale reading of .25 or .5 ampere should be used. It may be connected in series with the coil at C+ stud on rear of the element.

Step 3. Adjust the tension of the main coiled spring "A" connected to the moving arm so that the moving arm is horizontal. The travel of the moving arm is limited by the stop screws "B" and "C". With the arm in its mid-position the contacts on the arm should just clear the stationary contacts "L" and "R" mounted on the anti-hunt device. If the moving arm is horizontal, (arm parallel to top surface of magnet) and the contacts mounted on the anti-hunt device are not evenly spaced from the corresponding contacts on the moving arm, the contacts on the anti-hunt device should be adjusted until the spacing between each set of contacts is the same.

Step 4. Now increase the coil current to .202 ampere and adjust the "L" or rear stationary contact screw until the contact just "makes". This is located on the left-hand anti-hunt device.

Step 5. Decrease coil current to .198 ampere and adjust the "R" or front stationary contact screw also on left-hand anti-hunt device so that the contact just "makes".

Adjustments (Steps 4 and 5) give the regulator element a sensitivity of ± 1% for normal response.

Step 6. Increase coil current to .208 ampere and adjust the "AL" or front (quick-response) contact screw on right-hand anti-hunt device so that contact just "makes".

"R-3", each of which is provided with a slider for adjustment. Initial trials should be made using the factory settings of the resistors. If necessary, the setting may be changed to obtain improved performance.

50. The rheostat moving arm is controlled normally by the rheostat motor control switch on the switchboard, or by the voltage regulator. Manual control, by means of a handwheel, is also provided. When the handwheel is located at the rheostat it is necessary to mechanically engage the handwheel shaft and the rheostat shaft when turning the arm by means of the handwheel. A d-c. motor of the split-field series-wound type is used to operate the rheostat electrically, working through a suitable enclosed worm and gear unit. This type of motor permits readjustment of speed to meet operating conditions and requires minimum control apparatus. Tapped resistor "R-6" connected in parallel or series with the motor armature is provided for speed control. This resistor should be set to give a rheostat travel of 20 seconds from one extreme limit to the other limit. This is the factory setting.

51. The time of travel of the moving arm from limit to limit in either direction should be between 20 and 25 seconds, with 120 volts d-c. on the exciter. In general, the rheostat speed should be slow rather than fast. The speed of the rheostat motor may be adjusted by changing the position of the slider on resistor tube "R6", connected in series with the motor armature.

52. The rheostat arm movement should be free.

53. The limit switches which open to limit the travel of the arm should be checked for proper opening before the arm can jam mechanically as it approaches the end of its travel at normal speed, - that is, continuous speed, not notching action.

54. On these open-frame type rheostats, check for worn shoes, loose connections of shunt, and condition of shoe back-up springs. See that brush moves freely in its holder. Replace shoes if badly worn, and back-up spring if it has become annealed. Face plate segments, if burned or rough, should be smoothed so that the moving shoe will not catch or jam with resultant arcing and burning. Wiring in the frame between resistor taps and faceplate segments should be checked to see that it does not lay against resistor tap or terminal parts so as to damage insulation on the wire which might result in short-circuit.

55. Inspect the motor armature and brushes at regular intervals. Replace worn brushes.

56. After the rheostat is in place and ready for service, the small vent screw in the gear box should be removed providing a "breather" for the gear box. If this is not done changes in temperature may force some of the lubricant out through otherwise tight packing seals.

57. Check the lubrication of the motor bearings at regular intervals (about 6 months). Westinghouse Oil M#7251-2 or a light lubricating oil, should be used.

58. The gear box is filled with lubricant at the factory and requires no periodic refilling. Should accident or repair make refilling necessary use Westinghouse M#7280; or Navy Spec. No. 14-L-3b, Grade A.

CAUTION: Do not use excessive amounts of lubricant on the faceplate segment surfaces, or on the moving-arm shoe assembly.

capacity. It is desirable however for the auxiliary contacts which complete the circuit to the condenser to close a small amount ahead of the contacts which energize the anti-hunt device coil. Excessive spring-contact loading should be avoided since this would prevent proper "sealing" of the armature against the core when the coil is energized. In closing sequence, the middle (main) contact should close first, the right-hand contact next, and the left-hand contact last.

F. QUICK-RESPONSE CONTACTS "QR" AND "QL"

43. Check "QR" and "QL" high-speed field-forcing contactors in the same manner, noting that "QR" main contact is normally open and "QL" main contact normally closed. The main contact spacing is about 1/4 inch in the open position. See that nothing interferes with free motion of contacts. Check the auxiliary contacts.

44. The "QR" auxiliary contacts should "make" a little ahead of the closing of the main contacts. The "QL" auxiliary contacts should "make" a little ahead of the opening of the main contacts.

G. FIELD-FORCING-UP AND FIELD-REDUCING RESISTOR SETTING

45. Initial trials should be made using the factory settings of the resistors. If necessary, the settings may be changed to obtain improved performance. Too much resistance across either set of contacts is likely to cause overshooting of the voltage with consequently longer time for settling after a disturbance, and the possibility of hunting which the regulator may be unable to stop.

46. The setting of the field-reducing resistor depends upon the characteristics of the generator and the conditions under which it is to operate. With the voltage adjusted to its rated value through manual control of the motor-operated field rheostat the field-reducing resistor should, as a first approximation, be set to return voltage to normal after a large load change in the minimum time consistent with smooth operation. This resistor is introduced into the circuit by the opening of the normally-closed field-reducing contactor. For the purpose of testing the adequacy of the resistor adjustment, this contactor may be opened manually. Several values should be tried in order to determine best operation. More than the required amount of resistance is supplied in order to take care of unusual circumstances. Only that portion which is required for the particular installation, should be used.

H. MOTOR-OPERATED MAIN FIELD RHEOSTAT

47. A two-hundred-step, motor-operated rheostat provides means for changing resistance in the a-c. generator field circuit either by manual control, or under control of the type "BN-2" voltage regulator element. The voltage regulator controls the voltage of the a-c. generator by varying resistance in the generator field circuit by means of the motor-operated rheostat. When the a-c. voltage is normal the rheostat is stationary. For small deviations from normal voltage the regulator operates to change the position of the rheostat thus effecting the required change in field current to bring the generator voltage back to normal.

48. In this rheostat the resistance elements which make up the steps of the rheostat are supported in open construction, with wiring between taps on the resistors and the segments which are arranged circularly on the rheostat faceplate.

49. The rheostat assembly in addition to the rheostat resistance also includes the field-forcing-down resistor "R-5" and field-forcing-up resistor

I. REACTANCE COMPENSATOR

59. As noted under "Cross-Current Compensation" one cross-current compensator and one current transformer are furnished with each regulator for the purpose of making the generators share proportionally the reactive load. Care should be taken to see that the current transformer and compensator external connections agree with the wiring diagram.

60. The correct connections between the current transformer, compensator and voltage regulator can be determined as follows:

Step 1. Set compensator dial switches at zero compensation.

Step 2. By governor adjustment, pick-up approximately 1/2 load on the generator.

Step 3. Increase the lagging reactive kv-a. of generator by turning the control switch of the motor-operated rheostat in the direction to "RAISE" voltage.

Step 4. Turn the regulator control switch to the "TEST" position and balance regulator by means of voltage-adjusting rheostat until indicating lamps "RL" and "LL" burn brightly.

Step 5. Increase compensation by moving dial switches on the compensator until the "LL" lamp blinks. If the "RL" lamp blinks the compensation is reversed and should be corrected by reversing the current transformer connections at the compensator terminals "C" and "CO".

CAUTION: AVOID opening the secondary of an energized current transformer.

Step 6. After the proper connections of all current transformers have been checked independently, the correct value of compensation will have to be determined by operating conditions. 6% Compensation is ample for the usual application. A smaller amount may be used provided satisfactory division of reactive kv-a. between machines is secured. Once the proper connections and setting of the compensator value have been made, no further adjustment or attention is required.

Step 7. If it should be necessary to operate generators at different power factors, this adjustment should be made by means of the regulator voltage-adjusting rheostat.

OPERATION AND MAINTENANCE OF "BN-2" VOLTAGE REGULATOR

Description Of Voltage Regulator Action

A. NORMAL CORRECTIVE ACTION

61. Refer to the "Schematic Diagram" which is found in the rear of this part of instruction book. In the schematic diagram the regulator is shown energized and in control with the regulator control switch in the "AUTOMATIC" position. The regulator moving arm is in the mid-position, with the indicating lamps "RL" and "LL" burning.

62. Assuming that a small drop in voltage takes place and requires correction, the control element main contacts "R" close, causing the lamp "RL" to blink, and energizing the "NR" rheostat motor control relay.

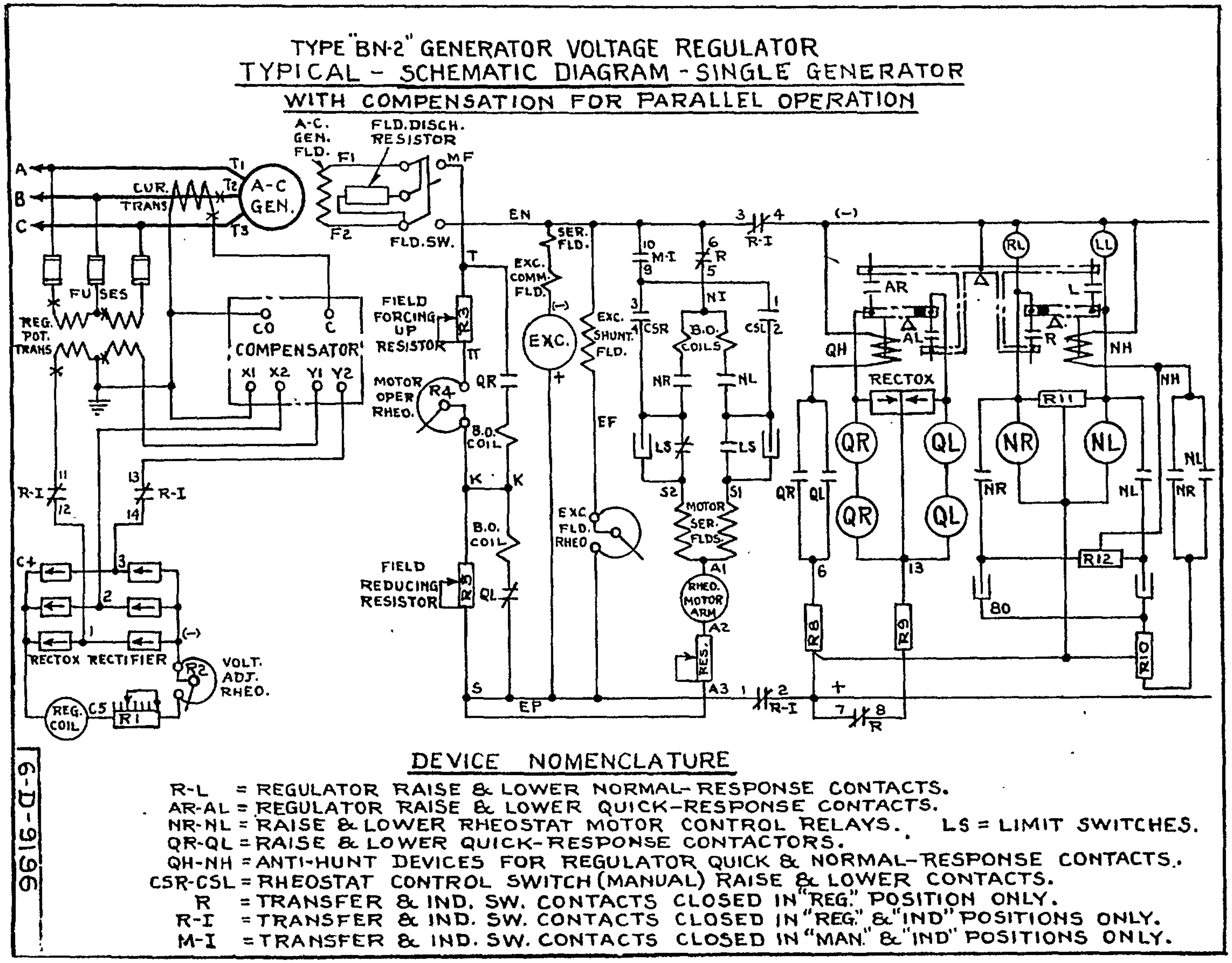


Fig. R-4 -- Westinghouse Type "BN-2" Voltage Regulator -- Typical Schematic Diagram
Single Generator with Compensation for Parallel Operation
(Drawing 6-D-9196-3)

Placing Voltage Regulator In Operation

A. FIRST TIME IN CONTROL

68. For the first trials the generator line circuit breaker should be open with generator speed and exciter voltage normal.

69. To check generator field rheostat operation the regulator control switch should be turned to the "MANUAL" position. In this position the rheostat is under "REMOTE MANUAL CONTROL" by means of the rheostat motor control switch. The regulator element and the regulator contact circuits are not energized. With the generator field circuit open, the rheostat motor control switch should be turned first to the "LOWER" and then to the "RAISE" position, and the operation of the rheostat observed to check proper direction of operation, free action of moving parts, and reliable operation of limit switches. After checking, the rheostat should be turned to the approximately "ALL-IN" position for the following test.

70. With the regulator control switch still in the "MANUAL" position, close the generator field switch and observe the effect of the field-forcing-up contactor "QR" by carefully closing it momentarily by hand. In a similar manner the effect of the field-reducing contactor "QL" may be observed to determine that connections have been properly made.

71. The regulator control switch should now be turned to the "TEST" position. In this position the regulator main coil is energized from its potential transformers, and exciter voltage is applied to the regulator circuits, which includes the normal-response "R-L" contacts, the "NR" and "NL" rheostat motor control relays, anti-hunting circuits, and regulator position indicating lamps. If either the "R" contacts or the "L" contacts close and the corresponding rheostat motor control relay closes, one of the indicating lamps will be out, and the other will burn brightly. The regulator contacts which are closed may also be determined by inspection, and the voltage-adjusting rheostat turned to the position where the lever arm is balanced between the contacts, at which time both indicating lamps will burn brightly.

72. With the regulator control switch still in the "TEST" position, the voltage-adjusting rheostat may be turned either way through a small angle to observe the correct operation of the "NR" and "NL" relays. At the same time observe contact-spreading action of the anti-hunt device and proper closing of the "NR" and "NL" auxiliary contacts.

73. Normal a-c. voltage may now be obtained by using the rheostat motor control switch to turn the a-c. generator field rheostat to the proper position. Then by means of the voltage-adjusting rheostat find the position where both the indicating lamps burn brightly, thus indicating that the regulator main control lever arm is floating between the contacts. The regulator control switch may now be turned to the "AUTOMATIC" position thus placing the regulator in control of the a-c. voltage.

74. By turning the voltage-adjusting rheostat through a small angle, the regulator will operate to raise or lower the voltage by means of the "R" or "L" contacts and the "NR" or "NL" rheostat motor control relays.

75. If the voltage-adjusting rheostat is turned quickly to a larger angle the "AR" or "AL" contacts will operate the "field-forcing" or the "field-reducing" contactors to bring the voltage to the new setting.

76. When the normally-open field-forcing contactor "QR" closes, the voltage will rise rapidly and the motor-operated generator field rheostat will move in a direction to reduce the resistance in the field circuit. In like manner, when the normally-closed field-reducing contactor "QL" opens, the

63. This relay completes the following operations.

Step 1. Energizes the rheostat motor which turns the generator field rheostat in the direction to cut out resistance, and increase the generator field current.

Step 2. Energizes the coil "NH" of the normal-response anti-hunting device. The spring-mounted armature of this device moves to increase the distance between the "R" contact thereby opening the circuit at this point.

Step 3. Energizes the condenser connected across the "NR" relay coil. The action of this condenser (and resistor circuit) maintains current in the "NR" coil for a sufficient time to permit the rheostat motor to move the rheostat arm approximately one step.

Step 4. The contact-spreading action of the anti-hunt device is only momentary, the contacts returning to their normal position in two or three seconds. Should further movement of the generator field rheostat be required the contacts "R" will again close and continue notching action as required.

64. In case the control element "L" contacts close to lower the voltage, similar action takes place.

B. HEAVY-LOAD CORRECTIVE ACTION

65. When a large drop in voltage occurs,-due, for example, to a large block of load being thrown on the system or due to a fault, the normal-response contacts "R" on the regulator close, followed by the closing of the quick-response contacts "AR". The "AR" contacts complete the circuit to the quick-response "field-forcing-up" contactor "QR", which short-circuits a block of resistance in the generator field circuit, thus applying full exciter voltage to the field circuit. This starts the generator voltage to return towards normal very rapidly.

66. When the field-forcing contactor "QR" closes, auxiliary contacts of this device close at the same time in the circuit of the anti-hunt device "QH". This operates to spread the "AR" contacts, as described for the "NH" device and the "R" contacts. Therefore, if the deviation of normal voltage is within the recalibration effect of the "QH" anti-hunt device, the field-forcing contactor will close and open rapidly while the rheostat arm approaches the required new position. If the deviation from normal voltage is greater than the recalibrated setting of the "QH" antihunt device, the field-forcing contact will close and remain closed until the voltage is brought within the setting of the anti-hunt device. However, when the a-c. voltage gets within the setting of the "AR" contacts, the normal response "R" contacts take control and by notching the rheostat, return the a-c. voltage to normal. Since the rheostat turns at maximum speed while the quick-response contacts are closed, it takes only a minimum of additional movement after the normal-response contacts take control, to return the voltage to normal.

67. In a similar manner, when a large block of load is removed from the system, thus causing a large increase in voltage, the quick-response contacts "AL" will close and energize the quick-response field-reducing contact "QL" which is normally closed. This contactor then opens its main contacts and inserts a block of resistance in the generator field circuit, causing the generator voltage to fall very rapidly. When the a-c. voltage gets within the setting of the quick-response "AL" contacts, the normal-response "L" contacts take control and settle the voltage by notching action of the rheostat.

supply compensating voltages in two legs of the three-phase regulator potential circuit, which insures applying a balanced three-phase voltage to the regulator element.

84. Two dial switches are provided on each compensator. One of these switches gives a coarse adjustment and the other a fine adjustment of the compensation. A total of 24 steps are available on the two switches, which in the case of the standard 12% compensator gives a 1/2% change in compensation per step. The 12% compensation is on basis of 4 amperes from the current transformer. Should the current transformer ratio give some other value of secondary current the compensation settings will be affected proportionally. 6% Compensation is ample for the usual application.

PART III

(Section 3) TEMPERATURE-INDICATING EQUIPMENT

GENERAL INFORMATION

Purpose

1. These instructions cover the application of permanent-magnet moving-coil switchboard instruments for the measurement of temperatures in electrical machinery operating in temperature ranges between 0°C. and 250°C. Reference should be made to Drawing No. 37-J-654, (Figure TI-1).

Description

2. The temperature indicator operates on the resistance-coil-detector principle, the detecting coil forming one branch of a Wheatstone Bridge, which is energized by rectifier a-c. control circuit. The detecting coils are embedded in the machinery windings and are wound with copper wire to an exact resistance of 10 ohms at 25°C. Six detecting coils are provided with each machine and are so located as to measure the temperature at "hot spot" locations. A selector switch allows the indicator to be connected to any coil desired.

<u>NOTE:</u> The Wheatstone Bridge is built into the case of the type "KX-24" Temperature Indicator.

3. When the detector coil is at a predetermined temperature the bridge is in balance and no potential exists on the instrument. This point is called the balance temperature and is selected depending upon the scale range of the instrument.

4. At any other temperature the resistance of the detector coil changes and therefore there will be an unbalance of the bridge. This results in a potential difference which deflects the pointer of the instrument. This potential difference is directly proportional to the resistance of the coil and thus the scale is calibrated in temperature of the coil.

5. The balance point is selected at the temperature at which the greatest accuracy is desired. At this temperature the indications will be independent of control circuit voltage. This point is marked by a red line on the indicator scale at 100°C.

6. At other temperatures the error due to incorrect voltage will be the difference between the actual temperature and the balance temperature, multiplied by deviation in control voltage. This error is small and can be neglected for ordinary variations in voltage, as the balance point is chosen near ordinary operating temperatures, and the error near the balance point is very small. For any reading and any incorrect control voltage the true reading, if desired, can be found as follows:--

B = Balance point temperature
T_1 = Observed temperature
E = Rated control voltage
E_1 = Actual control voltage
T = True Temperature

$$T = B - \frac{E\,(B - T_1)}{E_1}$$

For Example if:

Balance point temperature = $100^{\circ}C$
Observed temperature = 80°
Rated control voltage = 125 volts
Actual control voltage = 115 volts

$$T = 100 - \frac{125\ (100 - 80)}{115}$$

$$T = 100^{\circ} - 21.75^{\circ}$$

$T = 78.25^{\circ}$ an error of 1.75°

This error can usually be neglected for ordinary variations in control voltage.

INSTALLATION OF TEMPERATURE-INDICATING EQUIPMENT

Installation

7. The complete outfit includes the indicator proper, leads, terminal block (on machine), selector switch, test resistor, calibrating rheostat and trickle charger (Rectox rectifier). A selector switch is required for each machine or group of six search coils.

8. The leads to the search coils may be several hundred feet in length, but their resistance should be kept below .2 ohm for best results, and it is important that the resistance of lead "B2" from instrument to search coil be equal to resistance of any lead "B4" from instrument, through switch to search coil.

9. Best accuracy is obtained when three leads are brought out from each search coil, and connected as shown on Drawing 37-J-654, (Fig. TI-1).

Zero Adjustment

10. The pointer of the indicator should rest at the red mark or "balance point" on the scale when no voltage is applied to the circuit.

Calibration

11. Turn the selector switch to test coil position and apply control circuit. The indicator should show $0^{\circ}C$. If the indicator reads too high, it will be necessary to adjust the small rheostat assembled as part of the Rectox rectifier. Final adjustment can be made with the calibrating rheostat mounted on the panel. The latter can be used for correcting control voltage at any time before readings are taken.

12. The test resistor is desirable whenever control voltage is subject to variations or when recalibrating the instrument. It can be eliminated if control voltage is known to be always steady at the value for which the indicator is calibrated.

13. The test resistor has a constant resistance of 9.037 ohms which is equivalent to the resistance of a 10-ohm exploring coil at $0^{\circ}C$. Thus with the test resistor connected in place of the exploring coils, the instrument should read zero on the scale.

14. The panel-mounted rheostat is desirable when the line voltage fluctuates or when extreme accuracy with ease of adjustment is required. Otherwise, voltage variations can be corrected by means of the rheostat on the rectifier. The rectifier rheostat may not be as accessible as the panel-mounted rheostat.

Calibration Data

15. The following table gives the resistance of the search coils for which this instrument is calibrated, at various temperatures.

Temperature °C.	Resistance Ohms
0	9.037
25	10
50	10.962
100	12.887
150	14.812

16. The detector coil balances the internal bridge circuit at the temperature indicated by the red line on the scale of the instrument.

17. Reference drawings are as follows:-

37-J-654 (Fig. TI-1)	Temperature Indicating Equipment
37-J-653 (Fig. R-10)	Schematic Diagram for Type "BN-2" Voltage Regulator
18-A-5127 (Fig. R-6)	Schematic Diagram for Type "SRAN-4" Voltage Regulator

PART IIIA

TYPE WZN-1 VOLTAGE REGULATOR AND TYPE WTN STATIC EXCITER CVA-34

Section 1. GENERAL DATA

The voltage regulating system provides steady-state accuracy, and is insensitive to frequency changes within ±5 percent.

See Fig. R-1* for schematic diagram of the Regulating System, Fig. R-2 for component locations, Fig. R-3 for Connection Diagram and Fig. R-4 for Certification Data and Repair Parts List.

1.1 DESCRIPTIVE DATA

a. Type of Control: Semiconductor Amplifier.

b. Enclosures: Mounted inside Switchboard and Drip-Proof Protected Enclosure.

c. Ambient Temperature: 50° C Natural Convection.

d. Shock Class: High Impact—Class HI.

e. Circuited Controlled: AC Generator Field Circuit.

f. Operation: Parallel.

g. Compensation for Parallel Operation: Reactive Droop.

*NOTE

All Figure numbers referred to in Part IIIA refer to the figures included for CVA-34 only. These foldout figures bear the suffix letter "A".

voltage in phase with load current—current vector produced by reactor current lags by approximately 90 degrees the current vector produced by line current. The relatively high inductive impedance of the linear reactor produces this lag. Vector sum of these currents changes as magnitude of load current changes.

At zero power factor lagging—load current lags phase voltage by 90 degrees—current vector produced by line current is in phase with current vector produced by reactor current. Because a fixed generator terminal voltage requires an increase in excitation (field current) as power factor becomes more lagging, the circuit operates so that as the power factor becomes more lagging the vector sum of these currents increases. Zero power factor lagging condition represents greatest vector sum current that can be delivered to generator field.

At zero power factor leading—load current leads phase voltage by 90 degrees—current vector produced by line current is 180 degrees out of phase with current vector produced by reactor current. Because a fixed generator terminal voltage requires a decrease in excitation (field current) as power factor becomes more leading, the circuit operates so that as the power factor becomes more leading, the vector sum of these currents decreases. Zero power factor leading condition represents least vector sum current that can be delivered to generator field.

The potential feedback circuit operates so that if regulated voltage is increased, phase voltage at generator output terminals is also increased; thereby, increasing current vector produced by reactor current and generator field current. This increase in field current aids in supplying increased excitation required by higher generator terminal voltages. Similarly current feedback decreases as terminal voltage decreases. Potential feedback circuit also operates to compensate regulating system for changes in generator frequency. Because an increase in generator speed increases both generator frequency and terminal voltage, impedance of linear reactor also increases, thereby reducing current vector produced by reactor current and generator field current. This decrease in field current for an increase in frequency is proportional to decrease in excitation required to maintain regulated generator voltage. Similarly a decrease in frequency will result in a proportional increase in excitation and constant generator terminal voltage.

Under fault conditions at machine terminals—3-phase fault—there is no excitation energy from potential feedback circuit and, current feedback circuit is the only excitation energy source available. Vector summing transformer is designed so that secondary current that results under this condition is sufficient to maintain short circuit excitation but, saturation of vector summing transformer will limit generator field current to approximately four times rated current at short circuit conditions.

As described above, output of vector summing transformer approximates excitation requirements of generator. The purpose of voltage regulator is to act as a vernier which adds to vector summing transformer output.

2.1.5 Intelligence Input. The regulating system receives its voltage intelligence from three 450/112.5-volt potential transformers connected in delta. Value of regulated voltage is set by voltage adjuster unit. Voltage regulator unit compares reference signal derived from potential transformers and develops a push-pull type error signal which appears at the base of transistor Q1 of the amplifier circuit. Under steady-state system balanced conditions, error signal that appears at the base of Q1 is slightly negative. If bus voltage drops due to suddenly applied load, an error signal will be developed and amplified so that terminal O2 is negative with respect to COM. Similarly, if bus voltage rises, an error signal will be generated so that O2 is positive with respect to COM.

2.1.6 Bias Supply Unit. The bias circuit supplies a ±18-volt bias to terminals B1, COM, and B2; B1 is +18 (±10%) volts with condition, amplifier current flows through resistor R1 connected across the amplifier output. By adding two diodes X4 in series with thyristor amplifier X5 a greater voltage drop across X4-X5 thyristor amplifier/ rectifier circuit ensures that full commutating current will flow through commutating diodes X2. Surge suppressor, S1, is provided to protect solid-state devices of thyristor amplifier assembly from any inductive surges generated by auxiliary power source.

Nonlinear resistor assembly R2 is connected across generator field to protect solid-state devices of X1, X2, X4, and X5 from inductive surges that may originate in generator field.

2.1.2 Field Flashing Switch. The field flashing switch is a momentary switch which, when depressed during unit startup, connects an energy source to terminals PG1-PG2-PG3 of field flashing rectifier assembly X3. Field flashing energy is provided by the permanent magnet generator directly connected to the ac generator shaft.

2.1.3 Regulator Control Switch. Regulator control switch has four positions, AUTO, MAN, and two OFF positions. In AUTO, output of regulator is connected into firing circuit input, manual control rheostat is disconnected from firing circuit input, and output of thyristor amplifier assembly is directly controlled by regulator circuits. In MAN, a signal fixed by manual control rheostat setting is connected to firing circuit input, regulator output is disconnected from firing circuit input, and output of the thyristor amplifier assembly is directly controlled by manual control rheostat. In OFF position, all circuits are deenergized by tripping breaker 90-41. Contact 19-20 is available for use in trip circuit of line breaker device S2.

2.1.4 Self-Feedback Circuit. Total generator field excitation consists of a self-feedback, and a voltage regulator feedback. Since the greater part of excitation is fed back directly from terminals of generator, self-feedback circuit will be considered first. The circuit is subdivided into two parts: potential feedback, and current feedback.

2.1.4.1 Potential Feedback Circuit. The potential feedback circuit consists of three linear reactors L1, L2, L3 and the H1-H2 windings of three vector summing transformers T1, T2, T3. A linear reactor and an H1-H2 winding of a vector summing transformer are connected in series across each phase of generator. Voltage across H1-H2 winding of vector summing transformer is negligible compared to phase voltage; therefore, voltage across the linear reactor is approximately equal to phase voltage. Current through the linear reactor is equal to phase generator output voltage divided by impedance of reactor. This reactor current, which lags phase voltage by 90 degrees, flows through H1-H2 winding of vector summing transformer.

2.1.4.2 Current Feedback Circuit. Current feedback circuit consists of winding of vector summing transformers, T1, T2, T3, connected so that current through this winding is actual generator line current.

Three-phase currents produced by current feedback circuit, and three reactor currents produced by potential feedback circuit are transformed and added vectorially in X1-X2 windings of vector summing transformers. The X1-X2 transformer windings are connected in wye, and wye output is delivered into power rectifier assembly. Rectified output is applied to generator field.

A certain value of generator field current is required to maintain constant voltage for each value of load current and power factor. Current vector produced by reactor current in H1-H2 winding is constant regardless of load current or power factor, and is dependent only on phase voltage and frequency. Current vector produced by line current varies directly with load current, and phase angle of this vector with respect to phase voltage varies directly with power factor of load. At unity power factor—phase respect to COM, and B2 is -18 (±10%) volts with respect to COM. See Fig. R-7.

Firing circuit generates phase controlled pulses applied to gates of thyristors in thyristor amplifier assembly. As terminal I2 becomes more negative, gate pulses will be delivered earlier in the cycle, resulting in an increased output from thyristor amplifier.

2.1.7 Regulating Loop. Effect of regulating loop is to increase output from thyristor amplifier assembly when line voltage is low, and decrease output when line voltage is high. Time constant of firing circuit and thyristor amplifier assembly is in microseconds. Time constant of filter in voltage regulator circuit is in the order of 5-6 milliseconds. Because time constant of generator field is normally 1 to 1.5 seconds, regulator loop reduced to a one-delay system and damping is not required.

2.1.8 Manual Control. When system is operated in manual control, contact 7-8 is opened, isolating output of regulator from input of firing circuit, and opening regulating loop. Contacts 9-10, 11-12, and 13-14, which are closed in manual position, connect manual control rheostat to input of firing circuit.

Manual control signal is obtained from a resistive network consisting of a series combination of potentiometers R19 and R20 on firing circuit unit and manual control rheostat P2. An 18 (±10%) vdc source, generated at terminals B2-COM, is applied across resistive network. A negative feedback voltage signal, proportional to generator line voltage is applied to base of transistor Q2 of the firing circuit module. This voltage signal produces a stabilizing effect by phasing back the firing pulses when the generator terminal voltage rises; the firing pulses are phased forward when generator terminal voltage is reduced.

When it is desired to increase generator line voltage, manual control rheostat is moved so that voltage that appears across portion of rheostat P2 is increased. This increase in voltage at firing circuit input results in firing circuit output pulses that have less delay; thus, thyristor amplifier output increases. Increased excitation results in an increase in generator output voltage and an increase in voltage signal at base of Q2 of firing circuit module. This voltage signal causes phasing back of the firing circuit pulses. This is necessary, as increased generator line voltage will tend to produce in itself an increase in excitation through thyristor amplifier. In this way, degenerating effect of the stabilizing signal provides stable operation.

Field voltage is controlled by setting of manual control rheostat; that is, under manual control, field voltage is not regulated. This has several results, when generator is under manual control, as when load is added, setting of the manual control rheostat must be increased, or if load is removed, rheostat setting will have to be decreased. Rheostat serves the same function as field rheostat in a shunt field dc generator.

2.2 WZN VOLTAGE REGULATOR UNIT

2.2.1 General. The purpose of the voltage regulator unit is to produce an error signal in response to the instantaneous average of the terminal voltage of the ac generator. The error signal may be amplified or connected directly to the input of a firing circuit which fires controlled rectifiers which in turn, control the excitation of the ac generator.

2.2.1.1 Sensitivity. The normal sensitivity of the regulator is 0.2-volt dc change in the output for a 1-volt change in the input.

2.2.1.2 Burden. The voltage burden of the regulator unit on the generator terminals is approximately 40 va. The burden of the regulator unit on the droop current transformer will vary from 0 to 25 va depending on the percent droop set on the compensator.

The regulator panel is completely tested at the factory. No tests are required at the time of installation unless difficulties are encountered.

2.2.2 Description

2.2.2.1 Voltage Sensing Circuit. Three-phase, 60-Hz voltage is applied to a 3-phase, full-wave bridge rectifier through the

CONNECTION NOTES (EXTERNAL)

CONNECT DROOP C.T. WITH PRIMARY POLARITY MARK TOWARD GENERATOR
CONNECT DROOP C.T. WITH SECONDARY POLARITY MARK TO "C" ON REGULATOR
FOR C.T. IN Φ1 CONNECT Φ1 TO TERM. I2, Φ 2 TO TERM. I3, Φ 3 TO TERM. I1
FOR C.T. IN Φ2 CONNECT Φ1 TO TERM. I1, Φ 2 TO TERM. I2, Φ 3 TO TERM. I3
FOR C.T. IN Φ3 CONNECT Φ1 TO TERM. I3, Φ 2 TO TERM. I1, Φ 3 TO TERM. I2

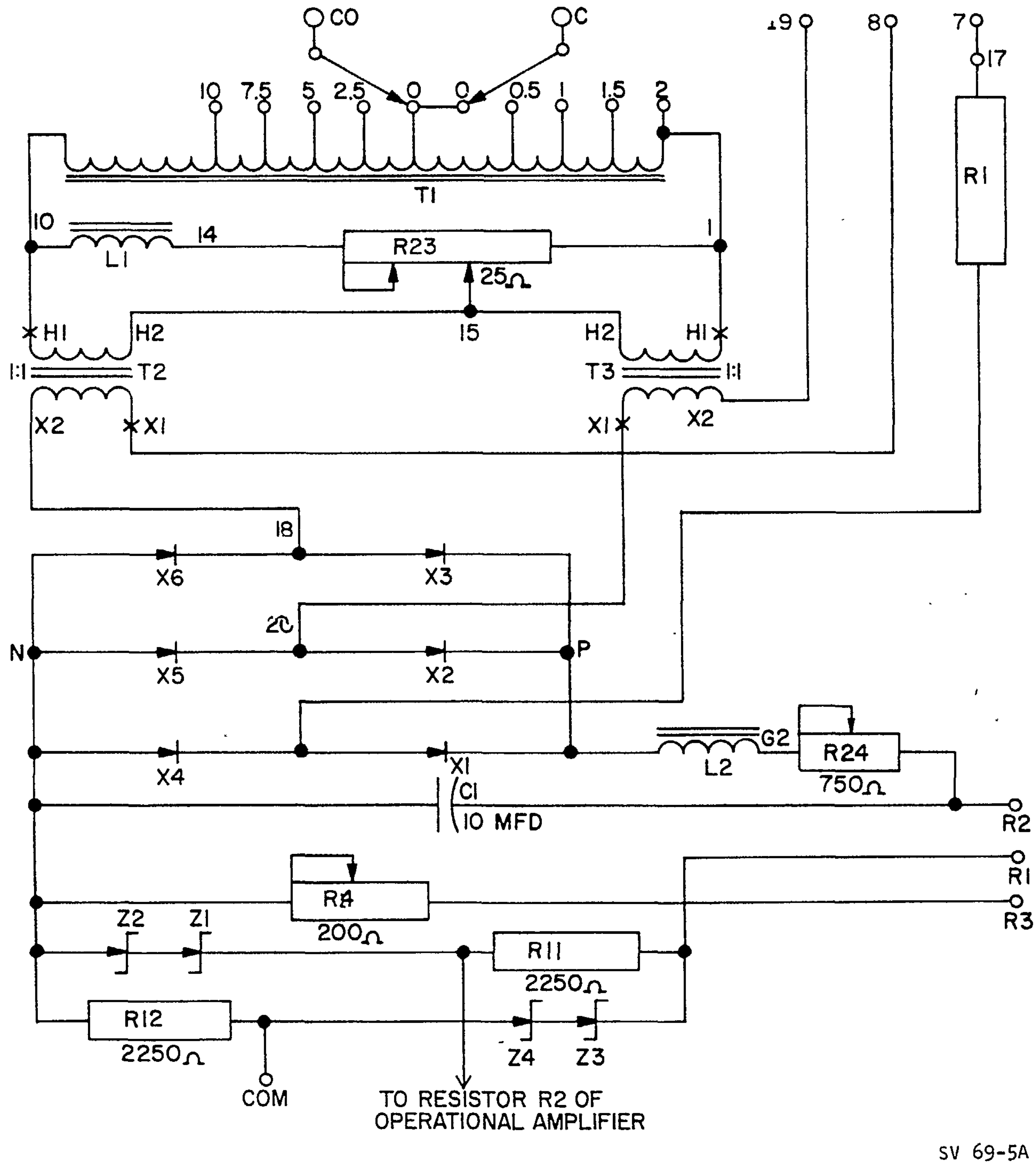
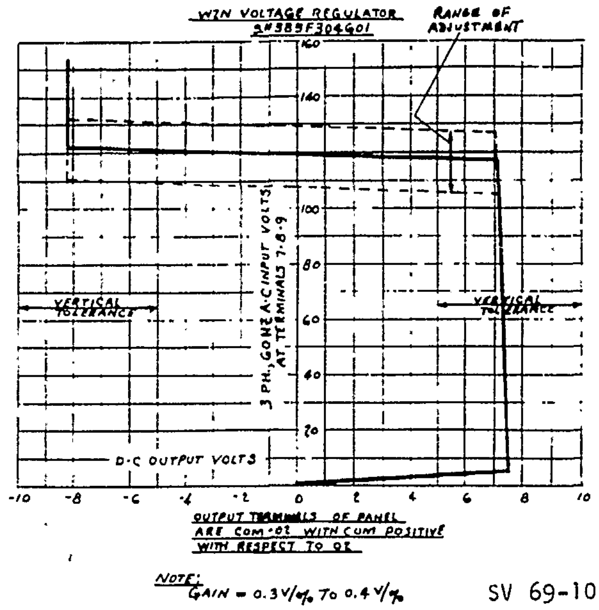


Figure 1. Voltage Sensing Circuit



SV 69-10

Figure 3. Transfer Curve

conducts 16 milliamperes. The voltage across the bridge for the balanced condition is approximately 36 volts and the output current and voltage is zero. Resistors R24 and R25 inductor L2 and the voltage adjusting rheostat act as a potentiometer network at the input of the Zener sensing bridge. Figure 3 shows the transfer curve for the regulator.

2.2.3.2 Preamplifier. The purpose of the dc preamplifier is to amplify the signal received from the 60-Hz voltage regulator circuit. The output voltage is compatible with the input requirements of the firing unit. This circuit is designed to yield an output swing of ±8 volts into the firing circuit. See Figure 3.

The dc amplifier consists of a high-gain operational amplifier with external feedback to adjust the overall gain. The operational amplifier has its input at the base of Q1 and its output at the collector of Q3; a positive signal at the base of Q1 will drive the output negative. Transistors Q1 and Q2 form a differential amplifier. They are mounted on common heat sink to ensure that their cases will be at the same temperature and thus minimize any drift in output caused by changes in ambient temperature. Transistors Q3 and Q4 increase the gain; the gain from Q1 to Q4 is about -1200. Positive bias is applied to B1, negative bias to B2, terminal COM is common to bias and output voltages.

A positive signal on the base of Q1 will cause an increase in the current in R5. Transistors Q1 and Q2 and resistors R5, R6, R7, R18, and R19 form a differential amplifier. R3 is adjusted to supply a small base current to the input of Q1 through R17. The input from the Zener diode bridge is filtered by R2 and applied to the base of Q1 through R13.

Transistor Q3 and resistors R8, R20, and R21 form an amplifier stage. Increase in the current of R5 will increase the base drive of Q3. Increasing base current in Q3 causes more current to flow in R21 and the base of Q4. Transistor Q4 and resistors R4, R9, and R10 comprise the output stage. With increasing base drive of Q4 output at collector of Q4 will be driven negative.

Capacitor C1 is connected to deliver a negative feedback signal that stabilizes the amplifier from oscillating at high frequencies caused by stray capacitances. Resistors R4 and R15 or R16 provide feedback to adjust the gain of the amplifier and R14 provides another input to the operational amplifier.

The output of the Zener bridge is applied to R2 and R13 to cause a current into the base of Q1. The output of the amplifier will be driven in such manner that the current feedback through R15 or R16 will just cancel that caused by the input signal thereby keeping the base of Q1 at zero volts. Because the amplifier tends to reduce the sum of all currents at the input to zero, it can be used to sum two signals. If one signal is applied from the Zener bridge and another at I1B through R14, the output will be the sum of the two multiplied by the gain of the amplifier. The gain of the overall amplifier is set by potentiometer R4. When movable arm is near output O2, the gain will be low since a large amount of output is fed back.

secondaries of transformers T2 and T3 and resistor R1. The dc output of rectifiers X1 to X6 is filtered by inductor L2 and capacitor C1. This output voltage is applied to the series circuit consisting of the inductor L2, resistors R24 and R25 and the voltage adjusting rheostat (connected between terminals R2 and R3). The voltage across R25 and an adjustable portion of the voltage across the voltage adjusting rheostat is applied to the bridge circuit composed of resistors R11 and R12 and Zener diodes Z1 to Z4. The output of bridge appears across the operational amplifier at COM and resistor R2. Resistors R11 and R12 are 1 percent, precision resistors. The Zener diodes are temperature compensated. The output of the Zener bridge is put into a dc preamplifier through R2 and R13.

2.2.2.2 Reactive Droop Compensation Circuit. A reactive compensation circuit is included on the panel to allow parallel operation of two or more ac generators. When ac generators are operated in parallel, the reactive kva carried by each should be in proportion to the generator rating. The proper division of reactive kva among generators can be obtained by causing each generator to droop its regulated voltage as the reactive load current supplied by it increases.

The compensator circuit consists of auto transformer T1, reactor L1, isolating transformers T2 and T3, and resistor R23. The compensator is supplied from a current transformer connected in one phase of generator output. The reactive droop compensation circuit produces voltages on the secondaries of transformers T2 and T3 that add to the 3-phase voltages at input terminals 7, 8, and 9. The resulting 3-phase voltage applied to rectifiers X1 to X6 is proportional to the generator terminal voltage plus a voltage proportional to the reactive current being supplied by the generator.

2.2.3 Operation

2.2.3.1 Zener Diode Bridge Sensing Circuit. The Zener diode bridge, Z1 to Z4, R11 and R12 sensing circuit utilizes the nonlinear characteristics of Zener diodes. See Figure 2. Consider the case with 17 volts across each leg of the bridge. At this voltage there is considerably more current flowing through the resistors than through the Zener diodes. This unbalance creates a higher potential at resistor R2 with respect to COM. With 19 volts across each leg of the bridge the Zener diodes conduct more current than the resistors and the unbalance creates a higher potential at COM with respect to R2.

For the balanced conditions, point A, in Figures 2 and 3, the Zener diodes and resistors each conduct approximately 8 milliamperes, so the total bridge circuit

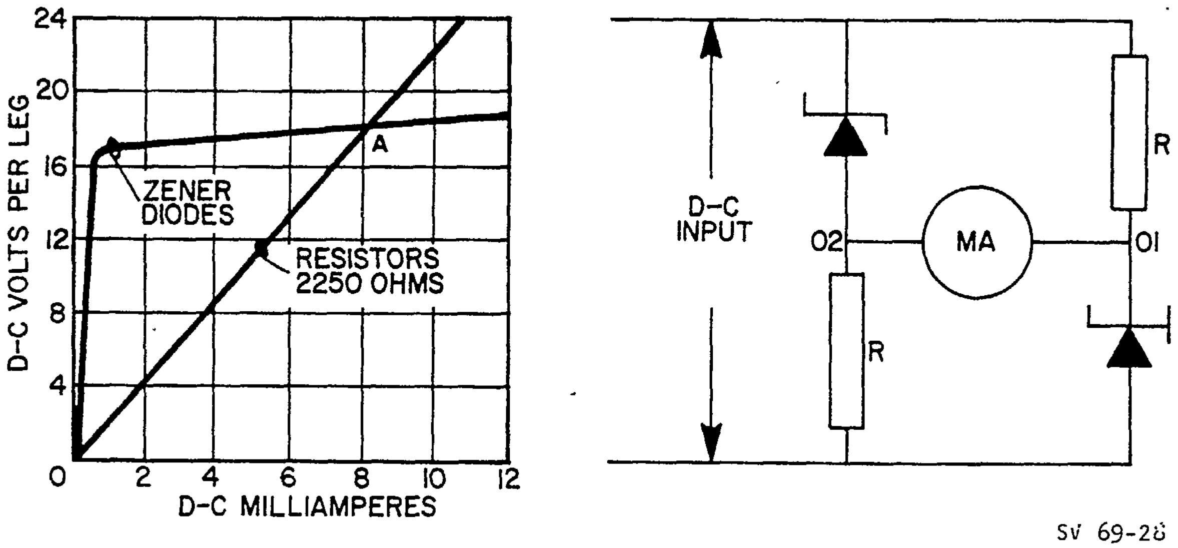


Figure 2. Zener Diode Bridge Sensing Circuit

2.2.3.3 Droop Compensation Circuit. The division of kilowatt load among parallel ac generators is dependent on the power supplied to each generator, controlled by the governor of its prime mover. The division of kilowatt load is independent of the excitation on the generators. Changes in the excitation of paralleled ac generators does effect the reactive kva of the generator output. Because the voltage regulator acts directly on the generator excitation system, it controls the division of reactive current.

The reactive droop compensation circuit causes the voltage "seen" by the regulator, that is the voltage input to rectifiers X1 to X6 to increase as the reactive load on the generator increases. When the regulator "sees" a high voltage, it reduces excitation on the generator until the voltage it "sees" is again the normal value corresponding to a reduced generator terminal voltage.

Terminals C and CO on the regulator are connected to the secondary of the current transformer in the generator output. With rated current on the generator approximately 4 amps will flow in the transformer secondary. Terminals C and CO of the regulator are connected to taps on auto transformer T1. Resistor R23 and linear reactor L1 in series are connected between the ends of transformer T1 winding. Voltage across reactor L1 will lead the current through it by 90 degrees. Voltage across resistor R23 will be in phase with the current through it. The primary of isolating transformer T3 is connected across a portion of resistor R23 and the primary of isolating transformer T2 is connected across reactor L1 plus a portion of resistor R23. Transformers T2 and T3 each have a one to one ratio. The sliders on resistor R23 are set so that the voltage appearing on the secondary of transformer T2 is equal in magnitude to that on the secondary of transformer T3 but leads it by 60 degrees. This can be seen by studying Figure 4a. The magnitude of voltage appearing on the secondaries of transformers T2 and T3 is determined by what taps on auto transformer T1 are used; the taps are marked in percent settings. The percentage indicates the approximate amount of voltage droop that should occur with rated kva and zero power factor lagging load on the generator. The higher the tap used on auto transformer T1 the more current will flow through reactor L1 and resistor R23. More current flowing through reactor L1 and resistor R23 in turn produces more voltage across the isolating transformer secondaries.

Voltages on the secondaries of transformers T2 and T3 add to the 3-phase voltages at the input as shown in Figure 4b. It can be seen from Figure 4b that unity power factor generator current will not change the magnitude of 3-phase voltage supplied to rectifier X1. Lagging power factor generator current will cause the voltage supplied to rectifiers X1 to X6 to rise and leading power factor generator current will cause it to drop.

2.2.3.4 Regulator Tests. Place a dc voltmeter across terminals COM-O2 (0-10 vdc). Jumper switch contacts 1-2, 3-4, 5-6. Turn regulator control switch to MAN. Operate the generator on manual control at 450 volts. Set the voltage adjusting rheostat so that with 450 volts on the generator terminals, there is zero output voltage from the regulator. If the voltage adjusting rheostat is not near the center of its range, adjust resistor R24. With zero output voltage from the regulator unit, the dc voltages should read as follows:

Across each Zener diode Z1 to Z4 - 9.0 (±5%) vdc
Across resistor R11 or R12 - 18.0 (±5%) vdc
From lead N to terminal R1 - 36.0 (±5%) vdc.

If any of the above values do not check replace the defective part.

Plot a curve of input volts to the regulator versus output voltage. It should agree with Figure 3. Remove the jumpers across the switch contacts to terminals 7-8-9 of the regulator.

To check the droop compensator circuit, temporarily connect terminal 18 to terminal 19. Set the compensator dial for 4 percent.

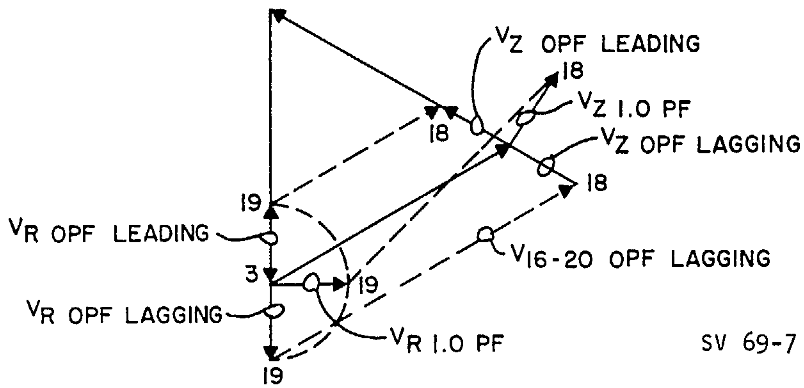


Figure 4B

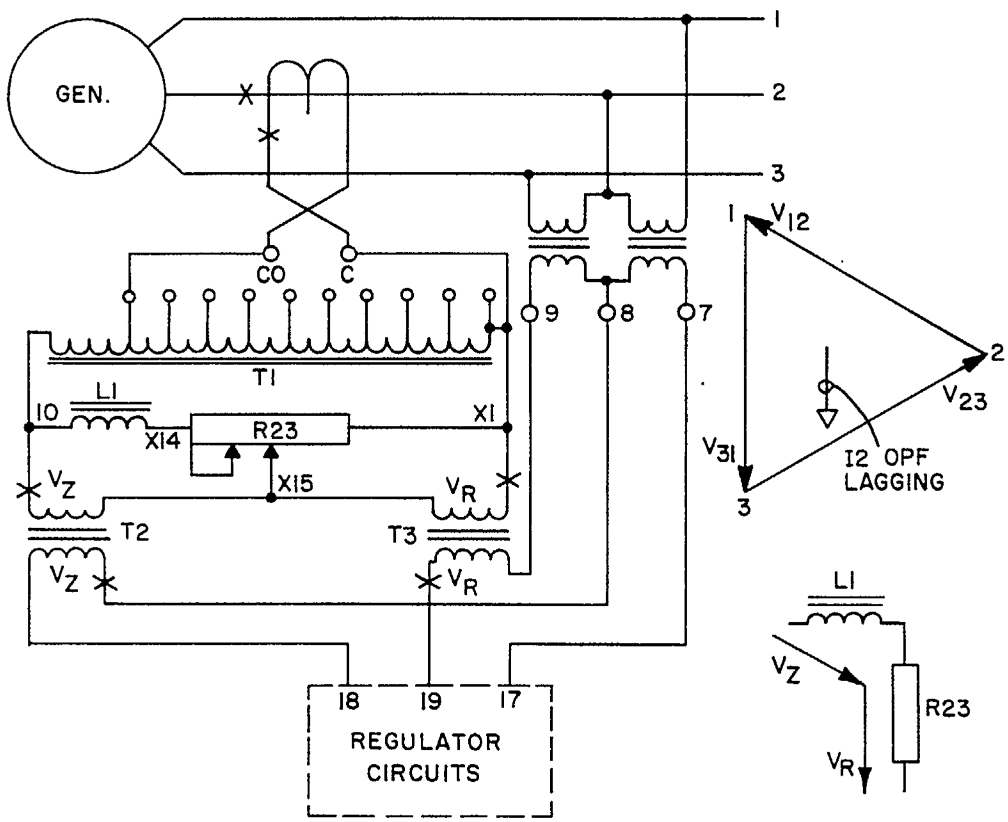


Figure 4A

SV 69-8

Figure 4. Droop Compensation Circuit

controlled rectifiers. The pulses are always of constant height and width but the position of the pulse is varied with respect to the supply frequency sine wave. A dc control voltage at the input will shift position of the pulses by approximately 160 degrees. A transformer delivers the pulses to the controlled rectifiers and the rectifiers constitute the power amplifier element in the generator voltage regulation system and control the amount of excitation energy delivered to the generator. See Figs. R-8 and R-9.

2.3.2 Over-Voltage Circuit. The over-voltage circuit takes control of the pulses in the event of over-voltage. The circuit will automatically phase back the delivered pulses 170 degrees and reduce the field excitation to a low value.

2.3.3 Firing Circuit. The pulses delivered are synchronized with the ac supply voltage and cause the controlled rectifiers to fire once during the positive half cycle of supply voltage at a variable angle; the angle is proportional to the amplified error signal obtained from the voltage regulator. When turned on, the controlled rectifier remains on during the entire positive half cycle.

The inputs are a dc reference and an ac reference signal. Their sum turns off Q1 of the differential amplifier formed by Q1 and Q2. C2 then charges until it fires the unijunction transistor Q5. The output of Q5 fires controlled rectifier Q6, allowing C3 to discharge through T1 and deliver the pulse. Q3 delays the pulse 10 degrees after the beginning of the positive half cycle, and Q4 prevents the pulses from being retarded more than 170 degrees. Diode X9 coupled to the over-voltage circuit delivers a retarded 170 degrees in event of an over-voltage condition.

The over-voltage circuit rectifies an ac signal proportional to signal voltage. When the rectified signal exceeds the R12 voltage drop, a Schmitt trigger formed by Q1 and Q2 turns on Q3. Q1 of the firing circuit is then grounded to common through X9 and Q3. Therefore C2 of the firing circuit does not charge and no pulse is delivered until Q4 turns on and charges C2, delivering a pulse retarded 170 degrees.

Positive bias is applied to B1, negative bias to B2. Terminal COM is common to bias, input, and synchronizing inputs.

The circuit has been designed to shift the output pulse from 10 to 170 degrees delay with a 2-volt change in dc voltage.

2.3.4 Outputs. Two isolated outputs are provided. Each output is one ampere short circuit, 20 microseconds long.

2.3.5 Burden. The burden on the dc supply is approximately 4000 ohms B1-COM. The burden B2 to COM is approximately 15,000 ohms.

2.3.6 Installation Tests. After all circuit connections have been checked, proceed as follows:

a. Check voltage at terminal B1 to be 18 (±10%) volts positive with respect to common.

b. Check voltage of terminal B2 to be 18 (±10%) volts negative with respect to common.

2.3.7 Operation. The dc control signal and ac supply voltage are balanced by R1 and applied to the base of Q1. The usual ac supply voltage is reduced to 2 volts peak-to-peak and phased to lead main signal voltage by 90 electrical degrees. Q1, Q2, R3, R4, and R5 form a differential amplifier. Base drive of Q2 is between 0 and -2 volts; and Q2 is normally off. Q1 is on until sum of dc control and ac reference signals becomes less than the base drive of Q2, then Q1 turns off. Current now flows through R3 and X2 charging C2 to about 9 volts, C2 fires the unijunction transistor Q5 through X4. Q5, R10, and R11 form the pulse into a sharp rising pulse needed to fire controlled rectifier Q6. C3 then discharges through Q6 and T1 giving the pulse for the controlled

Pass exactly 4.0 amperes, ac, through terminals C-CO. Measure voltages 8 to 18, 9 to 19, and 8 to 9. These should all measure approximately 4.8 volts and be equal within 0.3 volts. If these voltages are slightly outside of the tolerances adjust the sliders on resistor R23. V_{R23} from lead X1 to X15 should be 1.15 times V_{L1}. V_{R23} from lead X15 to X14 should be 0.5 times V_{L1}. If the voltages are quite unequal a reversed transformer polarity or incorrect wiring is indicated.

Remove the temporary jumper from 18 to 19. Set the compensator at 12 percent. Check that the voltage 8 to 18 and 9 to 19 decreases in large steps when the upper dial setting is lowered and in small steps when the lower dial setting is lowered.

2.2.3.5 Typical Data. With zero output voltage at terminals COM-O2 and 112.5-volts, 3-phase input on terminals 7-8-9:

V_{P-N} = 140 (±5%) vdc

V_{L2} = 8.8 (±5%) vdc

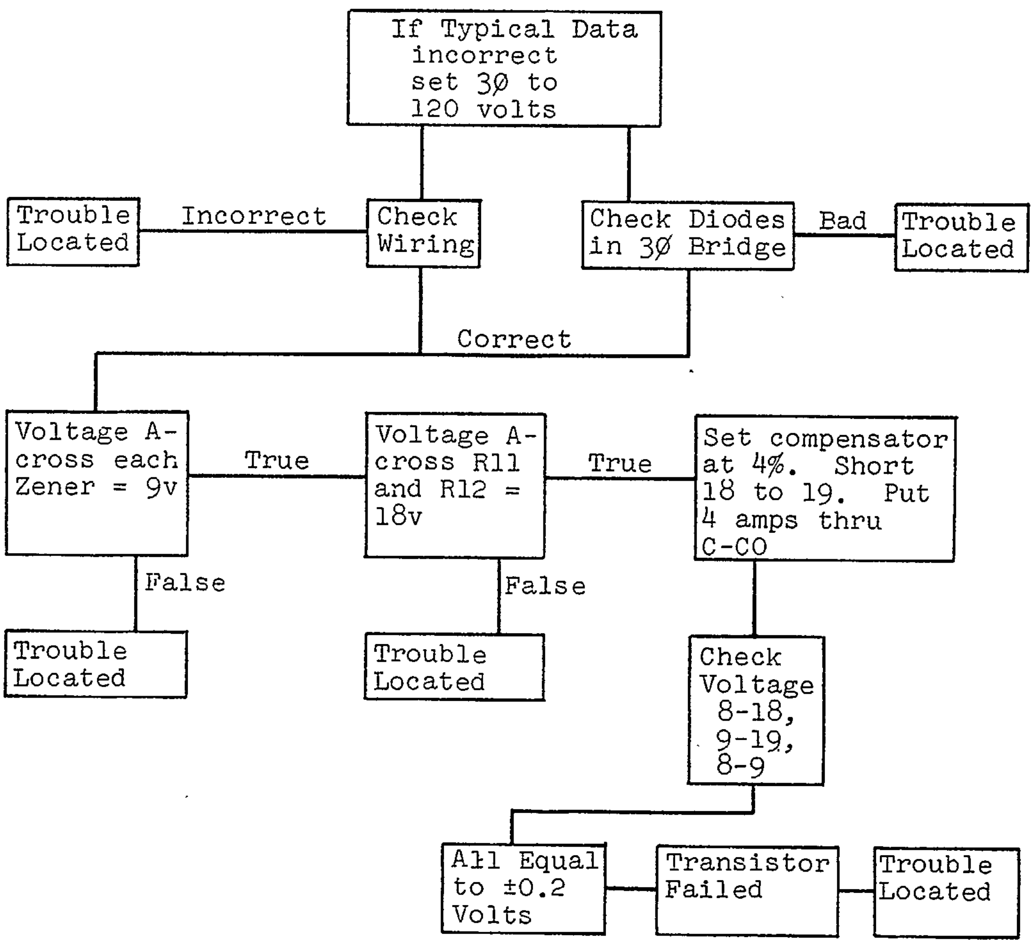
V_{C1} = 40 (±10%) vdc

V_{R12} = V_{R11} = 13 (±5%) vdc

V_{Z1} (each diode) = 9 (±5%) vdc

2.3 TYPE WTN STATIC EXCITER

2.3.1 General. The function of the firing circuit is to supply pulses to the gates of the



Typical Data Check

rectifiers. Resistors R14 and R15 limit the current delivered to the gates of the controlled rectifiers. See Figure 5.

Capacitor C3 was charged to about 30 volts during the previous negative half cycle of main supply voltage through R12, R13, X7, and X8. The total voltage applied to C3 is about 230 degrees ahead of the main supply voltage. It begins charging about 50 degrees after supply voltage goes negative. When the charging voltage becomes negative, X7 holds the charge on C3 until Q6 turns on, discharging C3 through Q6 and T1.

Transistor Q3 is on during the entire negative half cycle of the supply voltage since it is driven through R6 by an ac voltage 180 degrees ahead of supply. If Q1 would come on while Q3 is on, the current through R3 would not charge C2; therefore no pulse can be initiated until Q3 turns off. This occurs when the supply voltage becomes positive. When the supply voltage becomes positive Q3 turns off and C2 will charge when Q1 turns off. The degree delay occurs when the resultant value of ac voltage and dc signal is zero at base of Q1.

Transistor Q4 and resistors R7, R8, and R9 form a switch which is on from about -30 degrees to 160 degrees of the supply voltage; the base drive is positive during this part of cycle. At about 160 degrees, the base goes negative, turning Q4 off and C2 then charges through R9 and X3. Approximately 10 degrees later Q6 fires and delivers the pulse, retarded 170 degrees.

R2 and C1 form a filter to remove any high-frequency noise from the input signal. Diodes X1, X5, and X6 protect the transistors Q1, Q3, and Q4 from excessive reverse bias.

At lower frequencies the charging time of C3 is longer and the voltage on R12 and R13 is lower so that C3 is charged to about the same value at all frequencies. This ensures constant amplitude pulse (about one amp for 20 microseconds) at all operating frequencies.

An ac voltage proportional to the supply voltage is rectified by X1 through X6. R1, R2, and R3 form a voltage divider and R7, R8, R9, R10, R11, R12, R13, R14, Q1, and Q2 comprise Schmitt trigger. Under normal voltage conditions Q1 is off and Q2 is on. Q3, R16, and R17 form a switch normally off because the base is driven negative through R16.

If there is an over-voltage Q1 will turn on when the over-voltage on R3 tap exceeds the drop across R12 and the emitter-base of Q1. Q2 turns off and allows Q3 to turn on as the current will go through R14 and R15, driving the base positive. With Q3 on, terminal OV is essentially common.

Diode X9 of the firing circuit is connected with terminal OV. When Q1 of the firing circuit turns on during an over-voltage condition, collector of Q1 is common, so C2 will not be charged until the Q4 circuit fires a pulse near the end of the positive half cycle.

R3 tap can be adjusted to change the trip point of the Schmitt trigger. R9 can be adjusted to change the band width and R22 to vary the input voltage to the firing circuit. R19, R20, and R21 form a manually adjusted dc voltage into the input of the firing circuit. A potentiometer is connected to R19 and R20 which can be adjusted to set the range of the manual adjuster. Zener diode Z1 and resistor R18 supply the bias for the Schmitt trigger.

Rectifiers X7 through X12 form a negative dc voltage which is divided by R4, R5, and R6. The negative voltage on R4 tap provides the bias for Q2 of the firing circuit. The voltage on Q2, therefore, varies with the ac supply voltage and is used to keep the output of the exciter from drifting when on manual control.

The trigger voltage shown in Figure 5 is the voltage from Q to COM. With no dc input, the base of Q1 varies from +1 volt to -1 volt. The pulse is initiated when the sum of the dc and ac inputs becomes more negative than Q as the point at which the Q1 and Q2 voltages pass each other occurs

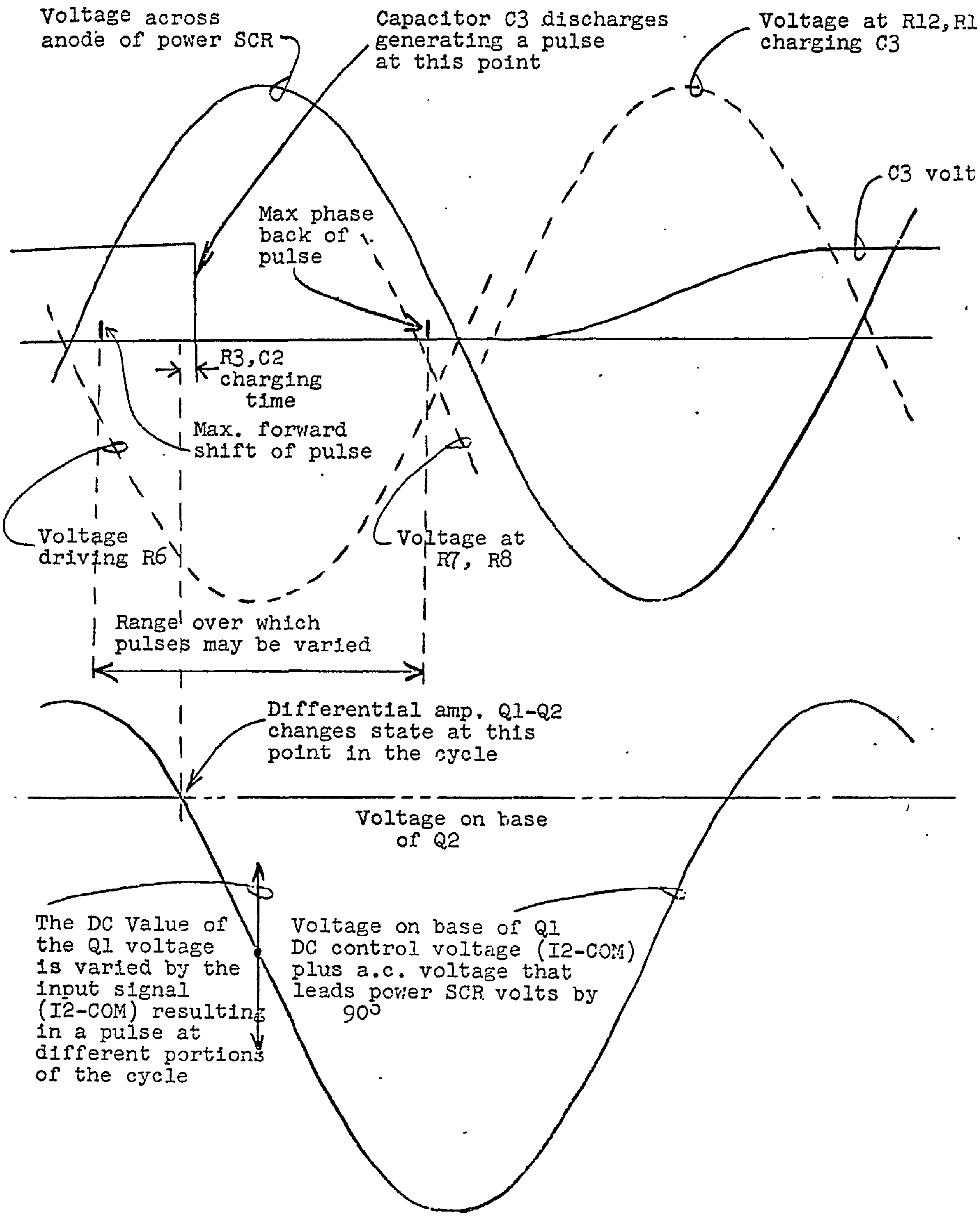


Figure 5. Firing Circuit

Section 3. INSTALLATION

3.1 RECEIVING, HANDLING AND STORAGE

The WZN-1 voltage regulator and WTN static exciter are shipped with the turbine-generator set and installed in accordance with shipbuilders plans.

Carefully unpack the equipment with particular attention to prevent damage to wiring and small parts; check packing material thoroughly to verify that no small parts are thrown away inadvertently.

Protect the equipment from moisture which lowers insulation resistance and increases the probability of breakdown. If the equipment is brought from cold to warm temperatures keep it sealed until its temperature has risen to ambient to prevent condensation on the parts.

If storage over a period of time is anticipated keep the equipment completely enclosed in covering of tarpaulin, wood, metal or roofing paper; provide space heaters to prevent condensation.

It is possible to do more damage to the equipment by careless use of hooks and bars before and during installation than would be caused by years of regular service. A blow on any part of the equipment is apt to damage a component and result in operational failure.

See Figure R-2 for the principal dimensions of the static exciter and voltage regulator.

3.2 INSTALLATION TESTS

3.2.1 System Test. After the equipment has been installed, perform a continuity check and then proceed as follows:

a. Check connections of all transformers, as polarity reversal of any one of transformer windings will cause regulator to malfunction. Check for proper phase rotation. Set manual control rheostat for minimum voltage.

b. Verify that generator line breaker is open and regulator control switch is in AUTO position.

c. Start turbine and bring it to rated speed; close breaker 90-41.

d. Turn flashing switch to FLASH; generator voltage should build up. As soon as voltage reaches 300 volts, allow switch to return to OFF.

e. Adjust generator terminal voltage to exactly 450 volts by means of voltage adjusting unit. Mark this position.

f. Turn voltage adjusting unit in raise direction (clockwise) and note that maximum generator voltage is at least 482 volts. Turn voltage adjusting unit in lower direction (counterclockwise) and note that minimum generator voltage is less than 436 volts.

g. After equipment has warmed up for about 15 minutes, set voltage adjusting unit so that generator voltage is exactly 450 volts.

h. Reduce turbine speed so that generator frequency will be 57 Hz; record generator voltage. Raise frequency to 63 Hz; record voltage. The voltage should change no more than 13.5 volts at either frequency.

i. Set manual control rheostat in counterclockwise position. Check across M1 and wiper arm of manual control rheostat and verify that resistance is zero. Turn regulator control switch 90-CS to MAN. Generator voltage will decrease. Adjust earlier in the cycle and the pulse will then occur earlier in the cycle.

2.3.8 Burden. The burden B1 to COM is approximately 1000 ohms. The burden B2 to COM is approximately 10 K ohms.

2.3.9 Calibration. The purpose of these instructions is overall calibration and checking the circuit. After the components have been checked and continuity test have been made, perform the following steps:

a. Connect a bias supply of 18 volts from B1-COM (B1+). Connect a bias supply of 18 from B2-COM (B2-). Use feedback resistor R15, 10 ohms. Apply 8 vdc from I1B to Common (I1B+); set moveable arm of R4 near output.

Leave all other terminals open. The voltage across R5 should be approximately 14.5 volts. If not, it may indicate a failure in the differential amplifier.

b. The voltage across R21 should be approximately 30 volts. If not, it may indicate failure of Q3.

c. The voltage across the output should be 8 volts. If not, Q4 may have failed.

Difference between maximum and minimum average of 3-phase voltages should not exceed 9 volts, provided frequency is held constant.

c. After test, return compensator settings to original positions.

3.2.5 Parallel Operation Checkout. To test parallel operation, proceed as follows:

a. With no-load on the bus, synchronize generator with bus and close generator breaker. Adjust voltage adjusting rheostat so incoming generator is supplying zero current to bus.

b. Apply load to bus. The reactive current supplied by generator should be in proportion to total reactive current being supplied to load as rating of generator is to rating of all generators connected to bus. If generator tends to supply more than its share to reactive current, shutdown and set reactive droop compensator on regulator to a higher tap and repeat above process. Set the droop compensator at minimum value consistent with proper starting of reactive current but not for more than 4 percent droop in any case. The 3 percent droop would be a good setting to try first.

c. The generator can be removed from the system by lowering the kilowatt load on the generator to zero, and then opening generator breaker.

generator to 450 volts and mark this position on manual control rheostat. This setting will give 450 volts at no-load. Observe that smooth control can be obtained. Turn manual control rheostat maximum counterclockwise. This will cause generator to go to minimum voltage.

3.2.2 Preamplifier Circuit Test. Check all circuit connections and then proceed as follows:

a. Check the voltage at terminal B1 to be 18 (±10%) volts positive with respect to common.

b. Check the voltage at terminal B2 to be 18 (±10%) volts negative with respect to common.

3.2.3 Firing Circuit Test. The firing circuits are designed to work with a sine wave voltage. Large amounts of harmonics or noise in the supply voltage can cause eccentric firing. Check the wave form, using an oscilloscope. Filter circuits may be required in the supply to the firing circuit to clean up the wave form.

To check firing circuit, proceed as follows:

a. Check proper operation of power amplifier.

b. Connect a bias supply of 18 volts from B1-COM (B1+). Connect a second bias supply of 18 volts from B2-COM (B2-). Do this to each firing circuit and over-voltage module.

c. Short circuit output windings of pulse transformer.

d. Connect terminal Q to ground; leave terminals 0, 18, 24, 30, S1, S2, and P3 open.

e. Measure voltages from R3, R4, and R9, to common. VR3 should be approximately the positive bias and VR4 and VR9 approximately 10 percent of positive bias supply.

f. Connect S2 to common; leave terminals 0, 18, 24, 30, Q, S1, and PB open.

g. VR3 should be approximately 10 percent of positive bias and VR4 should be approximately the bias voltage. A large departure from the expected value may indicate failure of Q1, Q2 or both.

h. Connect 0, 18, and 30 to common; leave terminals, 24, Q, S1, S2, and PB open.

i. VR9 should be approximately the positive bias voltage.

j. Connect S2 to common; leave terminals Q, 0, 10, 30, S1, and PB, open. Momentarily connect terminal 24 to B1 and place an oscilloscope across R14. Remove S1 from common and a pulse should appear across R14. Lack of a pulse indicates failure of Q6 or Q5. Repeat and check if a pulse appears across R10; no pulse indicates failure of Q5.

k. Leave all terminals except B1, B2, and COM open on over-voltage module. VR14 should be about 6 volts, VR8 less than 1 volt and VR17 about 2 volts or less. Voltage OV-COM should be approximately 16 volts.

l. Connect C1 to 50-volt dc source. (C1+) (COM-). Adjust R3 and observe VR8. VR8 should become 6 volts or more when R3-COM voltage is approximately 2.0 volts. If not, it indicates failure of Q1.

m. The voltage OV-COM should be approximately 10 percent of positive bias supply.

3.2.4 Generator Under Load. Make no-load checks and then, proceed as follows:

a. Set compensator circuit on WZN-1 regulator for zero percent compensation by moving rotating arms to terminals marked zero. Operate generator under regulator control (switch in AUTO position).

b. Load generator with whatever load is available, up to full load, rated power factor.

Section 4. OPERATION

Before operating the apparatus verify that it is in all respects properly serviced. Check new or repaired equipment or equipment that has been idle for some time, in accordance with Section 3.2.

4.1 STARTING UP

After initial checks have been made, operate regulating system as follows:

NOTE

The amount of reactive droop is set by means of the dial mounted on transformer T1. The dial is marked in terms of percent droop. Normally a setting of from 3 to 4 percent droop is required.

The setting of resistor R24 sets the range of voltage adjustment of the voltage adjusting rheostat. Increasing the resistance raises the range while reducing the resistance lowers it. Resistor R24 should be set with all resistance in.

a. Verify that generator line circuit breaker is open, and control switch in AUTO position.

b. Turn voltage adjusting rheostat and manual control unit to position for rated generator voltage at no-load.

c. Start turbine and bring it to speed; close breaker 90-41.

d. Turn buildup switch to FLASH. As generator voltage approaches 300 volts, allow buildup switch to return to OFF. Generator voltage should rise to approximately 450 volts. A slight readjustment of voltage adjusting unit may be necessary to set generator voltage at exactly 450 volts.

e. Synchronize generator to bus if it is to operate in parallel with other generators.

4.1.1 If it is desired to start with regulator control switch 90-CS in MAN, proceed as follows:

a. Verify that generator line breaker is open, turn control switch to MAN.

b. Repeat steps b, c, d, and e of Section 4.1.

4.2 SHUTTING DOWN

When load has been removed from generator, perform the following steps:

a. Disconnect generator from bus by opening generator circuit breaker.

b. Turn regulator control switch 90-CS to OFF. This automatically opens breaker 90-41.

c. Secure turbine.

Section 5. MAINTENANCE

5.1 PREVENTIVE MAINTENANCE

Because the static exciter and regulator have no moving parts and inherent long life characteristics, little maintenance is required. Clean the equipment and check all connections for tightness at periodic intervals determined by the severity of operating conditions.

5.1.1 Cleaning

WARNING

WEAR SAFETY GLASSES AND DIRECT AIR STREAM AWAY FROM OTHER PERSONS.

The equipment can be cleaned by gentle blasts of dry compressed air.

5.1.2 Inspection

1. Inspect rectifier cells to verify that all electrical and thermal connections are tight. Remove any dirt, corrosion products, etc. around the stud heat-sink connection. Keep ceramic insulating surface between lead and stud or housing of shell clean.

2. Carefully check for loose screws, nuts or components.

3. Check for broken or loose connections.

4. Check wiring and components for indications of overheating or deterioration.

Do not overheat leads when soldering new rectifier cells, Zener diodes, or transistors in place. Prevent this by use of low temperature solder (resin core) and attaching a small heat sink such as an alligator clip or pair of long-nosed pliers between rectifier and end of lead being soldered to prevent too much heat being conducted into the cell.

5.2 CORRECTIVE MAINTENANCE

In a system where currents and voltages are continually varying, it is not possible to assign specific values of current and voltage to all parts of the circuit. When incorrect operation is noticed, observe all the symptoms and refer to the Troubleshooting Chart, Table 5-1, and troubleshooting test instructions. A clear understanding of each circuit function will help isolate the trouble.

5.3 COMPONENT TESTING

It is sometimes necessary to test individual components of electrical systems. Carefully read the following instructions before testing any component.

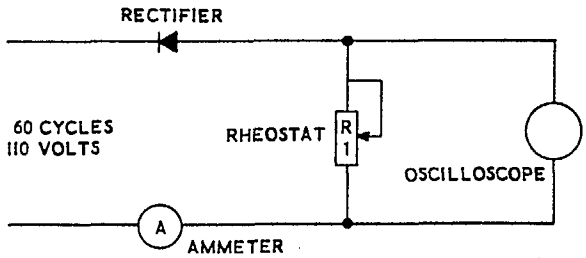
CAUTION

Use clip leads to short all rectifiers when using a megger or hipot to test the exciter-regulator.

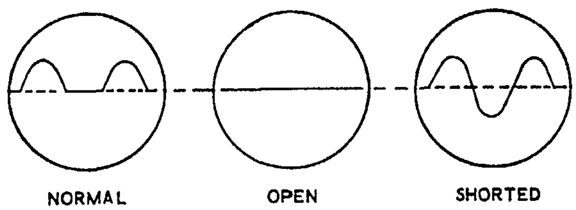
5.3.1 Rectifier Test. To test a rectifier cell, remove all leads from cell and, using an ohmmeter, measure the forward and reverse resistance of the cell. If reverse resistance is not at least ten times as high as forward resistance, check further by installing each cell in the test circuit shown on page 324A. The oscilloscope should show trace as indicated. If the oscilloscope does not show the alternate half sine wave, the cell is shorted or open and should be discarded.

Table 5-1. VOLTAGE REGULATOR TROUBLESHOOTING

Symptom	Probable Cause	Check
Generator field cannot be flashed	Flashing switch 31-CS not making contact, or loose wiring connections	Check switch 31-CS contacts and field flashing circuit wiring for continuity and loosen connections.
	Low flashing power to field	Output of field flashing circuit X3 should be about 18 volts
	Both legs of one phase of rectifier X1 or X3 shorted	Remove positive or negative lead from rectifiers X1 and X3 and remove ac leads from terminals AC1, AC2, and AC3 of X1 and measure forward and reverse resistance of rectifiers X1 and X3. Forward resistance should be 5 to 15 ohms when measured on the one ohm scale of a Simpson 260 multimeter. Reverse resistance should read at least ten times forward resistance.
Generator voltage drops to zero when flashing power is removed with regulator control switch 90-CS in either MAN or AUTO (after holding switch 31-CS in FLASH position for several seconds)	No gate pulses being produced at firing circuit unit terminals G1X-C1X, G1Y-C1Y, or G1Z-C1Z	Check if voltage (about 70 percent generator terminal voltage) and phase rotation is correct at terminals X, Y, and Z of firing circuit unit and if bias voltage is 18-0-18 when generator voltage is at least 70 percent of rated. Check for voltage at terminals I2 and COM with I2 negative with respect to COM. If any of the above do not check properly, replace the firing circuit unit.
	Complete loss of bias supply or loss or positive bias only	Meter bias voltage at terminals B1, COM, and B2 on regulator and firing circuit units. B1 should be +18 (±10%) vdc with respect to COM and B2 should be -18 (±10%) vdc with respect to COM. Loss of positive bias COM-B1 is an indication of defective wiring or failure of one of Zener diode X2.
	Control switch 90-CS contacts not making or faulty wiring of 90-CS switch	Check voltage on terminals 7, 8, and 9 of regulator panel and terminals X-Y-Z of bias supply and firing circuit units. Voltage should be about 1/4 of generator terminal voltage and voltage should be balanced. Check voltage on terminals COM and O2 of regulator unit. Voltage should be about



SV 69-11



SV 69-12

Oscilloscope Traces

5.3.2 Resistor Test. Test resistors by removing all leads from one end of resistor and connecting the resistor to an impedance bridge or multimeter and measuring the resistance. If the values are outside the tolerance (usually 10 percent), replace resistor.

5.3.3 Capacitor Test. Test capacitors by removing all connections from one lead of the capacitor under test and connecting it to an impedance bridge. If test results are not within the tolerance of the capacitor values, replace capacitor.

5.3.4 Transistor 2N1711 (NPN) Test

1. Disconnect two of the three leads of transistor from circuit.

2. Use a Simpson 260 multimeter or equivalent set to resistance times one scale.

3. Place positive meter lead on base of transistor. Place common meter lead on emitter and then collector. Both readings should be between 10 and 25 ohms. If readings are zero or infinity, replace transistor.

4. Place common meter lead on base of transistor. Place positive meter lead on emitter and then collector. Both readings should be infinite ohms or a very high ohm value; if not replace transistor.

NOTE

The transistor leads are emitter base and collector viewed in a clockwise direction, starting with the offset on the case and viewing it from the bottom where the leads protrude.

5.3.5 Transistor 2N1132 (PNP) Test

1. Perform steps 1 and 2 of Section 5.3.4.

2. Place the common meter lead on the transistor base lead.

3. Place the positive meter lead on the emitter and then the collector. The reading should be 20 and 40 ohms. If the readings are zero or infinity, replace the transistor.

4. Place the positive meter lead on the transistor base and the negative meter lead on the emitter and then the collector. Both readings should show near infinite ohms. If not, replace the transistor.

Table 5-1. VOLTAGE REGULATOR TROUBLESHOOTING (Cont)

Symptom	Probable Cause	Check
Generator voltage drops to zero when flashing power is removed with regulator control switch 90-CS in either MAN or AUTO (after holding switch 31-CS in FLASH position for several seconds) (Cont)	Control switch 90-CS contacts not making or faulty wiring of 90-CS switch (Cont)	6.0 volts dc with COM positive with respect to O2. If there is no voltage on COM and I2 of firing circuit unit, check contacts 7-8 or 90-CS wiring from regulator to switch and from switch to firing circuit.
Generator voltage goes to voltage limit and oscillates between the limit settings of the overvoltage limiter. Turning to MAN has no effect	Loss of negative bias	Check voltage across Zener diode. Voltage should be -18 (±10%) volts with respect to common.
	Transistors Q1 and Q4 in each phase of firing circuit module is open circuited	Check transistors Q1 and Q4 in each phase of firing circuit module.
	Transistor Q2 in each phase of firing circuit module is shorted	Check transistor Q2 in each phase of firing circuit module.
Generator voltage goes to the overvoltage limit and oscillates between the limit settings of the limiter. Turning to MAN obtains correct operation	Transistor on regulator module Q1, Q3, or Q4 is shorted or Q2 is open circuited	Check transistors Q1, Q3, and Q4 for a short circuit and check Q2 for an open circuit.

PART IV

PERFORMANCE DATA AND TESTS

The Test Data Recorded on Pages 405 to 414, covered machines which were electrical duplicates of the machines covered by this Instruction Book. Test Nos. 1-10P812 and 1-10P815 are therefore extended to cover machines on Navy Contract NOs. 93968, Westinghouse G.O. WG-35060.

PART IV

PERFORMANCE DATA AND TESTS

1. The following data were obtained during tests conducted at the plant of the manufacturer.

STEAM CONDITIONS

Normal

Pressure at throttle	525 psi. gage
Total temperature at throttle.	825 deg. F.
Exhaust pressure	1 psi. absolute

2. When operating under the normal steam conditions, as given above, the following performance was obtained:

Kw. Load on A-C. Generator	Kw. Load on D-C. Exciter	Total Steam Consumption Lbs/Hr.	Water Rate Lbs/Kw./Hr.
625.0	Excitation	6980	11.168
937.5	Excitation	9700	10.347
1250.0	Excitation	12660	10.128
1562.5	Excitation	15835	10.134

3. The turbine is also capable of delivering 1250 kw. (full load on a-c. and d-c. machines) with 420 psi. gage throttle pressure, 825°F. total temperature and 1 psi. absolute, back pressure.

4. When operating under normal steam conditions the turbine carried 150% load 1875 kw. on a-c. generator plus excitation for a period of five minutes.

5. The parts of the turbines subjected to high steam pressures and temperatures were tested hydrostatically as follows:

Steam Inlet Pipe	930 psi. gage
Throttle Valve..	930 psi. gage
Steam Chest Chamber of Turbine Casing.	930 psi. gage
Turbine Casing (H.P. End).	450 psi. gage
Turbine Casing (L.P. End).	50 psi. gage

6. The turbine exhaust casing relief valve was set at 10 pounds gage, and the sentinel valve at 2 psi. gage.

7. The excess back-pressure safety trip was set to trip the throttle at 5 psi. gage.

8. The low-oil-pressure alarm switch was set to operate at 4 psi. gage.

9. The overspeed trip mechanism was set to operate at 10% above normal full-load speed (or 1320 rpm. of the generator,) and will trip the throttle within 8% to 12% above normal full speed.

10. With gradual changes in load from 0 to 125% the variations in speed expressed in percentage of normal operating speed was within 4% of normal full-load speed.

11. With gradual changes in load from 20% to 100% the variations in speed expressed in percentage of normal operating speed was within 3% of normal full-load speed.

12. One unit was tested with the oil cooler out of service for a period sufficient to permit the tube bundle to be removed and replaced.

PRELIMINARY FACTORY TEST REPORT

LOAD-TEMPERATURE TEST

1250-KW. TURBO-GENERATOR

TURBINE SERIAL 2-A-8277-2

LOAD		THROTTLE		EXHAUST	SPEED	OIL COOLER TEMPERATURE				BEARING TEMPERATURES									OIL PRESSURE		
						WATER		OIL			SPINDLE		PINION		GEAR		GENERATOR				
%	Kw.	Pres.	Temp.	Vacuum	Rpm.	In	Out	In	Out	Thr. Out	No.1	No.2	No.1	No.2	No.1	No.2	No.1	No.2	Trans.	Gov.	Brg.
20	247	525	750	28.5	1230	80	114	142	120	145	160	155	165	145	135	145	90	117	44	90	8
40	500	525	750	28.5	1222	80	114	142	120	145	160	155	165	145	135	145	90	117	41	91	8
60	750	525	750	28.5	1215	80	114	142	120	145	160	155	165	145	135	145	90	117	40	92	8
80	1000	525	750	28.5	1220	80	114	142	120	145	160	155	165	145	135	145	90	117	39	91	8
100	1250	525	750	28.5	1200	80	114	142	120	145	160	155	165	145	135	145	90	117	35	91	8
125	1565	525	752	28.5	1190	80	114	142	120	145	160	155	165	145	135	145	90	117	33	92	8
100	1250	525	750	28.5	1200	80	114	142	120	145	160	155	165	145	135	145	90	117	30	92	8
80	1000	525	752	28.5	1210	80	114	142	120	145	160	155	168	145	135	145	90	117	35	93	8
60	750	525	750	28.5	1215	80	114	142	120	145	160	155	168	145	135	145	90	117	38	90	8
40	500	525	750	28.5	1222	80	114	142	120	148	160	155	168	145	135	145	90	117	40	90	8
20	250	525	750	28.5	1230	80	114	142	120	146	160	155	168	145	135	145	90	117	43	94	8
0	0	525	750	28.5	1237	80	114	142	120	145	160	155	168	145	135	145	90	117	45	95	8

150% LOAD, NORMAL STEAM AND VACUUM

Max.	1800	525	760	28.5	1175	80	114	142	120	145	160	155	165	145	135	145	90	117	20	80	8

80% NORMAL STEAM PRESSURE AND NORMAL VACUUM

Max.	1440	420	764	28.5	1170	80	114	142	120	145	160	155	165	145	135	145	90	117	22	82	8

PRELIMINARY FACTORY TEST REPORT

JUMP TEST

1250-KW. TURBO-GENERATOR   TURBINE SERIAL 2-A-8277-2

% LOAD	KW. LOAD	THROTTLE Pres.	THROTTLE Temp.	EXHAUST Vacuum	SPEED Rpm.	CONDITION
100	1250	525	750	28.5	1200	Steady
0	0	525	750	28.5	1255	Jump
0	0	525	745	28.5	1237	Steady
100	1250	525	750	28.5	1195	Jump
100	1250	525	750	28.5	1200	Steady
125	1565	525	750	28.5	1190	Steady
0	0	525	755	28.5	1258	Jump
0	0	525	755	28.5	1237	Steady
125	1565	525	750	28.5	1180	Jump
125	1565	525	750	28.5	1190	Steady

PARALLEL TEST

1250-KW. TURBO-GENERATOR   TURBINES SERIAL 2-A-8277-2 and 2-A-8277-4

% LOAD	THROTTLE Pres.	THROTTLE Temp.	EXH'ST Vacuum	SPEED Rpm.	WATTS 1-2	WATTS 2-3	LOAD KW.	% LOAD	THROTTLE Pres.	THROTTLE Temp.	EXH'ST Vacuum	SPEED Rpm.	WATTS 1-2	WATTS 2-3	LOAD KW.
20	525	610	28.5	1232	110	103	255	20	525	610	28.5	1232	105	70	210
40	525	615	28.5	1224	212	190	482	40	525	615	28.5	1224	220	185	486
60	525	620	28.5	1216	265	310	690	60	525	620	28.5	1216	310	305	738
80	525	620	28.5	1210	440	385	990	80	525	620	28.5	1210	365	430	954
100	525	625	28.5	1200	485	548	1239	100	525	625	28.5	1200	455	545	1200
125	525	640	28.5	1186	625	608	1480	125	525	640	28.5	1186	730	550	1456
100	525	635	28.5	1200	522	452	1168	100	525	635	28.5	1200	515	438	1144
80	525	635	28.5	1209	400	465	1038	80	525	635	28.5	1209	385	460	1014
60	525	630	28.5	1216	312	342	785	60	525	630	28.5	1216	285	330	738
40	525	630	28.5	1225	210	215	613	40	525	630	28.5	1225	215	240	546
20	525	625	28.5	1232	110	115	270	20	525	625	28.5	1232	95	85	216

Test No. 1-10P812
File C-70862

Date 4 January, 1943

FACTORY TEST RECORD—A. C. GENERATORS

ISSUED BY THE BUREAU OF ENGINEERING, UNITED STATES NAVY DEPARTMENT
To be used in connection with Navy Department Specifications 17G8 of latest issue

IDENTIFICATION DATA

CONTRACT OR ORDER DATA:
Contractor Westinghouse Electric & Manufacturing Company
Navy contract or shipbuilding order No. NOs. 70862 Date 11 January, 1940
To be installed on U. S. S. IOWA BB61, NEW JERSEY BB62, MISSOURI BB63, WISCONSIN BB64, ILLINOIS BB65, KENTUCKY BB66.
Navy Yards: Brooklyn and Philadelphia.

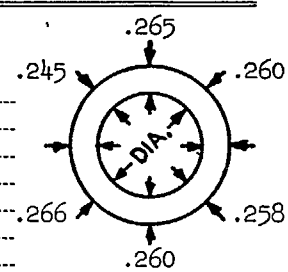
PRIME MOVER DATA:
Type and manufacturer Geared Steam Turbine by Westinghouse E. & M. Co., Essington, Pa.
Manufacturer's serial No.
Refer to factory test record Nos.

VOLTAGE REGULATOR DATA:
Type and manufacturer Navy Type "BN-2". Westinghouse Electric & Manufacturing Company
Uniform specification data plan—manufacturer's No. 31-J-276 Bu. Eng. No. BB61-S61-____ *
Rheostats or resistances serial Nos. S.O. 83-Y-500 Dwg. 31-J-483 BB61-S61-____ *
Refer to factory test reports on voltage regulator and rheostat component units See remarks in paragraph 17.
(Forms INM-23 and 35) Nos. (attached).

D. C. GENERATOR (EXCITER) DATA:
Type and manufacturer Type SK-103-6. Westinghouse E. & M. Co. Serial No. 1-10P815
Uniform specification data plan manufacturer's No. 5-A-9812 Bu. Eng. No. BB61-S61-097
Exciter rating: Volts 120 Kw. 16 Amperes 133
Refer to factory test report (Form INM-22) Nos. 1-10P815 (Pages 410-414) (attached).

A. C. GENERATOR DATA:
For (service application) Ships Power and Light
Type and manufacturer Special Fr. 6-44-1/2 x 22-1/2 by Westinghouse E. & M. Co. WG31965-TP
Uniform specification data plan manufacturer's No. 31-J-651 Bu. Eng. No. BB61-S61-083
Rating: Kw. 1250 P. F. 80% Kv.-a. 1562 Amperes 2005
Voltage 450 Phases 3 Cycles 60 R. p. m. 1200
Generator serial No. 1-S-10P812 Rotor serial No. 1-R-10P812

INSPECTION AND TEST DATA
(Refer par. F-1)



1. Adjustment, fit, material, and weight (on each generator, see par. F-3):
   (a) Materials According to plans and specifications.
   (b) Workmanship Good
   (c) Fit Good
   (d) Adjustment Satisfactory
   (e) Air gap measurements (record on figure at right) Average .260 inch
   (f) Does design conform in all particulars with approved plans? Yes.
   (g) Weights:

(1) A. C. generator	12,638 lb.		
(2) D. C. exciter	1,145 lb.		
(3) A. C. generator with exciter (complete)	13,783 lb.	Total	
(4) A. C. rotor	5,055 lb.		
(5) D. C. armature	240 lb.		
(6) A. C. generator spares (less spare rotor)	6,137 lb.	for 8 generators.	4354#) Without
(7) D. C. exciter spares (less spare armature)	127 lb.	for 8 generators.	92#) Boxes
(8) A. C. generator field rheostat	1,200 lb.		
(9) D. C. exciter field rheostat	30 lb.		

* Not available at date of publication.

Test No. 1-10P812
File C-70862

2. Effectiveness of enclosure (on each type, see par. F-4) Satisfactory for totally-enclosed, drip-proof. Due to closed system of ventilating air ducts, a suction of .7 inch of water is developed in the end bells and therefore the end bell hand hole covers should be kept tightly closed.

3. Inclined operation (at least one of each size and type on each order, see par. F-5)
NOTE.—This test shall be made and reported on combined unit test (Form INM-36 A or B).

Test on Space Heaters:- Stator winding temperatures after space heaters had been on 2 hours were 38°C. on Right Front, 32° on Lt. Fr., 26° on Rt. Rear, 25° on Lt. Rear with Room Air 22°C.--therefore space heaters should keep windings an average of 8°C. above room temperature.

4. Noise (on each generator, see par. F-6)
NOTE.—This test shall be repeated and reported on combined unit test (Form INM-36 A or B).

Not excessive.

5. Balance (see par. F-7):
(a) Mechanical balance (on each generator) Good. Each generator tested with its exciter assembled.
NOTE.—This test shall be repeated and reported on combined unit test (Form INM-36 A or B).
(b) Electrical balance (on each generator) Good. Voltage balance within 1% variation.
(c) Phase unbalance (at least one generator of each size and type on each order) Voltage unbalance 3.1% on
NOTE.—This test shall be repeated and reported on combined unit test (Form INM-36 A or B).
single-phase resistance-rack load of 25%: 503 amperes and phase voltages of 450, 436, and 436. Order of phase rotation for line terminals: A-B-C.

6. Lubrication: (At least one generating unit of each size and type on each order, see par. F-8)
NOTE.—This test shall be repeated and reported on combined unit test (Form INM-36 A or B).
(a) Temperature rise (on complete tests) 13°C. on Front bearing.
(b) Does lubricating system perform satisfactorily? (Other machines on order.) Yes, on each machine. Pressure-fed oil lubrication.

7. Voltage regulation, S. C. ratio and transient reactance (see par. F-9):
(a) Combined unit inherent voltage regulation
(At least one of each size and type, see pars. F-9 and F-20)
NOTE.—This test shall be made and reported on combined unit test (Form INM-36 A or B).
(b) Generator inherent voltage regulation 25.1% See Curve No. 266180. (Page 409)
By method No. 2—saturation curves .... percent (each generator).
(c) Short circuit ratio (at least one of each size and type on each order) 1.068

$$\frac{\text{Field current at rated open circuit armature voltage and rated frequency}}{\text{Field current at rated armature current on sustained symmetrical short circuit at rated frequency}} = \text{short circuit ratio.}$$

(d) Transient reactance (at least one of each size and type on each order). Oscillogram No. L-1526, Curve 264085.
Transient reactance 19.8 percent. Subtransient reactance 15.1%

8. Parallel operation (all generators, see par. F-10)
NOTE.—This test shall be made and reported on combined unit test (Form INM-36 A or B).

Test on space heaters:- 4 units in parallel, Style No. 1085726; 115 volts, 250 watts each; Measured input 115 volts, 8.6 amperes.

9. Wave shape (at least one generator of each size and type on order, see par. F-11):
(a) Deviation factor on all phases by means of oscillograph: Oscillogram No. P-1087, Field Amperes 118.5:-
On open circuit terminal voltage 564 volts 9.5 percent.
On 125 percent rated load voltage 21st.4% 11th.5 percent.; 9th.5%; 7th 1.0%; 5th 1.3%;
Harmonics in voltage wave 27th .5%; 25th 5.16 percent. 23rd 4.40%; 1st 99.75%; 3rd .6%.

10. Short circuit (on each generator, see par. F-12)
(a) Condition of windings after single phase dead short circuit for 2 minutes No change evident.
(b) Condition of windings after three phase dead short circuit for 2 minutes No change evident.
Comments: 2760 sustained short-circuit amperes on 3-phase test with 79.2 amperes in field. 4074 sustained short-circuit amperes on single-phase test with 76.4 amperes in field.

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11. Heating (see par. F-13):

Specified ambient temperature 50 °C.

MAXIMUM TEMPERATURE RISES

Name of Part Here list names of parts on which temperatures are recorded. (See table 1, appendix 1)	On Each Generator		On at Least One Generator of Each Size and Type on Each Order					
	At 100% load with designed P. F.		At 125% load for 5 hr. designed P. F.		At 150% load for 5 min. with designed P. F.		At 150% load for 5 min. with 0.5 P. F.	
	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
Stator Core	32.5		47.5		22.5			
Stator Copper	24	*40.5	38.2	*60	23			
Stator Copper	#41.5		#60		#29.5			
Rotor Copper	31	31	62					
Air Gap Iron	29.5		42					
Collector Rings	49		37					
Dampers	24		33					
Front Bearing	13							
Stator Res., Phase A-C. in ohms -	.00130						.00113	at 21°C.
Gal. of Water/minute through	Cooler	50		50				
Temp. of Water going in Cooler		26°C.		24°C.				
Temp. of Water out of Cooler		29°C.		28°C.				
Temp. of Air blowing out of	Cooler	43°C.		48°C.				
Temp. of Air blowing in Cooler		32.5°C.		31.5°C.		30.5°C.		
Temp. of Room Air		24°C.		29°C.				
Ambient Temperature	31°C.		31°C.		30°C.			

Comments: *By temperature detectors, Method 3. # By thermo-couple put on for test. Ambient temperature for forced air-duct ventilation.

12. Efficiency (one of each size and type on each order, see par. F-14):

(a) Conventional efficiency losses in kilowatts:	½ Load	¾ Load	4/4 Load
(1) I^2R loss in and stator			8.24
(2) Friction and windage loss			8.52
(3) Core loss			10.05
120 x fld.amp. (4) Brush contact loss and I^2R in rotor & rheostat			14.82
(5) Stray load losses			4.38
(6) Miscellaneous losses			.
(a) Excitation energy losses			.
(b) Field rheostat losses			.
(c) Blower losses			.
(d) Direct connected exciter loss (if used exclusively for excitation)			2.03
(7) Totals			48.04

(b) Calculated efficiency at ½ load 94.8 %; ¾ load 95.9 %; 4/4 load 96.3 %. 5/4-load-96.5%
(c) Alternate methods: 1/4-load-91.2%

13. Overspeed (on each generator, see par. F-15):
(a) Maximum overspeed 1500 r. p. m. (25% greater than normal for 30 minutes).
(b) Check for: Noise Not excessive Dynamic balance and smoothness of running Satisfactory
Evidence of distortion None Injury None apparent.
Noticeable change in condition of any part (comment):

14. Dielectric strength (on each generator, see par. F-16):
(a) Test voltage applied each circuit Stator 2000 volts. To space heaters 1600 volts.
(b) Test voltage applied field windings 2600 volts. To imbedded temperature detector coils 1600 volts.
Comment: All OK.

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15. Insulation resistance (on each generator, see par. F-17):
 (a) Insulation resistance in megohms: R = Rotor S = Stator.
 (1) R100, S100 megohms, while generator is hot (approximate temperature of generator 70 °C.)
 (2) .... megohms, after generator has cooled (approximate temperature of generator .... °C.)

16. Tests of generator field rheostat (with generator for which intended, see par. F-19): Face Plate Type, S#444485
 (a) Heating and smoothness of voltage adjustment (at least one of each size and type on order): #5-44-Y-485 L&M-83Y500
 (1) Temperature rise at generator rated load: 123 amperes and 63 volts drop in rheostat set on contact segment #24.
 (a) Metal of resistive conductor 293 °C.
 (b) Imbedding material None °C.
 (c) Issuing air, 1" from resistor ~~xxxxxxx~~ in top row 270 °C.
 Issuing air 1 foot above top row of resistors-- 96°C.
 Resistance of gen. field at 40°C. is .464 ohm
 (2) Smoothness of voltage adjustment:
 (a) Range of close voltage adjustment from 90% 405 volts to 105% 472 volts.
 Steps No. V66 to V58 Variation .75% 3.4 volts per step between 90% 405 volts and 96% 432 volts.
 Steps No. V58 to V40 Variation .5% 2.2 volts per step between 96% 432 volts and 105% 472 volts.
 (3) Smoothness of grading the resistance:
 (a) Field current with no load maximum 179 amps., minimum 23 amps.
 (b) Open circuit generator voltage for each rheostat point; voltages: Max. 610, Min. 368
 (b) Check tests (on each rheostat with generator for which intended):
 (1) Dielectric test of 1,500 volts, 60 cycle A. C. for one minute OK. Insulation Resistance 400+ megohms.
 (2) Total ohmic resistance of rheostat 4.8 ohms.
 (3) Graduations in the resistance, steps 149. Step to step resistances OK by volts drop test.
 (4) Other comparisons with rheostat given complete test: Satisfactory.

17. Tests of automatic voltage regulator (see par. F-20): N.D. Spec. 17-R-2. Only Tests on component parts here:-
NOTE.—This test shall be made and reported on combined unit test (Form ISM-38 A or B).
Parts were given standard tests for control equipment. Each voltage regulator element / was calibrated.

18. Tests of generator spares (all spares, see par. F-18): Spare Parts List on Dwg. No. 31-J-651.

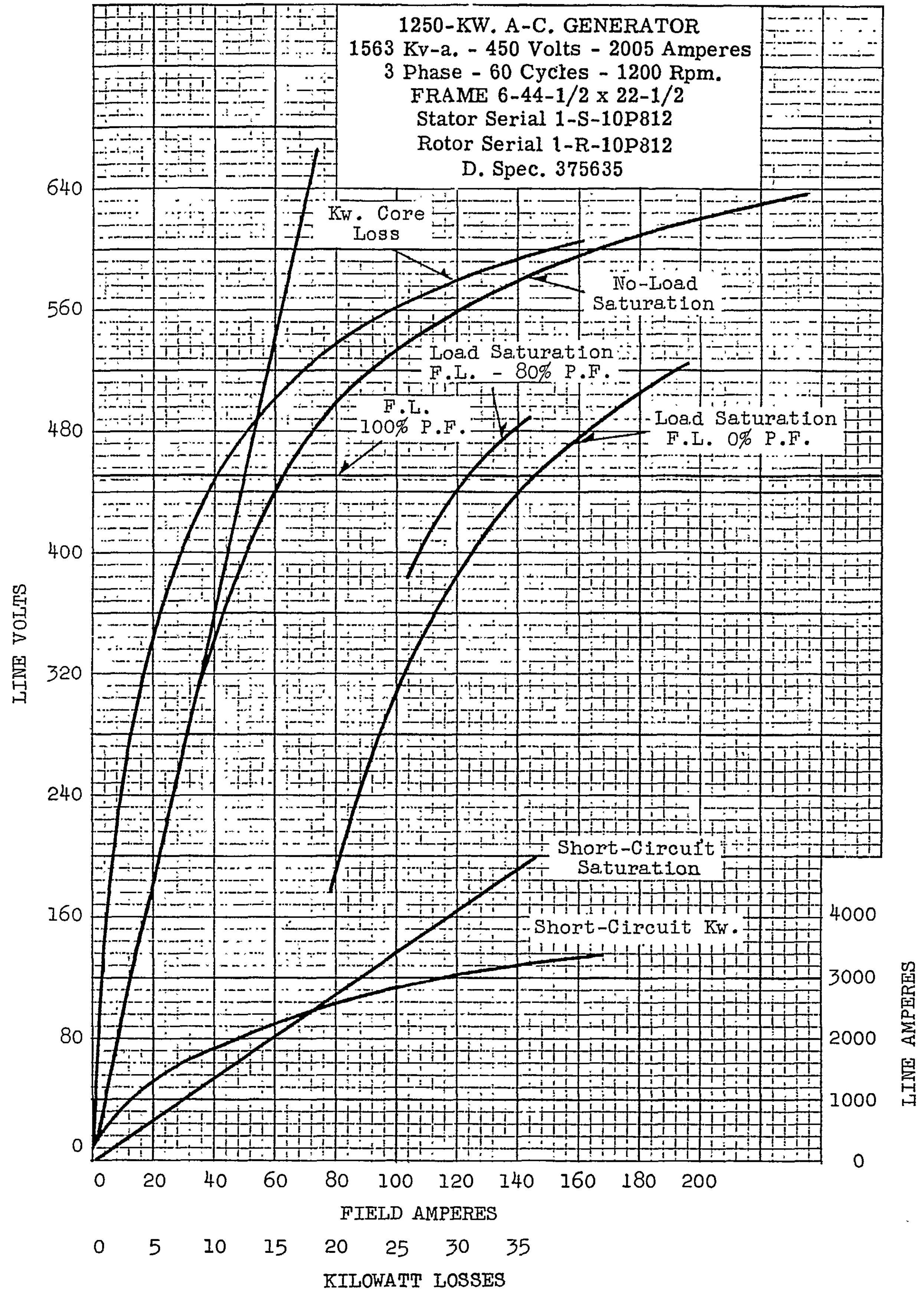
Item	Spare Parts as Applicable to Generator Furnished	Inspection Tests and Comments
A	Rotors, complete in every respect Serial No. 1-R-10P813,	2-R-10P813, 1-R-13P146, 2-R-13P146
	(a) Revolving field Tested in Frame	Tested in Fr. No.
	~~(b) Revolving armature~~	Tested in Fr. No.
B	Bearings or bearing linings (sleeve bearings shall be complete sets)	OK
C	Oil gages for sleeve type bearings (one complete unit of each type)	None
D	Brushes, carbon, complete set	OK
E	Brush holders, complete (three extra springs for each)	OK
F	Brush rigging insulation (complete sets of insulating pieces used)	OK
G	Coils of each size and type—including stator coils (complete sets)	OK Resistance readings Checked
H	Slot insulation (complete sets)	OK
I	Slip rings (complete assembly)	OK
J	Bearing lubricant seals (sets)	OK
K	Tools Packed with Exciter Spares.	OK
L	Protection and boxing Steel Boxing. Spec. 42B9	OK

19. Does the generator and spare parts meet the contract or order specifications and approved plans in every respect? Yes. This type test represents 32 generators, Serials No. 1 to 16-10P812, No. 1 to 16-13P145, 4 spare rotors above, and will represent 16 generators, Serials No. 1 to 16-15P184 for BB65-66, when these have been tested. A routine test was made on each generator. The 2nd generator given temperature tests as in Par. 11 was Serial No. 5-13P145; the rises were nearly the same as for this 1st generator, Serial No. 1-10P812.

Tests were made at the East Pittsburgh Works of the Westinghouse E. & M. Co. (1st on 7/1/41)

Inspector's signature,
(Signed) F.C. Hartman

Curve No. 266180



Revised 4 Jan. 1943

TEST No. 1-10P815
File C-70862

Date 28 April 1941

FACTORY TEST RECORD—D. C. GENERATORS

ISSUED BY THE BUREAU OF ENGINEERING, NAVY DEPARTMENT

To be used in connection with Navy Department Specifications 17G7 of latest issue

PRIME MOVER

Manufacturer ....

Manufacturer's serial No. ....

Refer to Test Record on supplementary Form ...., attached.

GENERATOR - EXCITER

(a) Manufacturer Westinghouse Electric & Manufacturing Company

Manufacturer's type and class Type SK - Frame #103-6 WG-31965-TP

Schedule No. .... Contract No. 70862 Navy Yard (or shipyard) Dwg. 5-A-9812

To be installed on U. S. S. Iowa - BB61; U.S.S. New Jersey - BB62.

(b) Generator classification:

(1) Prime mover Turbine

(2) Degree of inclosure Drip-proof - open

(3) Method of cooling Natural

(4) Distribution system ....

(5) Maximum unbalance in neutral (if 3-wire) ....

(6) Type of insulation, class A

(7) Voltage 120 Kilowatt 16 R. P. M. 1200

Main Poles
RECORD AIR GAP MEASUREMENTS, MINIMUM, AT EACH POLE

.080 .075 .076 .068 .068 .068

(c) Generator serial No. 1-S-10P815 Armature serial No. 1-R-10P815

Weight of generator 1161 Weight of armature 250

Number of poles 6 Diameter of armature 12 Diameter of commutator 9-1/4

Number of brush studs 6 Number brushes per stud 3 Brushes per set 18

Brush size 1-1/2 x 3/4 x 3/4 Brush grade B Brush manufacturer Stackpole Carbon

Collector ring brushes: Number None Size .... Grade .... Manufacturer ....

(d) Resistances:

	Calc. - At 75°C.	(Cold) 25° °C.	(Hot) 63° °C.
Armature	.02660	.02230	.02640
Shunt field	23.15	19.4	22.2)
Series field	.01018	.008525	.00979)
Interpole field	.00770	.006455	.00740) Calc.
Compensating field (if used)			

(e) Adjustment, fit, and materials Satisfactory in accordance with approved plans and specifications.

(f) Effectiveness of inclosure (type tests) Drip-proof as specified.

(g) Noise Not excessive.

(h) Balance Good

(i) Lubrication Oil - Navy Symbol 2110.

(j) Inclined operation 15° inclination test run made with exciter coupled to generator Serial No. 1-10P812

To be made on turbo-generator combined unit tests.

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(k) No-load saturation curve at normal rated speed (speed remaining constant throughout test):

ASCENDING		DESCENDING	
Generator volts	Shunt field amperes	Generator volts	Shunt field amperes
3.8	0	161	8.25
45.2	.74	149	5.58
59.8	1.02	134	3.56
77.9	1.36	120	2.43
98.6	1.84	103.4	1.82
108.4	2.13	88.6	1.54
120.0	2.57	73.4	1.18
139.8	4.12	54.5	0.85
161.0	8.25	49.8	0.76
		3.8	0

NOTE.—Plot curves on cross section paper, using above data, and attach them to this test report.

(l) For test data concerning voltage and speed regulation, parallel operation, heating, overload, and input—output, refer to Test Record .... on supplementary Form .... attached hereto.

(m) Commutation:

0-100% load, with gradual changes in load Satisfactory Comm. #1
0-125% load, with rapid changes in load Satisfactory 1
150% load Satisfactory 1

(n) Efficiency:

I^2R losses in windings	49.2	197	444	786
~~Bearing friction and windage~~				
~~Brush friction~~				
Core losses & F & W	555	555	555	555
Brush contact I^2R loss	66	132	200	266
~~Stray load losses~~ Loss	127.3	126	122	116
~~Miscellaneous losses~~				

Calculated efficiency at ¼ load 83.5 ½ load 89.0 ¾ load 90.2 ⁴⁄₄ load 90.3

(o) Overspeed: R. P. M. 1500 Time 15 Min. Remarks Satisfactory

(p) Dielectric strength: Volts 1400 Time 1 Min. Remarks Satisfactory

(q) Insulation resistance, megohms:

Following dielectric strength tests .4 Megohms at 50 ° C.
After generator has cooled down .45 Megohms at 25 ° C.

(r) Tests of generator shunt field rheostat:

Manufacturer Westinghouse Elec. & Mfg. Co. Serial or type No. Style No. 1169119
Number of resistance steps 66 in main plates, and 33 in 2 ohm vernier. Total resistance, cold (approx. 25° C.) 36.95 ohms

Range of voltage adjustment, per cent of rated voltage, volts	Number of resistance steps included in the range	Voltage variation per step, per cent of rated voltage	Resistance cut into circuit, or variation in resistance, to cover voltage range, ohms
Minimum to 90 per cent 102.5 to 108			
90 per cent to 105 per cent 108 to 126			
90 per cent to 96 per cent 108 to 115			
96 per cent to 105 per cent 115 to 126			

With generator operating without load, at rated speed:

Rheostat position	Shunt field amperes	Generator volts
All in	1.24	102.5
All out	7.65	162
Normal-load setting	2.38	120

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(r) Tests or generator shunt field rheostat—*Continued.*

Resistance gradation (step by step), voltage drop per step, rheostat in "all in" position, holding the current constant

Temperature rises, at normal setting 71.5 volts drop across rheostat and 2.54 amperes:- 130°C. rise on resistance imbedding material, 43°C. rise for air one inch from edge of rheostat plates, at room air temperature of 27°C.

Dielectric strength: Volts 1600 Time 1 Minute Remarks OK.

Insulation resistance: (a) Cold, 25 °C. 120 megohms. (b) Hot, 50 °C. 700 megohms.

(s) Tests of miscellaneous spares (enumerate articles and state character of inspection and tests) All spares checked for interchangeability.

(t) Tests of spare armatures: Running tests Each of the 4 spare armatures were given complete Routine Tests including - No-Load Saturated Curves, Voltage Regulation, Overload and Overspeed.

Cold resistance .022 ohms, at 26.5 °C.

Insulation resistance 100 ohms, at 40 °C.

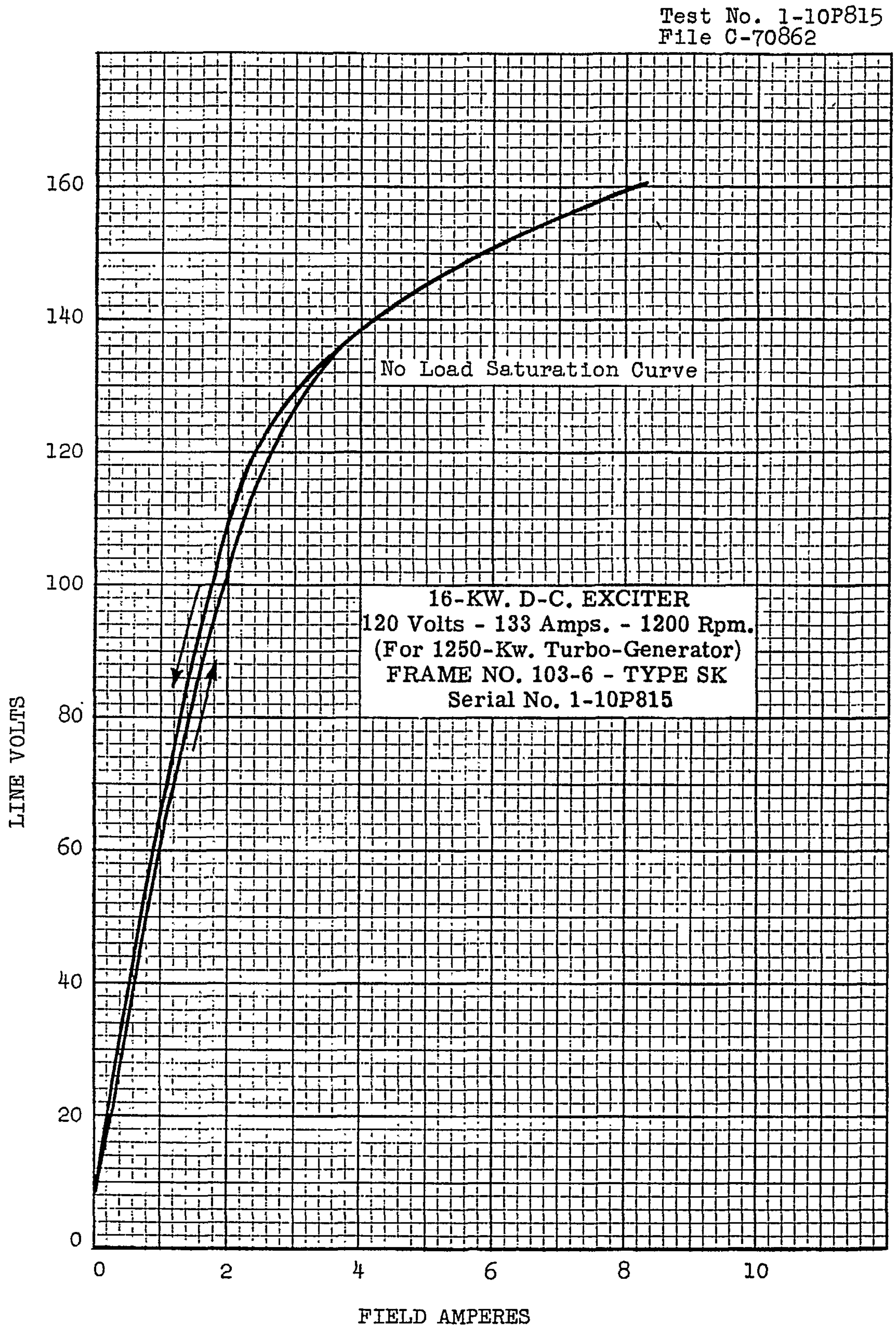
Dielectric strength: Volts 1600 Time 1 Min. Remarks OK

(u) Does the generator meet the specifications in every respect Yes. This test record represents the performance of 16 similar generators - Serials No. 1 to 16-10-P-815. All were given Routine Tests per Navy Specifications 17G7.

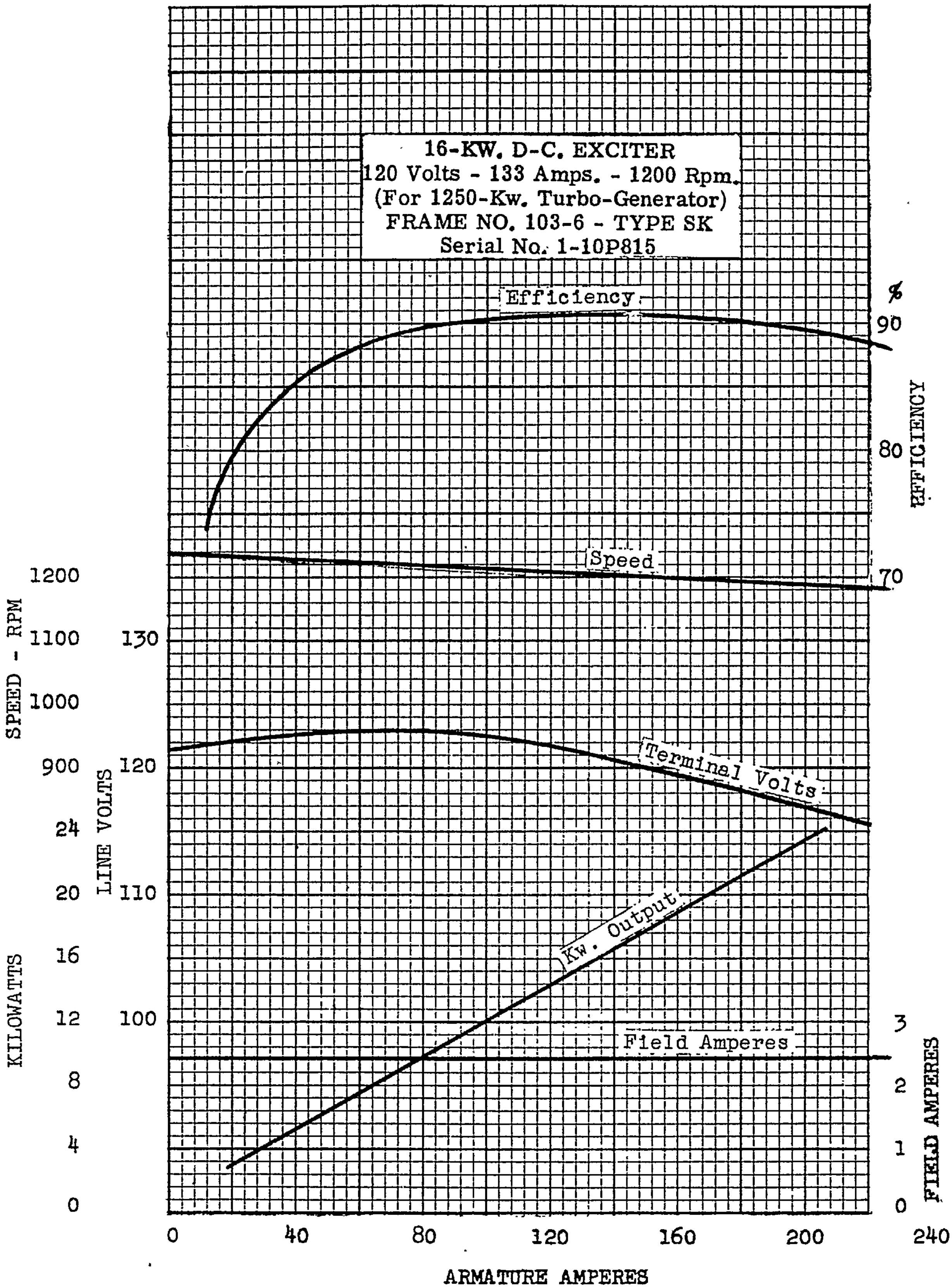
(v) Tests made at Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

Inspector's signature (Signed) J. J. Courtin

See 2 attached curve sheets marked 1-10P815.
This type test also represents 16 exciters, Serials No. 1 to 16-13P148 for BB63-64, and will represent 16 more exciters, Serials No. 1 to 16-15P187 for BB65-66, when they have been tested.


Test No. 1-10P815
File C-70862
No Load Saturation Curve
16-KW. D-C. EXCITER
120 Volts - 133 Amps. - 1200 Rpm.
(For 1250-Kw. Turbo-Generator)
FRAME NO. 103-6 - TYPE SK
Serial No. 1-10P815
LINE VOLTS
0
20
40
60
80
100
120
140
160
FIELD AMPERES
0
2
4
6
8
10

Test 1-10P815
File C-70862



PART V

SPARE PARTS AND TOOLS

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Ship's Spares—See Note "A", Page 510).

Item No.	Name of Piece	No. Req.	DRAWING NUMBER Contractor	Pc.	Bureau Ship's	Remarks
1	Oil Cooler Gasket	8	25-J-266	33	BB61-S61-107	
2	Oil Cooler Gasket	4	25-J-266	34		
3	Oil Cooler Gasket	4	25-J-266	35		
4	Pipe Plug	16	25-J-266	39		
5	Zinc Bar	16	25-J-266	40	BB61-S61-107	
7	Auto-Stop Governor Body	1	25-J-504	1	BB61-S61-76	
8	Weight	1	25-J-504	2		
9	Welding Rod	1	25-J-504	3		
10	Spring	2	25-J-504	4		
11	Retainer Half	2	25-J-504	5		
12	Nut	1	25-J-504	6		
13	Liner	1	25-J-504	7		
14	Liner	2	25-J-504	8		
15	Liner	1	25-J-504	9		
16	Liner	1	25-J-504	10		
17	Liner	1	25-J-504	11		
18	Set Screw	1	25-J-504	12		
19	Trip Lever	1	25-J-504	13		
20	Trip Latch	1	25-J-504	14		
21	Tip	2	25-J-504	15		
22	Lever Shaft	1	25-J-504	16		
23	Latch Pin	1	25-J-504	17		
24	Taper Pin	2	25-J-504	18		
25	Latch Spring	1	25-J-504	19		
26	Reset Bushing	1	25-J-504	21		
27	Fulcrum Pin	1	25-J-504	22		
28	Trip Spring	2	25-J-504	30		
29	Bracket Bushing	2	25-J-504	37		
30	Trip Lever Bushing	2	25-J-504	47		
31	Reset Handle Bushing	1	25-J-504	48		
32	Clevis Pin	2	25-J-504	49		
33	Clevis Pin	1	25-J-504	50		
34	Headless Set Screw	1	25-J-504	57	BB61-S61-76	
42	Oil-Flow Indicator Cover Glass	1	25-J-506	15	BB61-S61-37	
45	Gear Bearing (Upper Half) Generator End	1	25-J-507	1	BB61-S61-58	
46	Gear Bearing (Lower Half) Generator End	1	25-J-507	2		
47	Babbitt	10-1/2 lb.	25-J-507	3		
48	Dowel Pin	12	25-J-507	4		
49	Stop Pin	2	25-J-507	5		
50	Gear Bearing (Upper Half) Turbine End	1	25-J-507	6		
51	Gear Bearing (Lower Half) Turbine End	1	25-J-507	7		
52	Babbitt	10-1/2 lb.	25-J-507	8	BB61-S61-58	

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Ship's Spares—See Note "A", Page 510).

Item No.	Name of Piece	No. Req.	DRAWING NUMBER Contractor	Pc.	Bureau Ship's	Remarks
53	Pinion Bearing (Upper Half) Generator End	1	25-J-507	9	BB61-S61-58	
54	Pinion Bearing (Upper Half) Turbine End	1	25-J-507	10		
55	Pinion Bearing (Lower Half	2	25-J-507	11		
56	Babbitt	12 lb.	25-J-507	12		
57	Stop Pin	2	25-J-507	13		
58	Nipple	1	25-J-507	14		
59	Turbine Bearing (Upper Half)	2	25-J-507	15		
60	Turbine Bearing (Lower Half) Thrust End	1	25-J-507	16		
61	Turbine Bearing (Lower Half) Coupling End	1	25-J-507	17		
62	Babbitt	10 lb.	25-J-507	18		Assembled as one unit
63	Stop Pin	2	25-J-507	19		
64	Bearing Baffle (Half)	4	25-J-507	20		
65	Thrust Ring (Half)	4	25-J-507	21		
66	Screw (Fillister Head)	12	25-J-507	22		
67	Thrust Liner	8	25-J-507	23		
68	Thrust Liner	4	25-J-507	24		
69	Thrust Liner	8	25-J-507	25	BB61-S61-58	
73	Thrust Bearing Collar	1	25-J-508	4	BB61-S61-21	
74	Thrust Bearing Shoe	12	25-J-508	5		Assembled as one unit
75	Babbitt	1 lb.	25-J-508	6		
76	Support	12	25-J-508	7	BB61-S61-21	
79	Gages (For Gage Board)	1 ea.	25-J-643	10-14	CV9-S6100-522	
83	Gage	1	25-J-470	50	C31-S6100-61213	
86	Gear Shaft Oil Ring (Lower Half)	1	25-J-526	22	BB61-S61-23	
87	Gear Shaft Oil Ring (Upper Half)	1	25-J-526	23		
88	Baffle (Lower Half)	1	25-J-526	24		
89	Baffle (Upper Half)	1	25-J-526	25	BB61-S61-23	
91	Governor Details		25-J-487		BB61-S61-138	
92	Bushing	2	25-J-487	4		
93	Bushing	10	25-J-487	5		
94	Rod	1	25-J-487	6		
95	Bushing	2	25-J-487	24		
96	Adjusting Nut	2	25-J-487	26		
97	Pin	1	25-J-487	27	BB61-S61-138	
99	Governor Relay Bushing	1	25-J-488	1	BB61-S61-139	
100	Piston Rod	1	25-J-488	2		
101	Governor Closing Spring	2	25-J-488	5		
102	Governor Spring	2	25-J-488	6		
103	Spring Seat (Upper)	1	25-J-488	7		
104	Relay Rod-See Item No. 126	1	25-J-488	8		
105	Spring Seat (Lower)	1	25-J-488	9		
106	Spring Seat (Upper)	1	25-J-488	10		
107	Relay-See Item 126	1	25-J-488	11	BB61-S61-139	

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Ship's Spares—See Note "A", Page 510).

Item No.	Name of Piece	No. Req.	DRAWING NUMBER Contractor	Pc.	Bureau Ship's	Remarks
108	Speed Regulator Spring	2	25-J-488	12	BB61-S61-139	
109	Bushing	1	25-J-488	13		
110	Bushing	4	25-J-488	14		
111	Bushing	1	25-J-488	15		
112	Motor Shaft Extension	1	25-J-488	16		
113	Clutch Plate	1	25-J-488	19		
114	Clutch Plate	1	25-J-488	20		
115	Clutch Collar	1	25-J-488	21		
116	Worm Wheel	1	25-J-488	23		
117	Spring	2	25-J-488	24		
118	Worm Gear	1	25-J-488	25		
119	Handwheel Stem	1	25-J-488	26		
120	Worm	1	25-J-488	27		
121	Pin	4	25-J-488	29		
122	Bushing	1	25-J-488	31		
123	Pin	1	25-J-488	36		
124	Piston Ring	1	25-J-488	37		
125	Castle Nut	1	25-J-488	41		
126	Relay (Complete)	1	25-J-488	42		
127	Pin	1	25-J-488	43	BB61-S61-139	
130	Transformer Housing	1	25-J-489	1	BB61-S61-140	See Note C
131	Orifice	1	25-J-489	2		See Note C
132	Bolt	4	25-J-489	3		See Note D
133	Cap Screw	3	25-J-489	4		See Note C
135	Ring	1	25-J-489	6		See Note C
136	Bushing	1	25-J-489	7		See Note C
137	Relay	1	25-J-489	8		See Note C
139	Stop Ring	1	25-J-489	10		See Note C
140	Ring	1	25-J-489	11		See Note C
141	Welding Rod	1	25-J-489	12		See Note C
142	Stop Flange	1	25-J-489	13		See Note C
143	Cap Screw	4	25-J-489	14		See Note C
144	Worm Wheel	1	25-J-489	15		See Note C
145	Set Screw	1	25-J-489	16		See Note C
146	Pipe Plug	3	25-J-489	17		See Note C
147	Cap Screw	2	25-J-489	18		See Note C
148	Cap Screw	4	25-J-489	19		
149	Casing	1	25-J-489	20		See Note D
150	Cylinder (Outer)	1	25-J-489	21		See Note D
151	Cylinder (Inner)	1	25-J-489	22		See Note D
152	Hub	1	25-J-489	23		See Note D
153	Contact Ball	4	25-J-489	24		See Note D
154	Spring Guide	10	25-J-489	25		See Notes D&E
155	Spring Retainer	10	25-J-489	26		See Notes D&E
156	Seat	1	25-J-489	27		See Note D
157	Governor Weight	2	25-J-489	28		See Note D
158	Pin Key	1	25-J-489	29	BB61-S61-140	See Note D

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Ship's Spares—See Note "A", Page 510).

Item No.	Name of Piece	No. Req.	DRAWING NUMBER Contractor	Pc.	Bureau Ship's	Remarks
159	Governor Stop Screw	2	25-J-489	30	BB61-S61-140	See Note D
160	Spring	5	25-J-489	31		See Notes D&E
161	Spring Seat	1	25-J-489	32		See Note D
162	Clamp Bar	1	25-J-489	33		See Note D
163	Ball Seat	4	25-J-489	34		See Note D
164	Spacer	2	25-J-489	35		See Note D
165	Headless Set Screw	1	25-J-489	36		See Note D
166	Governor Spring	2	25-J-489	37		See Note D
167	Pin	4	25-J-489	38		See Note D
168	Cotter Wire	1	25-J-489	39		See Note D
169	Button Head Rivet	10	25-J-489	40		See Notes D&E
170	Nut	2	25-J-489	41		See Note D
171	Round Head Cap Screw	2	25-J-489	42		See Note D
172	Lock Nut	1	25-J-489	43		See Note D
173	Thrust Bearing	4	25-J-489	44		See Note D
174	Elastic Stop Nut	1	25-J-489	45		
175	Stud	1	25-J-489	46		
176	Pipe Plug	1	25-J-489	47		See Note D
177	Pin-Assemble with Item No. 137	1	25-J-489	48		See Note C
178	Screw, Oval Fillister Head Machine	2	25-J-489	49		See Note C
179	Liner	2	25-J-489	50		See Note C
180	Liner	1	25-J-489	51		See Note C
181	Liner	1	25-J-489	52		See Note C
182	Liner	1	25-J-489	53	BB61-S61-140	See Note C
185	Governor Body Bearing	4	25-J-490	3	BB61-S61-141	
186	Sleeve	1	25-J-490	4		
187	Sleeve Nut	1	25-J-490	5		
188	Oil Filter	1	25-J-490	9		
189	Straight Pin	2	25-J-490	14		
190	Spiral Gear (Driven)	1	25-J-490	15		
191	Spiral Gear (Driver)	1	25-J-490	16		
192	Liner	1	25-J-490	17		
193	Set Screw Dog Point	1	25-J-490	18		
194	Governor Body Shaft Key	1	25-J-490	19		
195	Governor Body Bearing	4	25-J-490	20		
196	Babbitt-For Items No.185 & 195	8 Sets	25-J-490	21	BB61-S61-141	
197	Valve No. 3	1	25-J-492	6	BB61-S61-143	
198	Valve Seat No. 2 and 5	2	25-J-492	8		
199	Valve Seat No. 1, 4 and 6	3	25-J-492	9		
200	Valve No. 2 and 5	2	25-J-492	10		
201	Valve No. 1, 4 and 6	3	25-J-492	11		
202	Welding Rod-For Item 197,198, 199,200,201 and 210	1 Set	25-J-492	12		
203	Lifting Rod	2	25-J-492	14		
204	Bushing (Upper)	2	25-J-492	15		
205	Bushing (Lower)	2	25-J-492	16		
206	Bushing	2	25-J-492	24		
207	Bushing	2	25-J-492	25		
208	Bushing	2	25-J-492	26	BB61-S61-143	

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Ship's Spares—See Note "A", Page 510).

Item No.	Name of Piece	No. Req.	DRAWING Contractor	Pc.	NUMBER Bureau Ship's	Remarks
209	Bushing	2	25-J-492	27	BB61-S61-143	
210	Valve Seat No. 3	1	25-J-492	40	BB61-S61-143	
212	Steam Piping Gage	1	25-J-565	32	BB61-S61-102	
216	Oil Strainer Packing	3 Rows	25-J-576	9	BB61-S61-83	
217	Basket Support	1	25-J-576	16		
218	Basket (Side)	1	25-J-576	16-A		
219	Basket (Bottom)	1	25-J-576	16-B		
220	Basket Handle.	1	25-J-576	16C		
221	Rivet	6	25-J-576	16D		
222	Union Nut	1	25-J-576	16F		
223	Union Check Nut	1	25-J-576	16G		
224	Pin	1	25-J-576	16J		
225	Basket (Side)	1	25-J-576	16M		
226	Basket (Bottom)	1	25-J-576	16MB		
227	Basket Ring	1	25-J-576	16S		
228	Magnet	6	25-J-576	17		
229	Magnet Rod	1	25-J-576	17A		
230	Magnet Pin	6	25-J-576	17C		
231	St. Jam Hex Nut	2	25-J-576	17D		
232	Nut	1	25-J-576	17E		
233	Pin (For Pc. 17E)	1	25-J-576	17F		
234	Union Plug	1	25-J-576	16E	BB61-S61-83	
236	Governor Speed-Changer (Motor Armature Complete)	1	31-J-755	54	BB61-S61-97	
237	Ball Bearing, No. 6200 SKF . .	4	31-J-755	3		
238	Brushes	24	31-J-755	13		
239	Brush Springs	6	31-J-755	8		
240	Brushholder	2	31-J-755	34		
241	Brushholder Screw	2	31-J-755	11		
242	Field Coil Set	8	31-J-755	17		
243	Brushholder Insulation	2	31-J-755	34	BB61-S61-97	
246	Relief Valve Spring	2	25-J-551	10	BB61-S61-49	
251	Relief Valve Oil Line Spring .	1	25-J-580	6	BB61-S61-115	
252	Relief Valve Oil Line Spring .	1	25-J-580	15	BB61-S61-115	
253	Throttle Valve Spring	1	25-J-566	68	BB61-S61-66	
255	Back-Pressure Safety Stop Spring	1	25-J-505	75	BB61-S61-77	
257	Oil Piping Thermometer	1	25-J-543	2	BB61-S61-105	
259	Oil Piping Sight-Flow Glass .	2	25-J-544	67	BB61-S61-106	Assembled
260	Spring Complete	2	25-J-544	86-87 88-92	BB61-S61-106	
262	Oil Pump Gear (Driver)	1	25-J-545	4	BB61-S61-44	
263	Pump Gear Shaft (Driver) . . .	1	25-J-545	5		
264	Pump Gear (Driven)	1	25-J-545	6		
265	Pump Gear Shaft (Driven) . . .	1	25-J-545	7		
266	Shaft Sleeve	1	25-J-545	8		
267	Bushing	2	25-J-545	11		
268	Pump Gear Key	2	25-J-545	12		
269	Bushing	2	25-J-545	17	BB61-S61-44	
271	Spindle Gland Packing Ring . .	8	25-J-558	10	BB61-S61-80	
272	Retainer Ring Segment	64	25-J-558	11	BB61-S61-80	

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Ship's Spares—See Note "A", Page 510).

Item No.	Name of Piece	No. Req.	DRAWING NUMBER Contractor	Pc.	Bureau Ship's	Remarks
273	Key	16	25-J-558	12	BB61-S61-80	
274	Spring	16	25-J-558	16	BB61-S61-80	
275	Packing Ring	8	25-J-558	26	BB61-S61-80	
278	Spindle Position Indicator . .		25-J-561		BB61-S61-99	
279	Contact Ball	1	25-J-561	4		
280	Retainer	1	25-J-561	5		
281	Spring	1	25-J-561	6		
282	Spindle	1	25-J-561	7		
283	Bushing	1	25-J-561	8	BB61-S61-99	

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Shore Spares—See Note "B", Page 510).

Item No.	NAME OF PIECE	No. Req.	DRAWING NUMBER			Remarks
			Contractor	Pc.	Bureau Ship's	
307	Blade (1st Rotating)	83	25-J-510	2	BB61-S61-78	
308	Blade (Last)(Rotating)	2	25-J-510	3		
309	Blade Stationary	27	25-J-510	4		
310	Blade (2nd Rotating)	71	25-J-510	5		
311	Blade (Last) Rotating)	2	25-J-510	6		
312	Pin (1st Rotating)	3	25-J-510	7		
313	Pin (2nd Rotating)	3	25-J-510	8		
314	Shroud Stock	12ft.	25-J-510	11		
315	Blade Start Piece	1	25-J-510	13		
316	Blade Stop Piece	1	25-J-510	14		
317	Screw (Flat Fil. Head)	2	25-J-510	15		
318	Caulking Piece	168	25-J-510	16		
319	Caulking Piece	44	25-J-510	17		
320	Caulking Piece	384	25-J-510	18		
321	Caulking Piece	88	25-J-510	19		
322	Caulking Piece	28	25-J-510	20		
323	Sealing Strip	2	25-J-510	21		
324	Sealing Strip	1	25-J-510	22		
325	Sealing Strip	1	25-J-510	23		
326	Lock Strip	4	25-J-510	24	BB61-S61-78	
331	Blade (1st Stage)	153	25-J-512	2	BB61-S61-81	
332	Blade (Last)(Stage)	2	25-J-512	3		
333	Shroud (1st Stage)	See It.366	25-J-512	4		
334	Shroud (1st Stage)	See It.366	25-J-512	5		
335	Blade (2nd Stage)	153	25-J-512	6		
336	Blade (Last) (Stage)	2	25-J-512	7		
337	Shroud (2nd Stage)	See It.366	25-J-512	8		
338	Shroud (2nd Stage)	See It.366	25-J-512	9		
339	Blade (3rd Stage)	153	25-J-512	10		
340	Blade (Last) (3rd Stage)	2	25-J-512	11		
341	Shroud (3rd Stage)	See It.366	25-J-512	12		
342	Shroud (3rd Stage)	See It.366	25-J-512	13		
343	Blade (4th Stage)	153	25-J-512	14		
344	Blade (Last) (4th Stage)	2	25-J-512	15		
345	Shroud (4th Stage)	See It.366	25-J-512	16		
346	Shroud (4th Stage)	See It.366	25-J-512	17		
347	Blade (5th Stage)	153	25-J-512	18		
348	Blade (Last)(5th Stage)	2	25-J-512	19		
349	Shroud (5th Stage)	See It.366	25-J-512 25-J-512	20		
350	Shroud (5th Stage)	See It.366	25-J-512	21		
351	Blade (6th Stage)	153	25-J-512	22	BB61-S61-81	

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Shore Spares—See Note "B", Page 510).

Item No.	NAME OF PIECE	No. Req.	DRAWING Contractor	Pc.	NUMBER Bureau Ship's	Remarks
352	Blade (Last) (6th Stage)	2	25-J-512	23	BB61-S61-81	
353	Shroud (6th Stage)	See It.366	25-J-512	24		
354	Shroud (6th Stage)	See It.366	25-J-512	25		
355	Blade (7th Stage)	153	25-J-512	26		
356	Blade (Last) (7th Stage)	2	25-J-512	27		
357	Shroud (7th Stage)	See It.366	25-J-512	28		
358	Shroud (7th Stage)	See It.366	25-J-512	29		
359	Blade (8th Stage)	125	25-J-512	30		
360	Blade (Last) (8th Stage)	2	25-J-512	31		
361	Shroud (8th Stage)	See It.367	25-J-512	32		
362	Shroud (8th Stage)	See It.367	25-J-512	33		
363	Caulking Piece	150	25-J-512	34		
364	Caulking Piece	1050	25-J-512	35		
365	Shroud (8th Stage)	See It.367	25-J-512	36		
366	Shroud Stock 1st to 7th Rows Inclusive	40'	25-J-512	37		3/32 x 7/8 See Note F
367	Shroud Stock 8th Rotating Row	7'	25-J-512	38	BB61-S61-81	1/8 x 1" See Note F
368	Blade Pin	16	25-J-513	1	BB61-S61-111	
369	Blade Pin	3	25-J-513	2	BB61-S61-111	
372	Low-Pressure Oil-Alarm Contact-Maker	1 Set	25-J-532	1 to 35 Incl.	BB61-S65-427	Assemble as one complete contact maker
375	Nozzle Block Welding and Assembly	1	25-J-534	1	BB61-S61-63	
376	Passage Unit	9	25-J-534	5		
377	Starting Piece	1	25-J-534	6		
378	Ending Piece	1	25-J-534	7		
379	Outer Ring Segment	1	25-J-534	8		
380	Inner Ring Segment	1	25-J-534	9		
381	Filler Piece	1	25-J-534	10		
382	Filler Piece	1	25-J-534	11		
383	End Bridge	1	25-J-534	12		
384	End Bridge	1	25-J-534	13		
385	Intermediate Bridge	4	25-J-534	14		
386	Filler Ring	1	25-J-534	16		
387	Wedge	30	25-J-534	17		
388	Locking Strip	2	25-J-534	18		
389	Sealing Strip	1	25-J-534	19		
390	Sealing Strip	1	25-J-534	20		
391	Screw	9	25-J-534	22		
392	Screw	2	25-J-534	23		
393	Welding Rod	1	25-J-534	24	BB61-S61-63	

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Shore Spares—See Note "B", Page 510).

Item No.	NAME OF PIECE	No. Req.	DRAWING Contractor	DRAWING Pc.	NUMBERS Bureau Ship's	Remarks
394	Welding Rod	1	25-J-534	25	BB61-S61-63	
395	Welding Rod	1	25-J-534	26	BB61-S61-63	
397	Sealing Strip (Half)	2	25-J-535	11	BB61-S61-64	
398	Locking Strip (Half)	2	25-J-535	12	BB61-S61-64	
400	Sealing Strip (Half)	2	25-J-536	15	BB61-S61-65	
401	Locking Strip (Half)	2	25-J-536	16	BB61-S61-65	
403	Sealing Strip (Half)	2	25-J-537	15	BB61-S61-73	
404	Locking Strip (Half)	2	25-J-537	16	BB61-S61-73	
406	Sealing Strip (Half)	2	25-J-538	15	BB61-S61-87	
407	Locking Strip (Half)	2	25-J-538	16	BB61-S61-87	
409	Sealing Strip (Half)	2	25-J-539	15	BB61-S61-85	
410	Locking Strip (Half)	2	25-J-539	16	BB61-S61-85	
412	Sealing Strip (Half)	2	25-J-540	15	BB61-S61-86	
413	Locking Strip (Half)	2	25-J-540	16	BB61-S61-86	
415	Sealing Strip (Half)	2	25-J-541	15	BB61-S61-91	
416	Locking Strip (Half)	2	25-J-541	16	BB61-S61-91	
418	Sealing Strip (Half)	2	25-J-542	15	BB61-S61-92	
419	Locking Strip (Half)	2	25-J-542	16	BB61-S61-92	
422	Pinion	1	25-J-550	10	BB61-S61-34	
423	Pinion Key	2	25-J-550	11	BB61-S61-34	
426	Relief Valve	1	25-J-551	1-22	BB61-S61-49	Assemble as Complete Valve
429	Seal Strip Ring	4	25-J-552	2	BB61-S61-114	
430	Seal Strip Ring	4	25-J-552	3		
431	Seal Strip Ring Segment	4	25-J-552	4		
432	Seal Strip Ring Segment	4	25-J-552	5		
433	Seal Strip Ring Segment	4	25-J-552	6		
434	Seal Strip Ring Segment	4	25-J-552	7		
435	Spring	16	25-J-552	9		
436	Seal Strip (Half)	12	25-J-552	10		
437	Seal Strip (Quarter)	24	25-J-552	11		
438	Seal Strip (Half)	12	25-J-552	12		
439	Seal Strip (Quarter)	24	25-J-552	13		
440	Caulking Strip (Half)	12	25-J-552	14		
441	Caulking Strip (Quarter)	24	25-J-552	15		
442	Seal Strip (Ring Segment) . . .	4	25-J-552	16		
443	Seal Strip (Ring Segment) . . .	4	25-J-552	17		
444	Seal Strip (Ring Segment) . . .	4	25-J-552	18		
445	Seal Strip (Ring Segment) . . .	4	25-J-552	19	BB61-S61-114	
448	Throttle Valve Assembly	1 Set	25-J-566	Comp.	BB61-S61-66	
452	Steam Strainer	1	25-J-571	3	BB61-S61-50	
453	Collar	2	25-J-571	4	BB61-S61-50	
454	Gasket	1	25-J-571	7	BB61-S61-50	
455	Cross Bar	1	25-J-571	8	BB61-S61-50	
457	Back-Pressure Safety . . . . . . Stop Diaphragm	1	25-J-505	63-65 79-80	BB61-S61-77	Assembled
459	Relief Valve	1	25-J-544	84-93	BB61-S61-106	Assembled

SPARE PARTS LIST FOR TURBINE AND REDUCTION GEAR

(Shore Spares—See Note "B", Page 510).

Item No.	NAME OF PIECE	No. Req.	DRAWING Contractor	Pc.	NUMBER Bureau Ship's	Remarks
478	Relief Valve Oil Line Cap. . . .	1	25-J-580	1	BB61-S61-115	
479	Adjusting Screw	1	25-J-580	2		
480	Locknut	1	25-J-580	3		
481	Gasket.	1	25-J-580	4		
482	Spring Step	2	25-J-580	5		
483	Spring..	1	25-J-580	6		
484	Cover	1	25-J-580	7		
485	Stem.	1	25-J-580	8		
486	Name Plate.	1	25-J-580	9		
487	Star.	1	25-J-580	10		
488	Sleeve.	1	25-J-580	11		
489	Body.	1	25-J-580	12		
490	Gasket.	1	25-J-580	13		
491	Drive Screw	2	25-J-580	14	BB61-S61-115	

NOTE "A" - Quantities indicated in Req. columns for ship spares are sufficient for one set. One set furnished per ship.

NOTE "B" - Quantities indicated in Req. columns for shore spares are sufficient for one set. Two (2) sets furnished for contract.

NOTE "C" - Assemble one set of Items 130, 131, 133, 135, 136, 137, 139 to 147 inclusive and 177 to 182 inclusive per ship.

NOTE "D" - Assemble one set of Items 132, 149 to 173 and 176 per ship.

NOTE "E" - Assemble four (4) sets of Items, 154, 155, 160 and 169 per ship.

NOTE "F" - Spare shroud stock to be furnished without holes for blade tenons and in convenient lengths for shipping.

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 34-J-902 BUREAU NO. CV9-S6100-577

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION : SHIP'S POWER & LIGHT

NAVY CONTRACT NOs. 93968 APPLIANCE : 1250-KW. TURB. GEN.

SHIPBUILDER'S ORDER NO. MANUFACTURER W. E. & M. CO.

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA			BUREAU DRAWING AND PIECE NUMBER	
				CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO. PC.	DWG. NO.	PC.	DWG. NO.
			SHORE SPARES					
			ONE SET SHORE SPARES CONSISTS OF ITEM 1 TO 3 INC.					
1	1	72	Stator Coils	D. 2-C-8998 Group 1	15 16	34-J-902		CV9-S6100-577
2	1	1	Slot Insulation	D. 36-J-838 Group 2	16 17 18 20 24 33 40	34-J-902		CV9-S6100-577
3	1	6	Rotor Coils Complete 2 Open 1 Open 2 Crossed 1 Crossed Includes Washers.	D. 9-B-3561 Group 1	117 to 123 217 to 223	34-J-902		CV9-S6100-577

G.O. WG-35060-TP SPARE PARTS S.O. 19-P-144

SPARE COILS (STOWED ASHORE) FOR USE WITH 1250-KW. TURBINE GENERATOR FRAME 6-44-1/2 - 22-1/2 BUILT ON S.O. 16-P-688 and 19-P-143

LEGEND—
- S—STYLE NUMBER
- D—DRAWING NUMBER
- L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.

WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 2 SHEET NO. 1

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 34-J-902 **BUREAU NO.** CV9-S6100-577

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION : SHIP'S POWER & LIGHT

NAVY CONTRACT NOs. 93968 **APPLIANCE :** 1250 KW. TURB.GEN.

SHIPBUILDER'S ORDER NO. **MANUFACTURER** **W. E. & M. CO.**

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA: CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO.: PC.	MFRS. DRAWING AND PIECE NO.: DWG. NO.	BUREAU DRAWING AND PIECE NUMBER: PC.	BUREAU DRAWING AND PIECE NUMBER: DWG. NO.
			SHIP'S SPARES					
			ONE SET SHIP SPARES CONSISTS OF ITEMS 4 to 13 INC.					
4	1	1	Bearing Lining (Refer to Coils, Insulation and Bearing Drawing 34-J-903 (CV31-S6100-414994) Before Using this Bearing as a Replacement.	D. 9-B-3455 Group 1	71 72 73	34-J-902		CV9-S6100-577
5	3	2	Bearing Oil Seals (Seal & Lock Strips)	D. 9-B-3484 Its. 3-4	77 78	34-J-902		CV9-S6100-577
6	3	2	Bearing Seal	D. 14-A-8188 It. 21	74	34-J-902		CV9-S6100-577
7	3	1	Air Seal (Seal & Lock Strips)	D. 9-A-3457 Its. 3-4	52 53	34-J-902		CV9-S6100-577
8	4	8	Brushes, Carbon Complete Sets	S. 1 240 018	81	34-J-902		CV9-S6100-577
9	1/8	8	Brushholder Complete	D. 9-B-3598 Group 1	79 80	34-J-902		CV9-S6100-577
10	3/8	8	Brushholder Springs	D. 9-B-3598 Group 2	80	34-J-902		CV9-S6100-577
11	1	1	Brush Rig. Insul.	D. 14-A-8212 Its. 3 to 7	83 84 86 87	34-J-902		CV9-S6100-577
12	1	1	Brush Tension Spring Balance } Furnished with Onboard Exciter Spare Parts					
13	1	1	Air Gap Feeler Gage } Furnished with Onboard Exciter Spare Parts					
*	1	1	Generator Field Discharge Resistor	S. 389 078	2	5-A-9347		

G.O. WG-35060-TP SPARE PARTS { S.O. 19-P-144, S.O. 19-P-149

SPARE PARTS (STOWED ABOARD SHIP) FOR USE WITH 1250-KW. TURBINE GENERATOR FRAME 6 - 44-1/2 - 22-1/2. BUILT ON S.O. 19-P-143 and 16-P-688.

* LISTED ON DRAWING 5-A-9347

LEGEND—
S—STYLE NUMBER
D—DRAWING NUMBER
L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.
WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 2 SHEET NO. 2

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 35-J-487 BUREAU NO. CV9-S6100-591

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION: EXCITERS FOR A.C. GENERATOR

NAVY CONTRACT NO. NOs. 93968 APPLIANCE: D.C. EXCITER

SHIPBUILDER'S ORDER NO. MANUFACTURER W. E. & M. CO.

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA: CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO.: PC.	MFRS. DRAWING AND PIECE NO.: DWG. NO.	BUREAU DRAWING AND PIECE NUMBER: PC.	BUREAU DRAWING AND PIECE NUMBER: DWG. NO.
			SHORE SPARES					
1	1	1	Armature Complete	D. 3-B-8878		34-J-902		
			SHIP'S SPARES					
2	1	1	Bearing Complete (It. 1 and. 2)	D. 84-C-168		34-J-902		
3	1/18	18	Brush Holder	S. 828 217		34-J-902		
4	1		Brush Stud Insulation Consisting Of					
		1	Rocker Ring (It. 1)	D. 6-D-9288		34-J-902		
5	3/18	18	Brush Holder Springs Comp. Brush Holder Supplied, Springs Not Seperable	S. 828 217		34-J-902		
6	4	18	Brushes	S. 782 769		34-J-902		
7	1/6	6	Comm. Field Coil	L. 372273+		34-J-902		
8	1/6	6	Series Field Coil	L. 372273+		34-J-902		
9	1/6	6	Shunt Field Coil	L. 372273+		34-J-902		
10	1	1	Feeler Gage, Per Page 2 of D. Spec. 397100					
11	1	1	Spring Balance, Per Page 2 of D. Spec. 397100					
			EXCITER FIELD RHEOSTAT					
*	1/2	2	Ward-Leonard Rheostat (Main)	S.1 183 606	13	5-A-9346		
*	1	1	Ward-Leonard Rheostat (Vernier)	S.1 183 607	14	5-A-9346		
			+ Except Use Insulation #61023					

G.O. WG-35060-TP SPARE PARTS S.O. 19-P-146

SPARE PARTS FOR USE WITH TYPE "SK", FRAME #6-10335, HORIZ., 16-KW., 120-VOLT, 1200-RPM. D-C. EXCITER. BUILT ON S.O. 16-P-689 AND 19-P-145

* LISTED ON DRAWING 5-A-9346.

LEGEND—
- S—STYLE NUMBER
- D—DRAWING NUMBER
- L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.
WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 1 SHEET NO. 1

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 46-J-245 BUREAU NO.

CLASSIFICATION OF VESSELS:

APPLICATION VOLTAGE CONTROL

NAVY CONTRACT NO. NOs-93968 APPLIANCE: "SRAN-4" VOLT. REG.

SHIPBUILDER'S ORDER NO. MANUFACTURER W. E. & M. CO.

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA: CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO.: PC.	MFRS. DRAWING AND PIECE NO.: DWG. NO.	BUREAU DRAWING AND PIECE NUMBER: PC.	BUREAU DRAWING AND PIECE NUMBER: DWG. NO.
			CONTROL ELEMENT					
1	1	4	Silver Button Assembly	S. 1 313 989	13	46-J-245		
2	1	1	Main Spring	S. 1 114 610	15	46-J-245		
3	1	2	Short Hinge Spring	S. 1 166 944	17	46-J-245		
4	1	2	Long Hinge Spring	S. 1 313 985	16	46-J-245		
5	1	1	Main Coil	S. 1 173 224	14	46-J-245		
6	1	1	Resistor 750 Ohms	S. 1 115 103	19	46-J-245		
7	1	1	Regulating Resistance Plate	S. 1 298 916	20	46-J-245		
			DAMPING TRANSFORMER & RECTOX RECTIFIER					
8	1	1	Damping Transformer	S. 1 313 987	28	46-J-245		
9	1	1	Rectox Rectifier	S. 1 257 681	27	46-J-245		
			VOLTAGE ADJUSTING RHEOSTAT					
10	1	1	Rheostat	S. 1 354 205	29	46-J-245		
			CROSS-CURRENT COMPENSATOR					
11	1	1	Compensator	S. 1 257 682	26	46-J-245		
			TRANSFORMERS					
12	1	1	Type "VN" Pot. Trans.	S. 1 294 692	32	46-J-245		
13	1	1	Type "UN" Cur. Trans.	S.O. 79-R-705	31	46-J-245		
14	1	1	Type "UN" Cur. Trans.	S. 1 304 232	30	46-J-245		

PIECE NO'S. 1 TO 13 ARE FOR S.O. 1-Y-1321

LEGEND—
S—STYLE NUMBER
D—DRAWING NUMBER
L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.

WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 1 SHEET NO. 1

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 37-J-650 BUREAU NO. CV31-S6100-63274

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION VOLTAGE CONTROL

NAVY CONTRACT NOs. 93968 APPLIANCE CONTROL ELEMENT

SHIPBUILDER'S ORDER NO. MANUFACTURER W. E. & M. CO.

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA: CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO.: PC.	MFRS. DRAWING AND PIECE NO.: DWG. NO.	BUREAU DRAWING AND PIECE NUMBER: PC.	BUREAU DRAWING AND PIECE NUMBER: DWG. NO.
			TYPE "BN-2" CONTROL ELEMENT	S.O. 94-Y-509		35-J-960		10-T-2568-L
1	1	4	Stud Contact	S. 844 172	9	35-J-960	9	10-T-2568-L
2	1	2	Contact With Long Spring	S. 847 838	10	35-J-960	10	10-T-2568-L
3	1	2	Contact With Short Spring	S. 942 827	11	35-J-960	11	10-T-2568-L
4	1	1	Main Coil	S. 1 087 427	12	35-J-960	12	10-T-2568-L
5	1	2	Anti-Hunt Hinge Spring	S. 1 257 683	13	35-J-960	13	10-T-2568-L
6	1	2	Short Hinge Spring	S. 1 247 162	15	35-J-960	15	10-T-2568-L
7	1	2	Long Hinge Spring	S. 1 247 179	16	35-J-960	16	10-T-2568-L
8	1	1	Main Spring	S. 1 166 946	20	35-J-960	20	10-T-2568-L
9	1	2	Anti-Hunt Coil	S. 1 247 173	38	35-J-960	38	10-T-2568-L
10	1	2	Anti-Hunt Main Spring	S. 1 257 684	39	35-J-960	39	10-T-2568-L
11	1	1	Set Of Tools	S. 1 019 379	1,2,3	50-C-889		

G.O. WG-35060-TPY

SPARE PARTS FOR TYPE "BN-2" VOLTAGE REGULATOR CONTROL ELEMENT USED WITH THE 1250-KW., 1200 R.P.M., 450-VOLT, 60-CYCLE, 3-PHASE, SHIP'S SERVICE GENERATOR.

LEGEND—
S—STYLE NUMBER
D—DRAWING NUMBER
L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.
WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 6 SHEET NO. 1

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 37-J-650 **BUREAU NO.** CV31-S6100-63274

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION VOLTAGE CONTROL

NAVY CONTRACT NOs. 93968 **APPLIANCE** CONTROL PANEL

SHIPBUILDER'S ORDER NO. **MANUFACTURER** W. E. & M. CO.

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA: CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO.: PC.	MFRS. DRAWING AND PIECE NO.: DWG. NO.	BUREAU DRAWING AND PIECE NUMBER: PC.	BUREAU DRAWING AND PIECE NUMBER: DWG. NO.
			CONTACTOR PANEL					
			Contactors "QR" & "QL"	S.O. 94-Y-508	2-3	37-J-651	2-3	CV31-S6100-63275
1	1	2	Coils	S. 861 701				
2	1	2	Blowout Coil	S. 895 986				
3	1	2	Stationary Contact	S. 897 493				
4	1	2	Moving Contact	S. 942 830				
5	1	2	Spring For Contactor "QL"	S. 1 020 920				
6	1	2	Spring For Contactor "QR"	S. 1 019 698				
7	1	2	Interlock Stud Contact	S. 943 348				
8	1	2	Interlock Spring Contact	S. 809 437				
			CONTACTORS "NL" & "NR"		4	37-J-651	4	CV31-S6100-63276
9	1	2	Blowout Coil	S. 1 247 163				
10	1	2	Main Silver Stationary Contact	S. 942 773				
11	1	2	Main Silver Moving Contact	S. 944 937				
12	1	4	Aux. Spring Contact	S. 793 013				
13	1	4	Aux. Stationary Contact	S. 1 040 923				
14	1	2	Main Coil	S. 966 753				
15	1	2	Spring	S. 440 876				
16	1	1	Rectox	S. 971 249	7	37-J-651	7	CV31-S6100-63277
17	1	1	Condenser	S. 918 694	8	37-J-651	8	
18	1	1	Resistor (R8 & R10) 6500 Ohms	S. 1 250 276	36	37-J-651	36	
19	1	1	Resistor (R9) 168 Ohms	S. 1 250 277	37	37-J-651	37	
20	1	1	Resistor (R11 & R12) 24000 Ohms	S. 1 250 278	38	37-J-651	38	

G.O WG 35060-TPY

SPARE PARTS FOR TYPE "BN-2" VOLTAGE REGULATOR CONTACTOR PANEL USED WITH THE 1250 -KW , 1200 R.P.M., 450-VOLT, 60 -CYCLE, 3-PHASE, SHIP'S SERVICE GENERATOR.

LEGEND—

- S—STYLE NUMBER
- D—DRAWING NUMBER
- L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.

WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 6 **SHEET NO.** 2

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 37-J-650 **BUREAU NO.** CV31-S6100-63274

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION : VOLTAGE CONTROL

NAVY CONTRACT NOs. 93968 **APPLIANCE :** AUXILIARY EQUIPMENT

SHIPBUILDER'S ORDER NO. **MANUFACTURER** **W. E. & M. CO.**

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA: CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO.: PC.	MFRS. DRAWING AND PIECE NO.: DWG. NO.	BUREAU DRAWING AND PIECE NUMBER: PC.	BUREAU DRAWING AND PIECE NUMBER: DWG. NO.
			AUXILIARY EQUIPMENT					
1	1	6	Rectox Unit (S.O. 94-Y-509)	S. 1 253 324	7	37-J-652	7	CV31-S6100-63276
2	1	1	Volt. Adj. Rheo. Plate	S. 1 250 157	5	37-J-652	5	CV31-S6100-63276
3	1	1	Resistor (R-1)	S. 1 115 103	6	37-J-652	6	CV31-S6100-63276
4	1	1	Type "VN" Pot.Trans.	S. 1 294 692	8	37-J-652	8	CV31-S6100-63276
5	1	1	Type "UN" Cur. Trans. 3000/5A.	S.O. 79-R-705	3	37-J-652	3	CV31-S6100-63276
6	1	1	Cross-Current Compensator	S. 1 257 682	2	37-J-652	2	CV31-S6100-63276
7	1	16	Type "VG-7" Neon Lamp	S. 1 166 955	8	37-J-652	8	CV31-S6100-63276

G.O. WG-35060-TPY

SPARE PARTS FOR AUXILIARY EQUIPMENT FOR TYPE "BN-2" VOLTAGE REGULATOR USED WITH THE 1250-KW., 1200 R.P.M., 450-VOLT, 60-CYCLE, 3-PHASE, SHIP'S SERVICE GENERATOR

LEGEND—

- S—STYLE NUMBER
- D—DRAWING NUMBER
- L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.

WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 6 SHEET NO. 3

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 37-J-650 BUREAU NO. CV31-S6100-63274

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION : VOLTAGE CONTROL

NAVY CONTRACT NOs. 93968 APPLIANCE : MOTOR OPER. RHEO.

SHIPBUILDER'S ORDER NO. MANUFACTURER W. E. & M. CO.

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA			BUREAU DRAWING AND PIECE NUMBER	
				CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO. PC.	DWG. NO.	PC.	DWG. NO.
			RHEOSTATS FOR 1250-KW. TURBO-GENERATORS	S.O. 94-Y-507				
1	1	80	Stationary Contacts	S. 1 224 730	14	37-J-912	14	CV31-S6100-63279
2	1	40	Stationary Contacts	S. 1 224 731	15	37-J-912	15	CV31-S6100-63279
3	1	40	Stationary Contacts	S. 1 224 732	16	37-J-912	16	CV31-S6100-63279
4	1	2	Brush & Brush Holder Comp.	S. 1 315 062	11	37-J-912	11	CV31-S6100-63279
5	1	2	Brush & Brush Holder Comp.	S. 1 315 063	12	37-J-912	12	CV31-S6100-63279
6	1	1	Resistor	S. 1 249 100	30	37-J-912	30	CV31-S6100-63279
7	1	1	Resistor	S. 1 249 101	30	37-J-912	30	CV31-S6100-63279
8	1	1	Resistor	S. 1 249 104	30	37-J-912	30	CV31-S6100-63279
9	1	1	Resistor	S. 1 249 105	30	37-J-912	30	CV31-S6100-63279
10	1	1	Resistor	S. 1 249 108	30	37-J-912	30	CV31-S6100-63279
11	1	1	Resistor	S. 1 249 115	30	37-J-912	30	CV31-S6100-63279
12	1	1	Resistor	S. 1 249 120	30	37-J-912	30	CV31-S6100-63279
13	1	1	Resistor	S. 1 249 124	30	37-J-912	30	CV31-S6100-63279
14	1	1	Speed Adj. Resistor	S. 204 637	29	37-J-912	29	CV31-S6100-63279
15	1	1	Condenser	S. 944 950	28	37-J-912	28	CV31-S6100-63279

G.O. WG-35060-TPY

SPARE RESISTORS AND DETAILS FOR FIELD RHEOSTAT USED WITH 1250 KW., 1200 R.P.M., 450-VOLT, 60-CYCLE, 3-PHASE, SHIP'S SERVICE GENERATOR.

LEGEND—

S—STYLE NUMBER
D—DRAWING NUMBER
L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.

WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 6 SHEET NO. 5

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 37-J-650 **BUREAU NO.** CV31-S6100-63274

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION : FOR RHEOSTAT OPERATION

NAVY CONTRACT NOs. 93968 **APPLIANCE :** MOTOR, D-C.

SHIPBUILDER'S ORDER NO. **MANUFACTURER** **W. E. & M. CO.**

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA: CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO.: PC.	MFRS. DRAWING AND PIECE NO.: DWG. NO.	BUREAU DRAWING AND PIECE NUMBER: PC.	BUREAU DRAWING AND PIECE NUMBER: DWG. NO.
			RHEOSTAT MOTOR					
1	1	1	Armature Complete	D. 28-B-733 Assy. 43	77	35-J-426	77	10-T-2572-L
2	1	2	Sleeve Bearing	S. 887 867	79	35-J-426	79	10-T-2572-L
3	8	2	Carbon Brushes	S. 840 242	69	35-J-426	69	10-T-2572-L
4	1	1	Brush Holder (Complete Rocker Ring Supplied)	S. 840 977	78	35-J-426	78	10-T-2572-L
5	1	3	Brush Holder Springs	S. 887 807	66	35-J-426	66	10-T-2572-L
6	1	1	Brush Rigging Insulation (Complete Rocker Ring Supplied)	S. 840 977	78	35-J-426	78	10-T-2572-L
7	2	1	Field Coil Set ∅	D. 47-B-684 Assy. 33	42	35-J-426	42	10-T-2572-L
8	10	2	Bearing Housing Cap	S. 858 435	9	35-J-426	9	10-T-2572-L
9	10	1	Rear Dust Ring	S. 887 168	19	35-J-426	19	10-T-2572-L
10	10	1	Front Dust Cap	#20028	18	35-J-426	18	10-T-2572-L
			∅ - Each Set Contains Complete Coils For One Motor.					

G.O. WG-35060-TPY

MOTOR SPARE PARTS S# 957935. FOR USE WITH MOTOR S# 957881 TYPE FK FRAME #125E15, 1/12 H.P.
HORIZONTAL, 120 VOLTS, D-C.
4150 R.P.M., 1.05 AMPERES

LEGEND—
S—STYLE NUMBER
D—DRAWING NUMBER
L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.
WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 6 SHEET NO. 6

LIST OF SPARE PARTS AND TOOLS

REPRODUCED FROM MFRS. DRAWING NO. 37-J-650 **BUREAU NO.** CV31-S6100-63274

CLASSIFICATION OF VESSELS: AIRCRAFT CARRIERS

APPLICATION : VOLTAGE CONTROL

NAVY CONTRACT NOs. 93968 **APPLIANCE :** TEMPERATURE INDIC.

SHIPBUILDER'S ORDER NO. **MANUFACTURER** **W. E. & M. CO.**

ITEM NUMBER	NUMBER OF SETS	NUMBER PER SET	NAME OF PART OR TOOL	MANUFACTURER'S DATA			BUREAU DRAWING AND PIECE NUMBER	
				CATALOG OR SERIAL ORDERING DATA	MFRS. DRAWING AND PIECE NO. PC.	DWG. NO.	PC.	DWG. NO.
			TEST RES. FOR TEMP. IND. EQUIP.	M.S. Item 3	2	37-J-654	2	CV31-S6100-63278
1	1	1	Resistor	S. 724 093				
			CALIBRATING RHEO. FOR TEMP. IND. EQUIP.	S.O. 94-Y-516	5	37-J-654	5	CV31-S6100-63279
2	1	1	Rheostat	S. 1 305 577				
			RECTOX RECTIFIER FOR TEMP. IND. EQUIP.	S.O. 94-Y-515	4	37-J-654	4	CV31-S6100-63280
3	1	1	Transformer	S. 708 946	4	5-B-3751		
4	1	1	Rectox Rectifier	S. 1 224 733	26	5-B-3751		
5	1	1	Rheostat	S. 1 216 747	17	5-B-3751		

G.O. WG-35060-TPY

SPARE PARTS FOR TEMPERATURE IND. EQUIP. USED WITH 1250-KW., 1200 R.P.M., 450-VOLT, 60-CYCLE, 3-PHASE, SHIP'S SERVICE GENERATOR.

LEGEND—
S—STYLE NUMBER
D—DRAWING NUMBER
L—ELECTRICAL SPECIFICATION NUMBER

NOTE:—SUFFIX LETTERS IN CONNECTION WITH IDENTIFYING NUMBERS FOR SPARE PARTS ARE FOR THE INFORMATION OF THE MANUFACTURER AND WILL NOT AFFECT THE MATERIAL FURNISHED ON FUTURE ORDERS.
WHEN REORDERING ALWAYS REFER TO APPARATUS SERIAL NUMBER.

NUMBER OF SHEETS 6 SHEET NO. 4

MEMORANDUM

MEMORANDUM

MEMORANDUM

MEMORANDUM

MEMORANDUM

MEMORANDUM

WESTINGHOUSE FORM 21491

MEMORANDUM

MEMORANDUM

MEMORANDUM

MEMORANDUM

OVERBLOWN DOCUMENTS

WITHIN THE CONTENT OF THIS EXHIBIT
ARE NOT IMAGED