

THE NAVAL GUN FACTORY AMPLIFIER FOR
40mm POWER DRIVES MK.5 & MK.6

INTRODUCTION

The following description is based on Drawings 259326, 259327, and 259328. It is brief and intended for use by ship's personnel until the final O.P. is prepared for use.

REASONS FOR CHANGE

The new type amplifier developed at the Naval Gun Factory at Washington, D.C. is identical for all Mark 5 and Mark 6 Power Drives. It will be referred to hereafter as the Naval Gun Factory amplifier.

The Naval Gun Factory amplifier is to be used instead of the former amplifier in order to eliminate the use of the selenium rectifiers heretofore used in the rate circuits, to substitute a two phase induction generator for the permanent magnet D.C. generator previously used as stroke generator and to eliminate the use of the 5B synchro motor with contact head formerly used in the "B" end synchro unit housing.

These changes were desirable because of the difficulty of securing selenium rectifier units of good quality and because these units deteriorated in service. Also the D.C. stroke generator commutator got dirty after about two hours of running and this caused roughness of operation. Furthermore the 5B synchro unit contacts often caused trouble and the synchro was expensive for the limited function which it performed.

THEORY OF OPERATION

The Naval Gun Factory amplifier uses an A.C. induction generator for a stroke generator. This generator has no brushes or slip rings to get dirty. The generator should never be taken apart as its characteristics may be changed upon reassembly. As is shown on the wiring diagram, one of its phases is excited with 115 volts A.C. and the other phase delivers a generated voltage whose magnitude and phase is proportional to the velocity of the aluminum cup shaped rotor, which rotates in the air gap between the laminated steel stator and core. The induction generator also produces a small voltage while the rotor is stationary due to leakage magnetic flux. This leakage flux voltage is balanced out by means of the potentiometer R28 which may be adjusted by a screw driver inserted through a hole in the cover of the amplifier housing. This same potentiometer also balances out any voltage due to tube unbalance of the 6SN7 (or 6SN7-W) and 1st 6N7 tubes designated as V1 and V2. This unbalance may exist because of the use of A.C. for the plate supply of these tubes.

The part of the amplifier including the tubes V2, V3 and V4 is the same as the old amplifier which used the selenium rectifiers except for the addition of T3 and R24. The purpose of R24 was to introduce a damping feed-back voltage to oppose the error and rate voltage from the synchros. This constitutes an additional stabilizing feed-back with dependence upon the mechanical frictions and inertias of the stroke mechanism and proportional to stroke motor torque.

The stroke generator stabilizing feed-back is proportional to stroke generator velocity and is also dependent upon the mechanical frictions and inertias of the stroking mechanism. Both of these feed-backs are necessary for proper operation and oppose the error and rate signals from the synchros. Without R24 the operation may be rough. T3 is used to feed the output of the stroke generator, R24 and R28 into the amplifier input.

The balancer circuit has been changed only slightly to give better operation.

The "B" end generator may be either D.C. or induction A.C.

The fine and coarse synchros are connected in a series circuit in conjunction with a selenium rectifier limiter in such a way that the 5B synchro is no longer necessary and only one rate circuit is necessary. The limiter consists of two SR1 full wave selenium rectifiers in series to limit the amount of voltage from the fine synchro that can be fed to the balancer circuit and to T1. The limiter does this by being a high resistance for fine synchro R1R2 voltages up to errors of about 15 minutes and then its resistance decreases very rapidly for larger errors to very low values. This action allows the fine synchro to control for small errors of 15 minutes or less and prevents the fine synchro from interfering with coarse synchro control for larger errors because it shorts out the fine synchro for these errors.

The single rate circuit necessary consists of V1 (a 6SN7 tube) and cathode resistances R10 and R11 and condensers C1 and C2. The 6SN7 or 6SN7W tube is a double 3 element tube with separate cathodes. The fact that the average D.C. cathode current increases on one plate of the 6SN7 and decreases on the other as the A.C. signal is applied to the grids is made use of to measure the rate of increase of this A.C. signal on the grids. Since the plate supply to V1 through R12 is A.C., for any given signal only one side of V1 has a positive grid and plate at the same time. The other side has a negative grid when its plate is positive. This means that the average D.C. cathode current will be greater on one side than on the other. When this same grid signal is increased the larger average D.C. cathode current increases and the smaller average D.C. cathode current decreases. When the condensers C1 and C2 are present, the average D.C. cathode current changes occur with an initial surge which dies down to a steady value corresponding to the new A.C. signal strength on the grids.

This surge in average D.C. cathode current allows a corresponding surge in tube signal output, and this surge in tube output is proportional to the rate of increase (or time derivative) of the A.C. signal on the grids. The surge increase of average D.C. cathode current on one side is due to the condenser on that side charging up to the higher average D.C. potential existing across the cathode resistor due to the increase of average D.C. cathode current. The simultaneous surge decrease of average D.C. cathode current on the other side is due to the discharging of this condenser to a lower value of average D.C. potential existing across the cathode resistor due to the decrease of average D.C. cathode current. This discharge tends to maintain a high average D.C. cathode bias with respect to the grid and results in a quicker decrease (or surge decrease) in average D.C. cathode current on this side than if the condenser were not there. A corresponding surge decrease results in tube output on this side, resulting in an increase of overall tube output because this last side opposes the other side. The reverse process occurs for a signal decrease.

The entire process may be briefly referred to as a method of obtaining rates with a delayed average D.C. cathode bias voltage, the delay being obtained by means of the usual cathode bias resistors and condensers.

CHARACTERISTICS AND POSSIBLE TROUBLES

The Naval Gun Factory amplifier results in greater accuracy for the Mark 5 drives and the same or greater accuracy for the Mark 6 drives.

Because of the very much lower inertia and friction of the new A.C. induction stroke generator the mount is more stable and has a quicker response. This results in a higher frequency roughness than with the old amplifier.

Roughness is kept at a minimum by keeping stroke gearing and stroke linkage lost motions as well as "A" and "B" end leakages at a minimum. The backlash in the stroke generator gearing must be kept at an absolute minimum also. If the stroke generator gearing is meshed tightly enough to bind mechanically, excessive roughness will result.

The limiters may or may not change much with age. Their characteristics are not at all critical for good operation however.

They should just begin to cut off at about 12 or 15 minutes of error for best operation, but with values 1/2 or twice this the mount will still operate and operate well.

Not all tubes are suitable for use in the amplifiers. When the mount is in automatic and on a stationary signal, tapping the 6SN7 or 6SN7-A tube with a pencil should not disturb the mounts. If a disturbance results of more than one minute from pencil tapping firing shocks will cause increased errors during firing.

*.Revised to one mil.

The voltage output of transformer T2 as measured by a cathode ray oscilloscope should not vary more than $\pm 20\%$ from the average output voltage when, with the mount in manual control, the mount is accurately displaced 20 degrees from the signal in first one direction and then the other.

The accuracy of displacement of the mount in each direction should be checked with a voltmeter or oscilloscope on the R1F and R2F synchro leads.

ADJUSTMENTS

The dither motion should be adjusted so that dither motion is easily observable in the main drive couplings but not in the mount.

If the stroke generator should become connected up backward, the mount will hunt back and forth violently in automatic no matter what other adjustments are made.

There are three amplifier adjustments. Potentiometer R-28 (which takes the place of R-11 in the selenium rectifier amplifier) is used to balance the amplifier on a stationary signal until exact dial correspondence is obtained between the director and the gun if the gun is boresighted for exact dial correspondence. This adjustment is accessible through the plug in the top of the intermediate housing cover.

Potentiometer R6 is used to control the amount of error applied to the amplifier. Potentiometer R-6 and R-24 are mounted on the amplifier chassis and their adjustments are secured by acorn nuts. R-6 and R-24 are adjusted alternately on a stationary signal for minimum hunt only when the mount is hot. R-6 should be turned clockwise as far as possible without causing the mount to be unstable and R-24 is adjusted for minimum hunt.

R-28 is in the center of the chassis, R-24 is the closest to R-28 and R-6 is the farthest from R-28.

R-6 and R-24 are set at the factory and should not require adjustment in the field unless amplifiers are changed.

Test for Operation of Amplifier with A.C. Rate Circuit on the Mount

1. Amplifier Circuit (3-6N7 stages of amplification)

A. Apply the A.C. input in both directions across C1 and C2 on terminal block of intermediate housing. This may be accomplished by connecting a low reading A.C. voltmeter across C1 and C2. Connect R1C to C1 and R2C to C2. Then, by proper rotation of the director, the input voltages shown below may be obtained. (Full C.C.W. R-24)

Place the selector lever in manual control and connect B2 to B3. The power motor should not be running unless this is necessary to obtain a local supply as in the case of some 440 volt A.C. drives.

B. The allowable minimum, average and maximum outputs as listed below are read with a second A.C. voltmeter across SM2 and SM4.

The maximum allowable voltage output with zero input should be read first by shorting C1 and C2 with a screwdriver and balancing R28 until the output voltage is a minimum. Continue the test with this setting of R28.

C. Input	0	.05	.10	.25	.50	1.0
Min.		1.7	4.0	8.6	10.1	11.0
Avg.		2.7	4.9	10.1	12.45	13.6
Max.	2.0	4.0	6.4	12.4	14.12	15.2

D. Remove jumper from B2 to B3, R1C to C1, and R2C to C2 when test is completed.

2. Rate Circuit (6SN7-W)

A. Open R1F on terminal board to disconnect one side of fine synchro.

B. Turn the director or the mount to obtain the voltage listed below across R1C and R2C on the terminal board.

C. Place the mount selector switch in manual position.

D. Read the output voltages across A1 and A2 with a calibrated oscilloscope.

E. Turn R-6 full clockwise.

F. Input	0	2.25
Output Min.		.85
Output Avg.		1.17
Output Max.	.45	1.5

G. Connect wire removed from R1F when test is completed.

3. Balancer Circuit (6H6)

A. Place selector lever in manual position.

B. Turn director for exact correspondence as shown by 0 output with a low reading voltmeter on R1F and R2F to obtain the zero input test. R1C and R2C should also be 0 at this point.

C. The 10' error input may be checked by measuring the voltage across R1F and R2F with an A.C. voltmeter. 10' error is equivalent to approximately 6 volts on the R1F and R2F.

D. Read the D.C. output voltages across condensor C-11 in the intermediate housing with a D.C. vacuum tube voltmeter.

E. Input	0	10' Error (each direction)
Output Min.		.7
Output Avg.		.8
Output Max.	.3	1.5

Test for Operation of Amplifier with A.C. Rate Circuit

1. Amplifier Circuit (3-6N7 Stages of Amplification)

A. A.C. input applied in both directions across A-B (14 pt. plug).

B. Output read across 30 ohm load between A-B (4 pt. plug, feedback control out (Full C.C.W. R-24)).

C. Use A.C. voltmeter. Connect B of output (4 pt. plug) to J (14 pt. plug).

D. For maximum reading with 0 input balance R28 until the output voltage is a minimum. Continue the test with this setting of R28.

E. Input	0	.05	.10	.25	.50	1.0
Min.		1.7	4.0	8.6	10.1	11.0
Avg.		2.68	4.9	10.1	12.45	13.6
Max.	2.0	4.0	6.4	12.4	14.2	15.2

2. Rate Circuit (6SN7-W)

A. 2.25 volt input to F-G both directions. Output read across E-H. With calibrated oscilloscope. Turn R-6 full C.W.

B. Connect a 6 mfd. condenser from D to M and a 6 mfd. condenser from M to N. Use paper or oil condensers.

C. Input	-	0	Output	-	.45 max.
Input	-	2.25	Output	-	1.5 max.
					1.17 avg.
					.85 min.

3. Balance Circuit (6H6)

A. 6 V. input to C-G both directions.

B. Output read across H & L (14 Pt. Plug) with D.C. V.T. voltmeter.

C. Input	-	0	Output	-	.3 V. Max.
Input	-	6.0	Output	-	1.5 V. Max.
					.8 V. Avg.
					.7 V. Min.

D. The maximum unbalance with reversal of 6 V. input shall be 0.6 V.