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OP 1063 CHANGE 1

4 January 1946

1 Page — Page 1

ORDNANCE PAMPHLET 1063
is changed as follows:

STABLE ELEMENT MARK 6 MODS. 4 AND 6

1. Insert attached page 220a after page 220.

2. Insert change 1 instruction sheet before title page.

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OP 1063 CHANGE 2

13 March 1956

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3 Pages (with enclosures) Page 1

ORDNANCE PAMPHLET 1063
is changed as follows:

STABLE ELEMENT MARK 6 AND MODS

1. This publication is hereby downgraded to UNCLASSIFIED. Delete the words RESTRICTED SECURITY INFORMATION from all pages, front cover through back cover.

2. Page 23, INPUTS AND OUTPUTS - STABLE ELEMENT MARK 6, after last line of paragraph beginning with "The outputs of the Mark 6 Stable Element consist of:", add:

"5. Train, Continuous, electrically at 1 and 36 speeds. (Mods 7 and 9)
6. Level, Continuous, electrically at 2 and 36 speeds. (Mods 8 and 9)"

3. Page 24, MOD CHART, under last line of chart, add:

"Stable Elements Mark 6 Mods 7 and 9 each yield Train Output electrically at 1 and 36 speeds. For other outputs see Mods 1 and 8, respectively.
Stable Element Mark 6 Mod 8 yields Continuous Level Output electrically at 2 and 36 speeds. For other outputs, see Mod 0."

4. Page 72, Figure 50, add:

"Stable Elements Mark 6 Mods 7 and 9 are each equipped with a Train Transmitting Unit. (See Figure 78B)"

5. Between pages 94 and 95, insert attached new pages 94-A through 94-T.

6. Between pages 110 and 111, insert attached new pages 110-A and 110-B.

7. Page 141, Figure 139, add steps:

"11A. REMOVE TRAIN TRANSMITTING UNIT and connecting wires. (See Figure 78B).
11B. REMOVE CONTINUOUS LEVEL TRANSMITTING UNIT and connecting wires. (See Figure 78E)."

8. Page 166, at the bottom of the page, add the following NOTE:

"NOTE: During reassembly of the Stable Element after it has been disassembled for overhaul or repair, the following adjustment procedure should be followed when installing the level gimbal:

(a) Align the "V" countersink in the gimbal pivot mounting bushing with the threaded set screw hole in the level gimbal.

(b) Adjust the pivot studs in the level gimbal to give approximately 0.002-inch total play between opposite bearings.

(c) After completion of assembly of the bushing and pivot studs, check that there is a minimum of 1/32-inch clearance at all points between the level gimbal and the rotating gyro gimbal."

9. Page 183, after last line, add:

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"See page 94-A for adjustment of Train Transmitting Unit.
See page 94-L for adjustment of Continuous Level Transmitting Unit."

10. Page 200, paragraph A, change first sentence to read:

"Too little or no D. C. grid bias caused by open or short circuit in the transformer windings, potentiometer units or in the connections to them, or caused by faulty setting of a potentiometer."

11. Page 210, Tests 21, 22, 23, and 24, under "PROBABLE CAUSE OF TROUBLE", add:

"Faulty potentiometer setting."

12. Page 216, Tests 38 and 39, under "UNIT UNDER TEST", add:

"Resistor replaced by potentiometer. (See page 110-A.)"

13. Page 219, "Resistors R-27 and R-28", under "VALUE", delete:

"4,000 to 12,000 ohms, 1 watt" and insert "25,000 ohms, 2.25 watts" and under "THEIR PURPOSE AND LOCATION", change first sentence to read ""K" D.C. bias calibration potentiometers."

14. Between pages 224 and 225, insert attached new pages 224-A and 224-B.

15. Page 227, CHART (B), WEIGHTS AND DIMENSIONS, add new Mods as follows:

TYPE	WEIGHT	HEIGHT	WIDTH	DEPTH
Mk 6 Mod 4	895 lbs			
Mk 6 Mod 5	980 lbs			
Mk 6 Mod 6	900 lbs			
Mk 6 Mod 7	928 lbs			
Mk 6 Mod 8	893 lbs			
Mk 6 Mod 9	898 lbs			

16. Page 230, CHART (F) PRINCIPAL DRAWINGS & NUMBERS, after "Functional Diagram, Mark 6 and Mark 6 Mod 1 . . . . . . 166849" add:

"Functional Diagram, Mark 6 Mods 4 and 6 317240
Functional Diagram, Mark 6 Mods 7, 8, and 9 . . . Fig. 78D OP 1063 (2)"

After Gear Diagram, Mark 6 and Mark 6 Mod 1 . . . . 228008" add:

"Gear Diagram, Mark 6 Mod 7 698315
Gear Diagram, Mark 6 Mod 8 878295
Gear Diagram, Mark 6 Mod 9 . . . . Fig. 78C OP 1063 (2)"

After " KSP Motor Assembly . . . . 227943" add:

"1G Synchro Generator 213036
5G Synchro Generator . . . . 698727"

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16. (Continued)

At the bottom of the page, change "†" footnote to read:

"† indicates ARMA CORPORATION Drawing Numbers."

17. Item 8 of this CHANGE cancels or supersedes NAVORD OML F2-52, dated 9 July 1952.

18. Insert this CHANGE sheet in the front of the book, following CHANGE 1.

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~~RESTRICTED~~ ORDNANCE PAMPHLET NO. 1063

631

STABLE ELEMENT
MARK 6 AND MODS.

JANUARY 1944

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Prepared for the Bureau of Ordnance
by the
ARMA CORPORATION
Brooklyn, New York

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NAVY DEPARTMENT
BUREAU OF ORDNANCE
WASHINGTON, D. C.

RESTRICTED

JANUARY, 1944

ORDNANCE PAMPHLET NO. 1063

STABLE ELEMENT MARK 6 AND MODS.

1. Ordnance Pamphlet No. 1063 describes the theory, care, and operation of the Stable Element Mark 6 and Mods. Data on the associated Control Panels Marks 7 and 8 are included. Although Ordnance Pamphlet No. 1063 was written primarily for the Stable Element Mark 6 and Mods., occasional notes have been added to indicate wherein the Stable Element Mark 5 differs from the Stable Element Mark 6.

2. Ordnance Pamphlet No. 1063 is to be used by: operating personnel both during instruction and on actual duty; maintenance personnel both ashore and afloat; personnel of installing activities; and inspectors and other officers of the Bureau of Ordnance.

3. Ordnance Pamphlet No. 1063, in so far as the Stable Element Mark 6 is concerned, supersedes Ordnance Data No. 2599. Accordingly, activities having only the Stable Element Mark 6 should destroy Ordnance Data No. 2599. Ordnance Pamphlet No. 1063 does not include certain wiring and functional diagrams included in Ordnance Data No. 2599 relative to Stable Element Mark 5. Those activities having Stable Element Mark 5 should retain Ordnance Data No. 2599.

4. This publication is RESTRICTED and should be handled in accordance with the provisions of Article 76, U. S. Navy Regulations 1920.

G. F. HUSSEY, JR.
REAR ADMIRAL, U. S. NAVY
CHIEF OF THE BUREAU OF ORDNANCE.

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SECTION 10—ADJUSTMENTS 167

SECTION 11—CASUALTIES 185

SECTION 12—INFORMATION 221

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THIS MANUAL is intended to serve two purposes, the first of which is to explain the Construction, Function, and Principles of Operation of the Stable Element. The second is to provide a cross-indexed manual of instructions covering Operation, Maintenance and Service of the Instrument, including disassembly procedure, adjustments, etc.

Should the Stable Element become disabled for any reason, this manual should enable competent naval personnel to return the instrument to service with a minimum of delay and with its original accuracy.

Treat the unit with care. While rugged, it is a precision instrument and deserves intelligent attention to enable it to properly perform its duty in the fire control system.

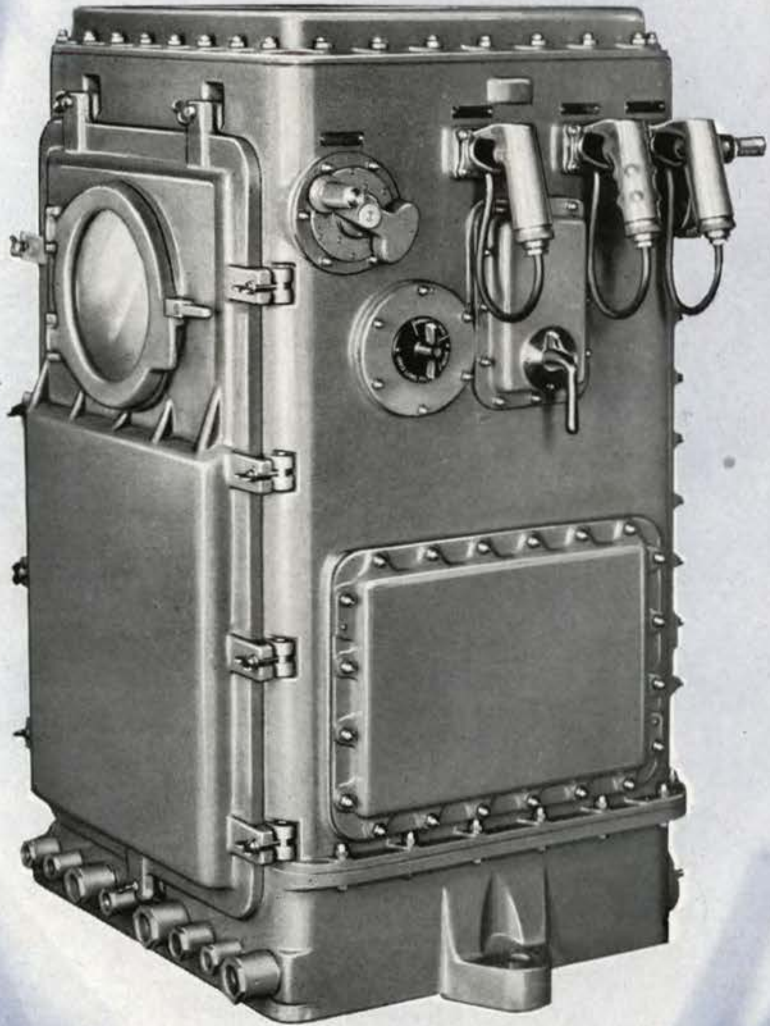

Fig. 1

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CONTROL PANEL MARK 7

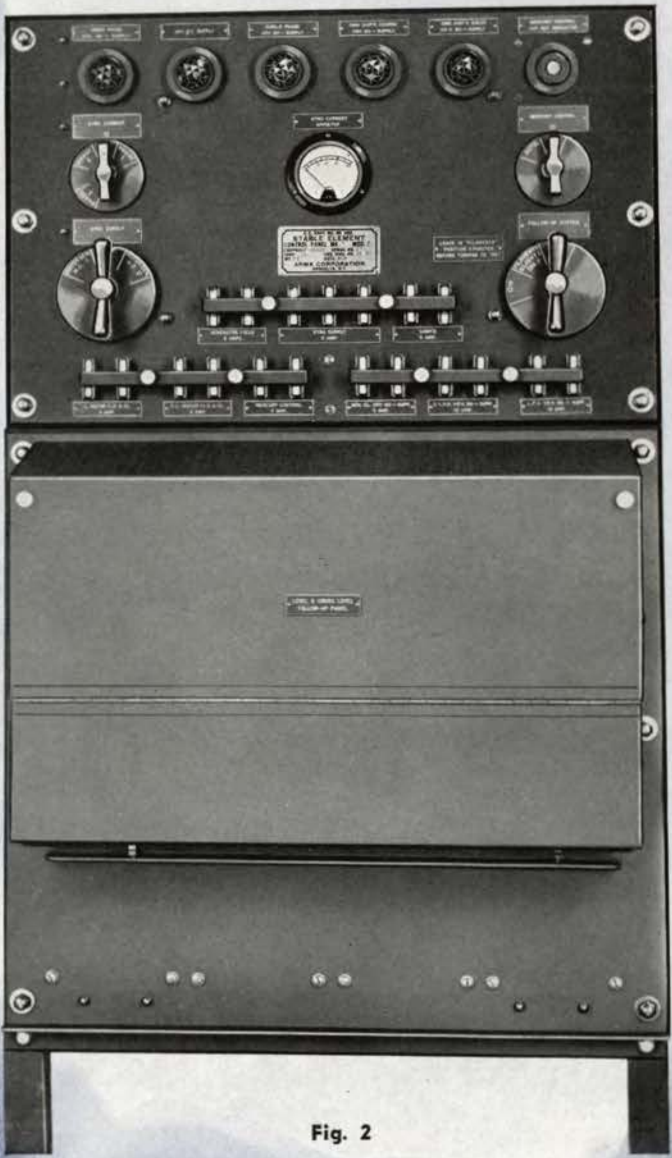

Fig. 2

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TERMINOLOGY

In this manual covering the Stable Element a few basic terms will be used which, if properly visualized from the beginning, will aid in clarifying the principles and operation.

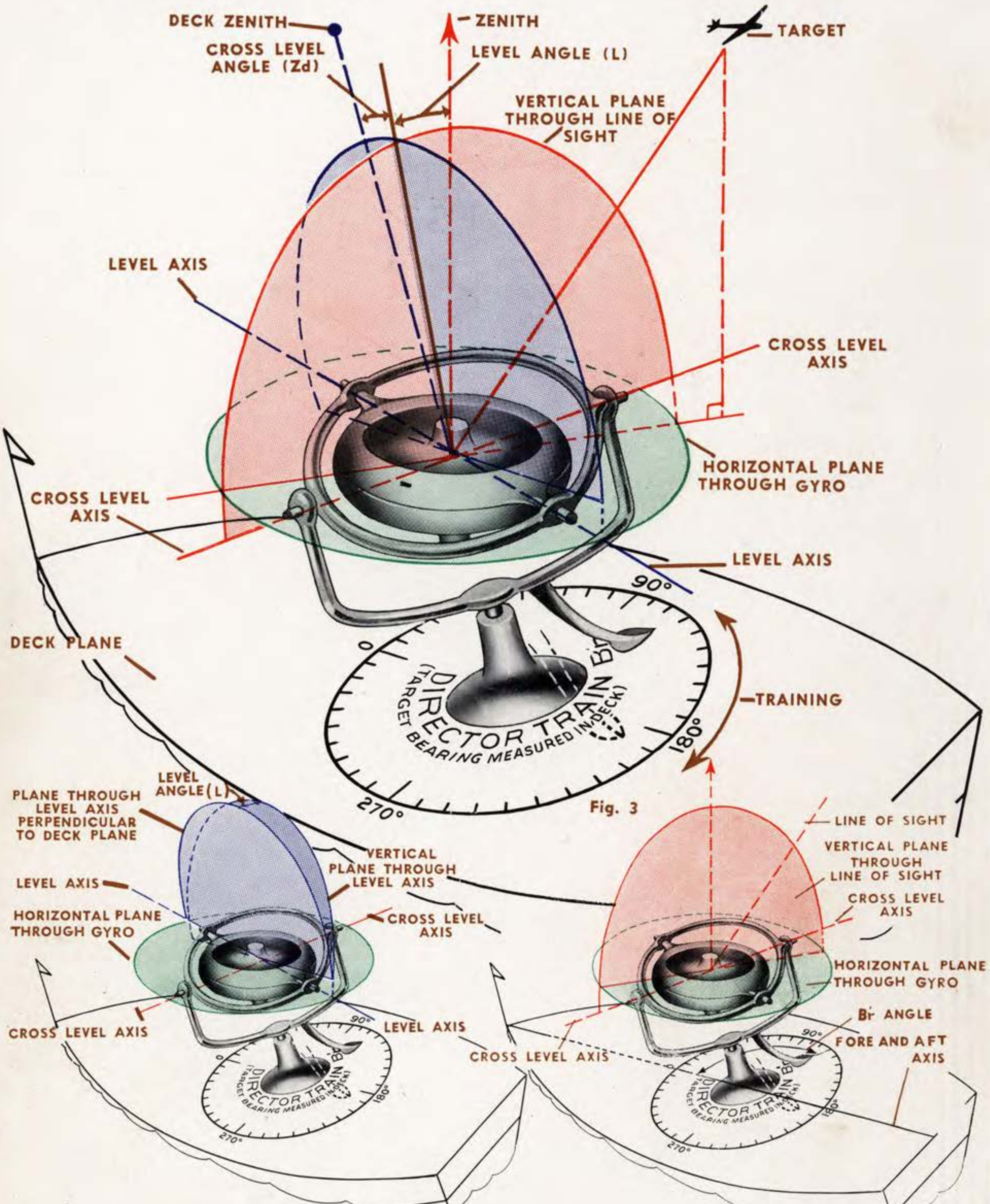

Fig. 3

Fig. 5

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LINE OF SIGHT (Figs. 3 and 5)

The line of sight is an imaginary line extending from the observer to the target.

TRAINING (Fig. 3)

Rotation of the line of sight, guns, search lights, etc., as measured in the plane of the deck, is called "training."

DIRECTOR TRAIN—B'r* (Fig. 5)

(Target Bearing Measured in Deck)

The angle between the fore and aft axis of own ship and the vertical plane through the line of sight, measured in the deck plane clockwise from the bow.

LEVEL ANGLE—L (Fig. 4)

Level angle measured about an axis in the horizontal plane; the angle between the horizontal plane and the deck plane, measured in the vertical plane through the line of sight. (Positive when the deck toward the target is below the horizontal plane).

*NOTE: At the time this instrument was designed the term "Target Bearing" was loosely used for that quantity now known as "Director Train", and the dial on the Stable Element indicating this quantity was engraved "Target Bearing". Due to the great number of these instruments now in use with their attendant descriptive literature which refers to this quantity under the old name, the title "Target Bearing" has been retained for the sake of uniformity.

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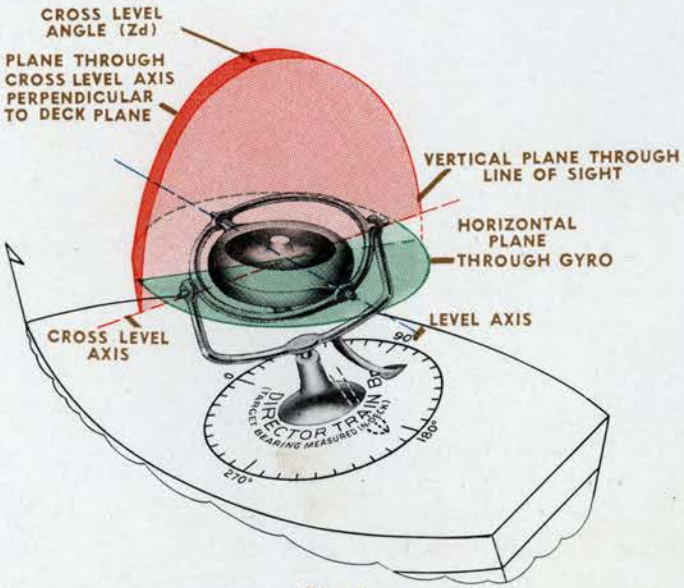

Fig. 6

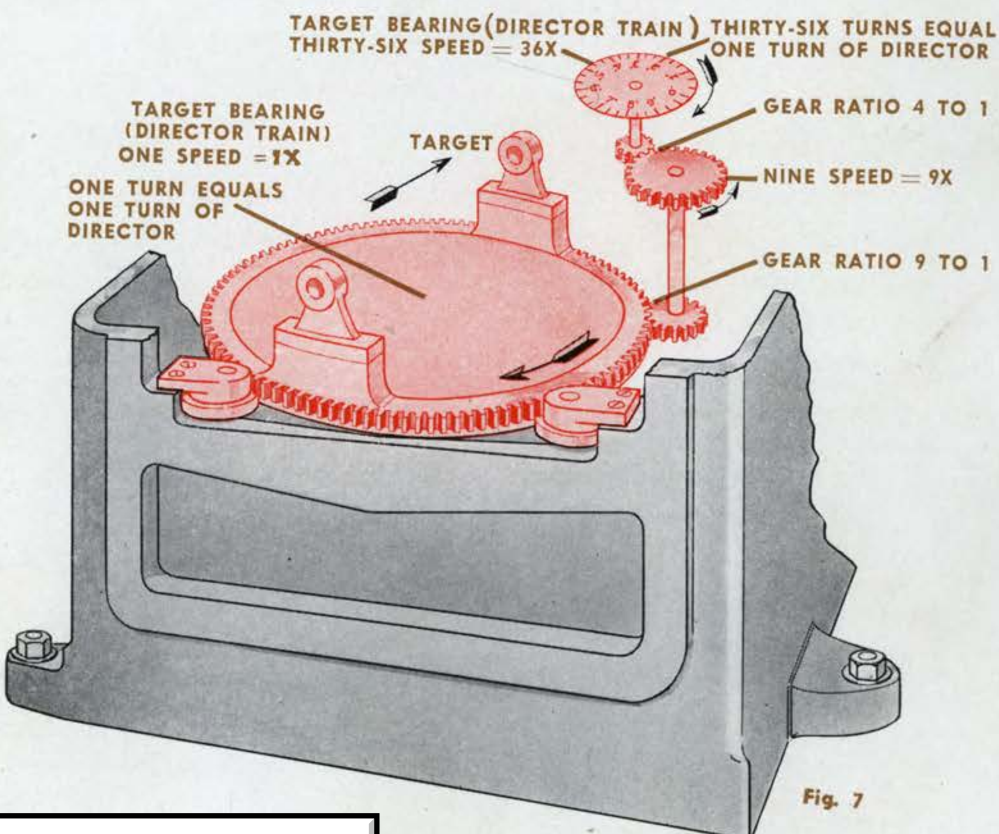

Fig. 7

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CROSS LEVEL ANGLE—Zd (Fig. 6)

Cross Level angle measured about an axis in the deck; the angle, measured about the intersection of the plane of the deck with the vertical plane through the line of sight, between the vertical plane and a plane perpendicular to the deck through this axis. (Positive if when facing the target the right hand side of the ship is up).

Most frequently the deck, with reference to the horizontal plane, will be tilted in a direction that includes both Level and Cross Level angles. The two angles expressed in minutes rather than in degrees, are indicated on the dials of the Stable Element. These dials turn in exact accord with the changing values of both Level and Cross Level angles.

For convenience, both the Level and Cross Level dials are calibrated from 500 to 3500 minutes. At 2000 minutes on both dials, the deck is in a true horizontal plane. Any change in the deck's position will add or subtract angles from 2000 on one or both of these dials, depending upon whether Level, Cross Level or both angles are involved.

SPEED RATIO-X (Fig. 7)

Throughout this manual and on certain drawings pertaining to the Stable Element, reference is made to the "speed" of certain units, such as shafts, motors, dials, etc. This nomenclature is used to indicate the ratio of the number of revolutions of the shaft or other unit to the basic quantity with which it is associated.

Thus: 1x=1 speed=1 turn for 1 turn of the basic quantity.

36x=36 speed=36 turns for 1 turn of the basic quantity.

In certain parts of the following descriptions the word speed is used to denote rate of rotation of certain shafts or units, but it will only be used in this sense in cases where there can be no possible ambiguity.

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FUNCTION OF THE STABLE ELEMENT

This section defines briefly the basic functions of the Stable Element, as well as the input and output connections and functions of both the Stable Element itself and its Control Panel.

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FUNCTION

The Stable Element is located adjacent to the Computer in the Plotting Room and performs two major functions:

1. It measures Level and Cross Level angles caused by variation of the position of the deck of the ship with respect to the horizontal, and utilizes these angles in such a manner as to keep the lines of sight of the telescope and the rangefinder positioned automatically on the target while the ship pitches and rolls.
2. It provides means for firing the guns.

LEVEL AND CROSS LEVEL ANGLES

(Transmission and Indication)

The first major function listed above is the basic duty of the Stable Element. The method by which the instrument performs this function is described in detail in the section on Application, but it may be briefly stated here that a gyroscope is the heart of the instrument, the gyroscope providing a horizontal reference plane about which Level and Cross Level Angles are measured as the ship pitches and rolls. The construction is such that any motion of the ship's deck with respect to this plane causes relative motion between the gyro and the gimbals in which it is mounted.

Any motion or angular displacement due to these causes is measured by maintaining a pair of follow-up coils, which are mounted on one of the gimbals, in alignment with a magnet mounted on the gyro case. This is accomplished by an electronically actuated motor-driven follow-up mechanism. As the follow-up mechanism acts to keep the follow-up coils aligned with the magnet, the angle generated by each gimbal is indicated about its corresponding (Level or Cross Level) axis on dials calibrated in minutes of arc.

In addition, the angle generated by each gimbal is also applied to Synchro generators and to mechanical output shafts for transmission to other instruments or elements to be controlled.

FIRING THE GUNS

The instrument also provides means for automatically firing the guns. The guns may also be fired by means of the firing keys on the front of the housing. Settings are possible for:

1. Continuous Fire
2. Automatic Firing in Selected Level
3. Automatic Firing in Selected Cross Level
4. Hand Firing in Level
5. Hand Firing in Cross Level

These operations are further explained in the section on Operation, Page 123.

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INPUTS AND OUTPUTS—STABLE ELEMENT, MARK 6

Inputs to the instrument consist of:

1. Own Ship's Course (Co) electrically at single speed from the Gyro Compass.
2. Target Bearing (Director Train) mechanically at 120 speed from the Computer.

In addition, the electrical inputs to the Control Panels are:

1. 115 volts D.C.
2. 115 volts 60 cycle 1 phase A.C.
3. 115 volts 60 cycle 3 phase A.C.
4. 70 volts 146 cycle 3 phase A.C.
5. Own Ship's Course (Co) electrically at 36 speed.
6. Own Ship's Speed (So) electrically at one speed from the Pitometer Log.

The outputs of the Mark 6 Stable Element consist of:

1. Cross Level (Selected or Continuous) mechanically at 120 speed.
2. Level (Selected or Continuous) mechanically at 120 speed.
3. Cross Level, Continuous, electrically at 2 and 72 speeds.
4. Level plus a function of Cross Level, Continuous, mechanically at 120 speed.
5. TRAIN, CONTINIOUS, ELECTRICALLY AT 1 & 36 SPEEDS (MODS 7 & 9)
6. LEVEL, CONTINIOUS, ELECTRICALLY AT 2 & 36 SPEEDS (MODS 8 & 9)

For exceptions to these specifications, see Mod. Chart on next page, covering different Mods. of both Stable Element and Control Panels.

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MOD. CHART

OUTPUT LEGEND
D—To Director
C—To Computer
S—To Searchlights
O—Others

			Stable Element Mk. 5	Stable Element Mk. 6	Stable Element Mk. 6 Mod. 1	Control Panel Mk. 7 Mod. 0	Control Panel Mk. 7 Mod. 1	Control Panel Mk. 7 Mod. 2	Control Panel Mk. 7 Mod. 3	Control Panel Mk. 7 Mod. 4	Control Panel Mk. 7 Mod. 5	Control Panel Mk. 8 Mod. 0	Control Panel Mk. 8 Mod. 1	Control Panel Mk. 8 Mod. 2	Control Panel Mk. 8 Mod. 3	Control Panel Mk. 8 Mod. 4	Control Panel Mk. 8 Mod. 5	Control Panel Mk. 8 Mod. 6	Control Panel Mk. 8 Mod. 7	Control Panel Mk. 8 Mod. 8
CONNECTIONS – INPUT		115 V. D.C.	x Through	x Control	x Panel	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CONNECTIONS – INPUT		70 V. 146 ∿ 3 ϕ A.C.	x Through	x Control	x Panel	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CONNECTIONS – INPUT		115 V. 60 ∿ 1 ϕ A.C.	x Through	x Control	x Panel	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CONNECTIONS – INPUT		115 V. 60 ∿ 3 ϕ A.C.				x	x	x	x		x									
CONNECTIONS – INPUT		Target Bearing (Director Train) 120 Speed	x	x	x															
CONNECTIONS – INPUT		So 1 Speed					x	x	x	x	x			x	x	x	x	x	x	x
CONNECTIONS – INPUT	Co	1 Speed	x	x	x															
CONNECTIONS – INPUT	Co	36 Speed				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
CONNECTIONS – OUTPUT	LEVEL	2 Speed Electrical			S															
CONNECTIONS – OUTPUT	LEVEL	36 Speed Electrical			S															
CONNECTIONS – OUTPUT	LEVEL	120 Speed Mechanical	C	C	C															
CONNECTIONS – OUTPUT	CROSS LEVEL	2 Speed Electrical	D	D	D															
CONNECTIONS – OUTPUT	CROSS LEVEL	72 Speed Electrical	D	D	D															
CONNECTIONS – OUTPUT	CROSS LEVEL	120 Speed Mechanical	C	C	C															
CONNECTIONS – OUTPUT	LEVEL Zd/30	72 Speed Electrical	O																	
CONNECTIONS – OUTPUT	LEVEL Zd/30	120 Speed Mechanical		O	O															

HOW TO USE THIS CHART

The inputs and outputs to the Marks and Mods. of Stable Elements and Control Panels are tabulated here for convenience in comparing units. Along the top are listed the instruments in order of Mod. numbers. Following down any column, a cross in a box indicates that the particular Mod. has the input or output listed at the left of the horizontal row in which the box in question is located.

Certain electrical inputs go to the Stable Element through switches or controls on the Control Panel, and are so indicated in the chart.

* see oposite page

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* STABLE ELEMENTS MK 6 MODS 7 & 9 EACH YIELD TRAIN OUTPUT ELECTRICALLY AT 1 & 36 SPEEDS. FOR OTHER OUTPUTS SEE MODS 1 & 8 RESPT.

STABLE ELEMENT MK 6 MOD 8 YIELDS CONTINUOUS LEVEL OUTPUT ELECTRICALLY AT 2 & 36 SPEEDS. FOR OTHER OUTPUTS SEE MOD 0.

FUNDAMENTALS

As an aid to intelligent operation, maintenance and servicing of the Mark 5, Mark 6 and Mark 6 Mod. 1 Stable Elements some knowledge of the principles involved is necessary. The more important of these will be briefly discussed in this section.

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PROPERTIES OF A FREE GYRO

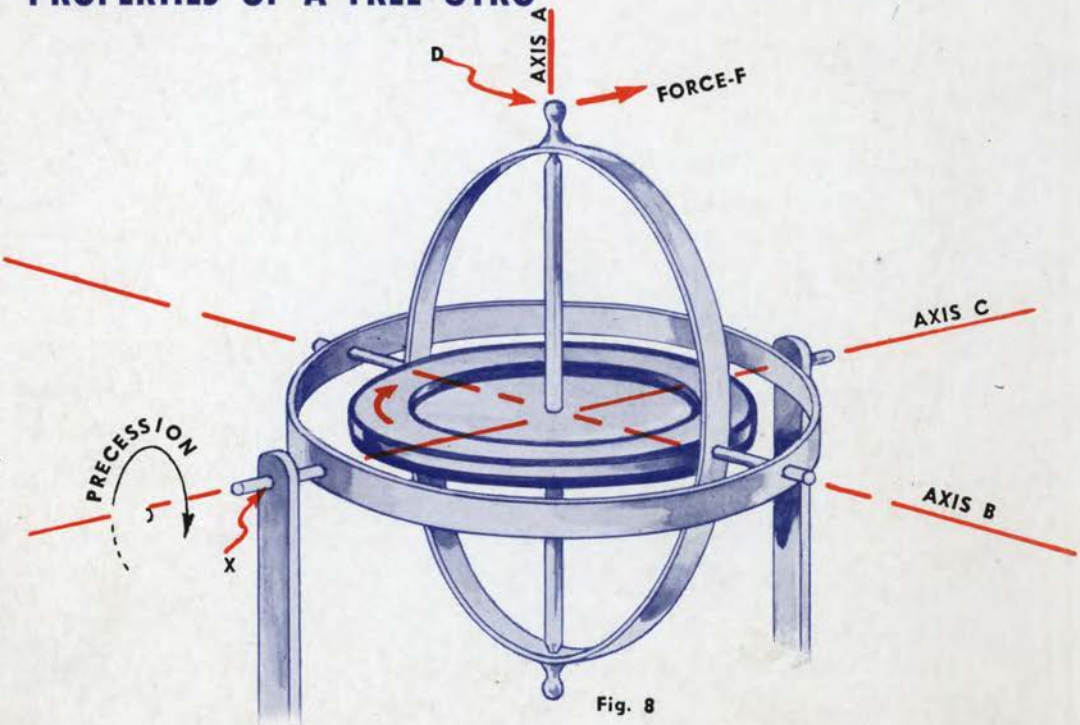

Fig. 8

If a heavy wheel is mounted so that its shaft is free to turn in any direction, it is known as a free gyroscope, or as it shall be called, a free gyro. Usually the mount is constructed with three mutually perpendicular axes about which the wheel may turn. Thus in Fig. 8 the wheel is free to spin about axis A, to turn about B, and finally to turn about C. The gyro wheel is located so that its center of mass coincides with the intersection of these three axes.

For purposes of illustration, all bearings are considered to be without friction. It is evident that the gyro wheel, when not rotating, is in a state of indifferent or neutral equilibrium; that is, it will remain in any position in which it may be placed. In addition it will yield in the direction of any force which tends to rotate it about one of its axes, just as any free mass will move in the direction of an applied force.

If now the wheel is set spinning rapidly, it will exhibit entirely new phenomena. It will resist rather than yield to an applied force. A force F applied at point D, Fig. 8, produces a force at right angles to the axis B. This force, instead of moving the frame in the direction of the applied force, as it would do if the wheel were not spinning, will be opposed by the frame.

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Additionally, the wheel will start to rotate slowly (precess) about axis C in the direction indicated. If the mount is without friction, as was assumed, this action will continue as long as the force is applied at D.

Similarly, a force applied at D in a plane through B tends to rotate the wheel about the C axis but the gyro will resist this motion and turn instead about the axis B.

It should be noted that a pressure applied to the gyro wheel frame always results in reaction forces at the bearings. If, as in the cases illustrated by this figure, the applied force and bearing reaction are not in the same straight line, these forces form a couple which tends to rotate the gyro wheel axis. The free gyro does not, however, turn about the couple axis but rotates about another axis perpendicular to the couple axis. Thus, in Fig. 8 a couple about axis B results in a rotation or precession of the wheel and frame about C.

Experiments show that the gyro does not resist translation, that is, motion which keeps the spin axis A parallel to its original position.

RIGIDITY OF PLANE

Rigidity of plane is that property of a gyro by which it tends to maintain the plane of its wheel parallel to its original position in space. This property results from the fact that a mass in motion can have its direction of movement changed only by applying a force to the mass.

PRECESSION

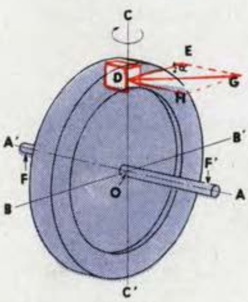

Fig. 9

Fig. 9 shows a rapidly spinning gyro in which the axis of spin is A. A couple represented by forces F-F′ tends to twist the gyro wheel about the couple axis B perpendicular to and in the same horizontal plane as A. Consider a small section of the wheel rim at D. Due to the rotation of the wheel, section D has a high linear velocity in the direction DE.

The couple F-F′ exerts a force upon this small mass along DH and so accelerates it in this direction. During a short interval of time this acceleration will give the particle a component of velocity DH. The result of combining velocities DE and DH is a new velocity DG different in direction from DE. This is equivalent to a rotation thru angle α about axis C. Therefore the effect of a couple F-F′ acting about the B axis is to cause a slow rotation of the gyro wheel about the C axis. This rotation is known as precession.

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In order to obtain a high rigidity of plane and slow precession, gyro wheels are made heavy in weight and are operated at a high rate.

RULES FOR PRECESSION

Precession is the name given to the slow movement of a gyro wheel resulting from the application of an external force or couple which tends to change the direction of its spin axis. It has been shown that if the gyro wheel is freely supported as in Fig. 8 and a force or couple is applied about the axis B, the wheel will not turn about the axis B, but will slowly turn about an axis C at right angles to the axis of the applied couple.

To determine the direction of precession apply the following rule:

The axis of a freely mounted gyro will tend to turn or precess in such a direction that it becomes parallel to the axis of the applied torque, by the shortest path, and with the rotation of the wheel in the same direction as the applied torque.

APPARENT ROTATION

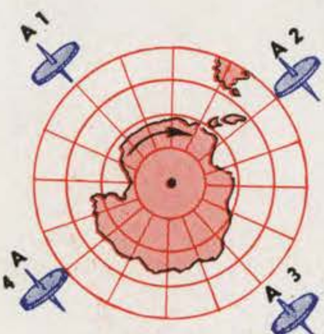

Fig. 10

Assume now that the gyro wheel supported by its universal mounting as before is placed at the equator of the earth with its A axis vertical as shown in position 1 of Fig. 10. Once the wheel is started spinning in this position it will continue to spin parallel to its original plane because there is no force present to rotate that plane. The earth, however, is turning about its own axis at the rate of one revolution every 24 hours. The gyro wheel, therefore, will assume the successive positions shown in Fig. 10. To an observer standing on the earth the wheel will appear to rotate at the rate of one complete turn in 24 hours. This rotation might seem puzzling were it not remembered that it is the earth that is turning, not the gyro.

EFFECT OF FRICTION

In the practical construction of the universal mounting described, some friction is inevitably present at the trunnion bearings. Assuming for the moment that the bearings of the horizontal axis B, Fig. 8, have slight friction, it is apparent that the earth's rotation will apply a slight turning moment or couple to the

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gyro wheel. It will be recalled that a free gyro does not turn in the direction of an applied couple but precesses around an axis 90° from that of the couple. Consequently the slight friction in the bearings of axis B will cause the gyro wheel to precess about the axis C. With proper construction of bearings B this precession may be made very slow.

In the case just described it was assumed that the bearings of axis C were without friction. The extent to which friction is present in these bearings determines the ability of a gyro wheel to maintain its plane of rotation fixed in space against the friction of bearings B. If, to take an extreme case, the supporting frame were locked about axis C (X, Fig. 8), the gyro wheel would immediately lose its resistance to the friction of bearings B and so would partake of the earth's rotation just as if the wheel were not spinning. The importance of extreme freedom about axis C is therefore apparent.

EFFECT OF LATITUDE

Fig. 11

It has been noted that the earth's rotation causes an apparent rotation of a gyro which is set spinning with its A axis perpendicular to the earth's surface. At the equator this appears to be a straight backward gyration (with respect to the earth's rotation) at the rate of one revolution every 24 hours about a North-South axis. At either pole this phenomenon does not occur (again assuming frictionless bearings), since the gyro axis A is already parallel to (or an extension of) the earth's axis, as in Fig. 11. At any point or latitude between the pole and the equator, however, the wheel appears to gyrate once every 24 hours about an axis parallel to the axis of the earth's rotation, and in a direction opposite to that of the earth's rotation, as in Fig. 12.

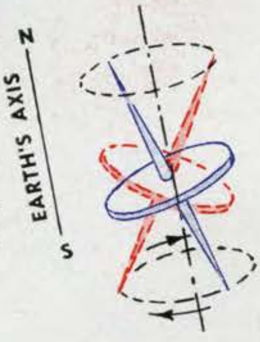

Fig. 12

COMPENSATION

In any application of the gyro to precision instruments, corrections for the earth's rotation, friction, acceleration, turning, etc. must be applied if the gyro is always to spin in a fixed plane with respect to the earth's surface at any latitude.

Compensation for these errors is explained on Pages 44 to 50 under Application.

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FUNDAMENTALS OF THE DIFFERENTIAL

The purpose of a mechanical differential is to add the motions of two rotating shafts such that a function of the sum of their motions appears as rotation of a third shaft. Differential gears are arranged in several forms, two of which are described below.

BEVEL GEAR TYPE

In Fig. 13 is shown the common form of differential mechanism. The gear marked A is directly connected to bevel gear B, while gear C is directly connected to bevel gear D. Part of the unit is shown in cross-section to illustrate the use of ball bearings and the method of obtaining the output function through one of the input gears. (For the sake of clarity, the bearings and supports are not shown for the other shafts or gears illustrated.) If motion is imparted to gears A and C such that they run at the same rate but in opposite directions, bevel gears E and F merely spin or float between B and D. However, if gear C is run at a slower rate than A, gears E and F tend to be retarded by D while still being driven at original speed by B. Thus, in order to keep from locking, they "crawl" around on gears B and D, thereby turning spider G and its associated shaft and output gear H at a rate equal to half the difference between the absolute speeds of A and C. This is the differential action, and the rotation of gear H (driven by the spider G) will always be as follows:

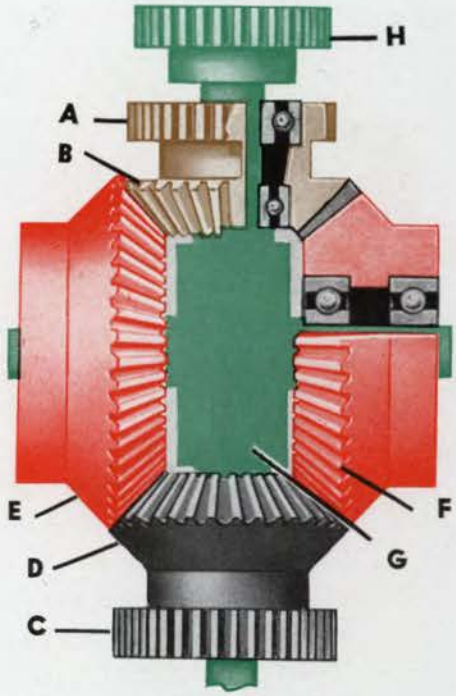

Fig. 13

1. If A and C are rotating in opposite directions—H will rotate in the same direction as that of the faster running drive gear and at a rate equal to half the difference between the absolute speeds of A and C.

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2. If A and C are rotating in the same direction—H will rotate in the same direction as both the driving gears and at a rate halfway between the sum of the speeds of A and C.

(Gear H can also be used as one input and either A or C used as the output.)

PLANETARY TYPE

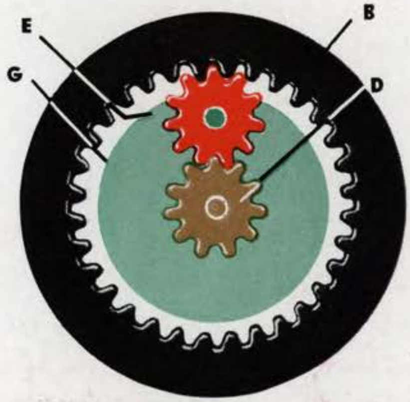

Fig. 14

The same principle of operation applies to the planetary type of differential, which can be thought of as a completely flattened out unit of the bevel gear type. If gear B is enlarged and gear D reduced in size to the point where gears E and F have to "lay over" 90 degrees from their original positions in Fig. 13, they will all lie in a plane as represented in Fig. 14. (Only one of the planet gears E is shown in this illustration.) In this position, B has become an internal gear and D a spur gear. The planet gear E is also a spur gear of a size necessary to mesh with both B and D. The spider is now a plate G in the planetary type, but its rotation still represents the difference between the motions of B and D, multiplied, however, by a factor which is determined by the tooth ratio of gears B and D.

USE IN STABLE ELEMENT

The bevel gear type is used in several places in the Stable Element to provide mechanical outputs which are the sum or difference of two or more rotary motions within the instrument. Definite applications are explained more fully in the section on Construction.

The planetary type (of special design) is the basis of the synchronized clutches which provide one and only one locking point between two mechanical shafts. This action is also described under Construction.

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It is frequently desirable in electro-mechanical computing circuits to transmit a position or angular displacement to a remote point. One means of accomplishing this is to transmit the quantity mechanically by means of shafts. Another method which is more convenient when the distances are great or the path tortuous, is the Synchro transmission system shown in Fig. 15.

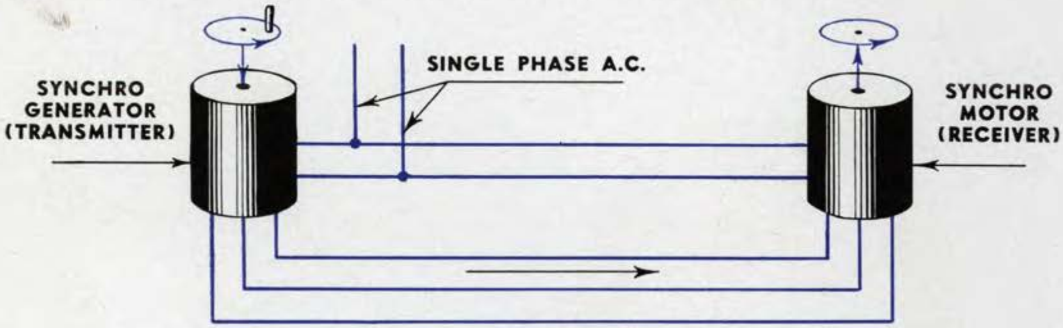

Fig. 15

Each unit shown in the figure contains within its housing a three phase field winding, in the electrical field of which is a single phase two-pole armature or rotor which is supplied from an Alternating Current (A.C.) source of the proper voltage. When any two of these units are electrically connected together—three phase winding to three phase winding, and with both armatures energized from a common single phase A.C. supply—the rotors immediately assume the same relative position in their respective fields.

Now, if the rotor of either Synchro shown in the figure is rotated through a desired angle, the other Synchro will rotate through the same angle. The Synchro which is turned is called the generator or transmitter, and the other one the motor or receiver.

Basically, the Synchro-system operates as follows:

An A.C. source is used to supply voltage to both rotors. Each Synchro then has induced into its three phase stator, voltages dependent upon the angular position of its rotor. Since the stators are connected together the only time that current will not flow between them is when the voltages across the respective phases of both stators are equal and opposite. This occurs only when the two Synchros have similar angular positions.

Turning the transmitter Synchro rotor changes the magnitudes of the voltages across the phases of its stator. Hence, current flows between the stators, and the

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resulting torque between the receiver stator and rotor produces rotation. This rotation is such as to again bring about a balance which occurs only when the two Synchros are at similar angular positions. Hence, the receiver Synchro position always follows the transmitter Synchro position.

SYNCHRO-GENERATORS

Theoretically both of the units described can be exactly alike—either one can act as the generator. In actual practice, however, a Synchro-system is not reversible. The generator is usually designed to operate several motors, thus requiring larger bearings and brushes and heavier windings. Other considerations influence the design of the Synchro-motor.

SYNCHRO-MOTORS

Due to various factors, a Synchro-motor tends to oscillate or "overshoot" especially under rapidly changing positions of the generator. To prevent this, Synchro-motors are fitted with mechanical damps, which are usually built into the unit just inside the housing at the output shaft end. The torque of the motor is zero at synchronism, and at a small angular displacement is still quite small. A large torque requirement of a load connected to the motor may keep the rotor displaced from the position of the rotor of the generator. Because of this limitation the transmission system shown in Fig. 15 is used only when the load on the receiver is very small.

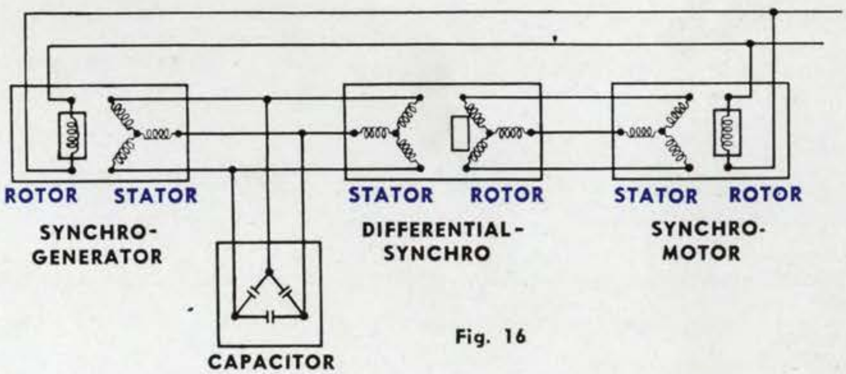

Fig. 16

DIFFERENTIAL SYNCHRO

If, instead of a single phase rotor, a three phase rotor is placed in the three-phase field, a differential Synchro results. Physically it resembles a three-phase wound-rotor induction motor. Like a mechanical differential, its output shaft (rotor) turns as a function (sum or difference) of the inputs from two Synchro-generators. Conversely, if it is installed between a Synchro-generator and a Synchro-motor, as shown diagrammatically in Fig. 16, it will modify the electrical angle received in one of its windings so that the Synchro-motor will assume a position which will represent the algebraic sum of the angles mechanically applied to the Synchro-generator and differential Synchro.

Any number of differential Synchros may be inserted electrically between a generator and a motor, and the motor will operate to indicate the algebraic sum of the angular inputs to all the rotors in the system.

A capacitor, as shown in Fig. 16, is inserted between the Synchro-generator and the differential Synchro to absorb reflected currents from the load and thus prevent their imposing a disturbing torque on the generator. Fig. 17 shows two differential Synchros between a generator and a motor. It will be noticed that

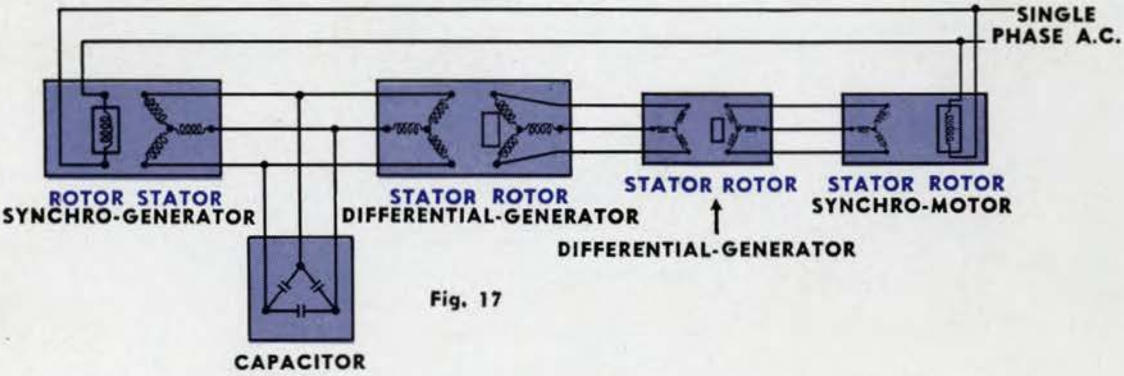

Fig. 17

one capacitor serves this system. This is allowable only if the first differential Synchro is of large capacity as compared to the second differential Synchro and the Synchro-motor.

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The basic electronic principles of amplifiers and rectifiers are but briefly explained here, inasmuch as maintenance of the electronic components of the Stable Element is a matter of following through a simplified procedure as explained in the section on Casualties, and an advanced knowledge of electronics is not necessary in the performance of these steps.

VACUUM TUBES

The vacuum tube is the heart of electronic control circuits, being the "valve" which performs the actual control function. Basically, its construction and operation are as follows:

Within an evacuated envelope (usually of glass) are placed a cathode and an anode, between which there may be located one or more grids. Structurally the cathode consists of a filament or other emissive surface which, when heated, either directly or indirectly, produces a cloud of negatively charged particles called electrons. In the case of a diode, or two element tube (no grid), if the anode, or plate, is charged to a high positive potential with respect to the cathode, by a battery or other source, the electrons are attracted to the anode. This flow of electrons constitutes a current flow in the circuit, as shown in Fig. 18. The rate of flow depends on the potential difference between cathode and anode, being greater at higher values of plate voltage. This current is limited by the quantity of electron emission and by resistance in the circuit (R, Fig. 18).

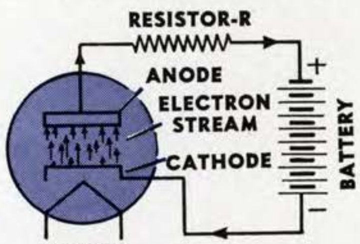

Fig. 18

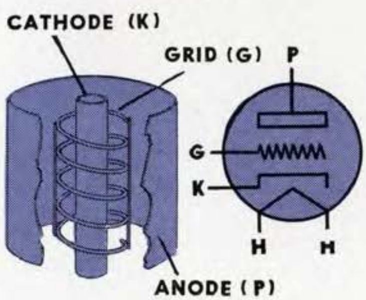

Fig. 19

The grid, which consists of several spaced turns of fine wire, spirally wound, is supported between the cathode and anode, as shown in Fig. 19, to control the flow of electrons to the anode. This function is explained in subsequent paragraphs. In some types of tubes, several grids are located between the cathode and the anode, the one closest to the cathode usually being the control grid and the others serving special purposes, the explanations of which are beyond the scope of this book.

Vacuum tubes of different types serve as rectifiers or amplifiers and a discussion of each type follows in the ensuing paragraphs.

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AMPLIFIERS

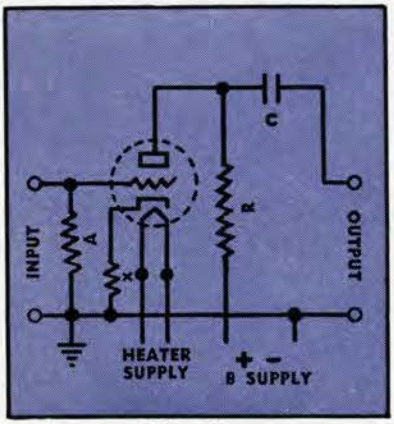

Fig. 20

Referring to Fig. 19, if a voltage is applied to the grid, this element will control the flow of electrons by virtue of a potential difference between it and the cathode. If the applied grid voltage is negative, the grid repels many of the electrons attempting to travel to the anode, and the plate current is therefore reduced. If a positive voltage is applied to the grid, it attracts the electrons from the cathode, accelerating them toward the plate, greatly increasing the flow of current.

Since the grid is closer to the cathode than the plate, a much lower potential will be required on the grid than on the plate to obtain the same control over the electron stream. Thus, a small change of voltage on the grid will cause much greater changes in plate current than the same change in plate voltage would cause, and therein lies the ability of a vacuum tube to amplify small signals.

Looking at it in another way, for a given value of plate current, the ratio of the change in plate voltage to the change in grid voltage necessary to maintain the plate current constant is the amplification factor, or gain, of the tube.

The amount of plate current drawn when there is no signal voltage applied to the grid depends upon the value of a Direct Current (D.C.) or fixed voltage which is applied to the grid and holds it at some potential difference with respect to the cathode. This fixed voltage is called the "bias" voltage, and is obtained from the voltage drop across a resistor in the cathode return to the plate supply, or from some other external source. Referring to Fig. 20, if current flows from the cathode to the plate, hence through resistors R and X and back to the cathode, there will be a voltage drop across resistor X. This voltage drop produces a potential difference between the cathode and the grid, since the circuit between the two is completed through resistor A. Resistor A serves to prevent short-circuiting of the input while still maintaining a complete electrical circuit between cathode and grid. Tubes are usually biased negatively in order to obtain linear amplification. This also limits the plate current under no-signal conditions to a nominal value.

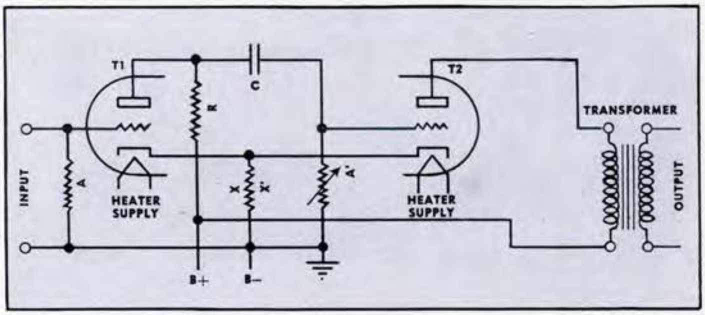

Fig. 21

Fig. 20 represents a simple circuit utilizing a triode (three element tube) for amplification. If an input signal voltage (A.C.) is applied to the grid by superimposing it upon the biasing voltage, it will cause a variation of the plate current. This variation of the plate current will cause a variation of the voltage drop across resistor R. The voltage variations across resistor R are at the same frequency as the input signal, but 180° out of phase and much greater in amplitude.

The amplified signal is applied to the output terminals through a coupling condenser C which passes the A.C. component but blocks passage of the D.C. anode potential. Between the output terminals, then, there exists an amplified A.C. voltage which may be used as the input to another tube, or in any other way desired. The complete circuit of Fig. 20 represents one "stage" of amplification.

For greater amplification than is obtainable with one tube, two or more tubes (or stages) are connected together, the output of one being the input of the next. This is called "series" or "cascade" connection and is illustrated in Fig. 21. There are several ways of coupling two or more stages together, two of which are shown in this figure. The coupling between the two stages shown is accomplished by means of a condenser C. This method is known as "resistance coupling," or the circuit as a "resistance-capacitance coupled amplifier."

"Transformer coupling" is shown in the output of the second stage. In this type of coupling, the separated windings prevent the D.C. plate potential from being applied to the following input terminals, while the inductive coupling between transformer windings transfers the signal voltage from one winding to the other.

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RECTIFIERS

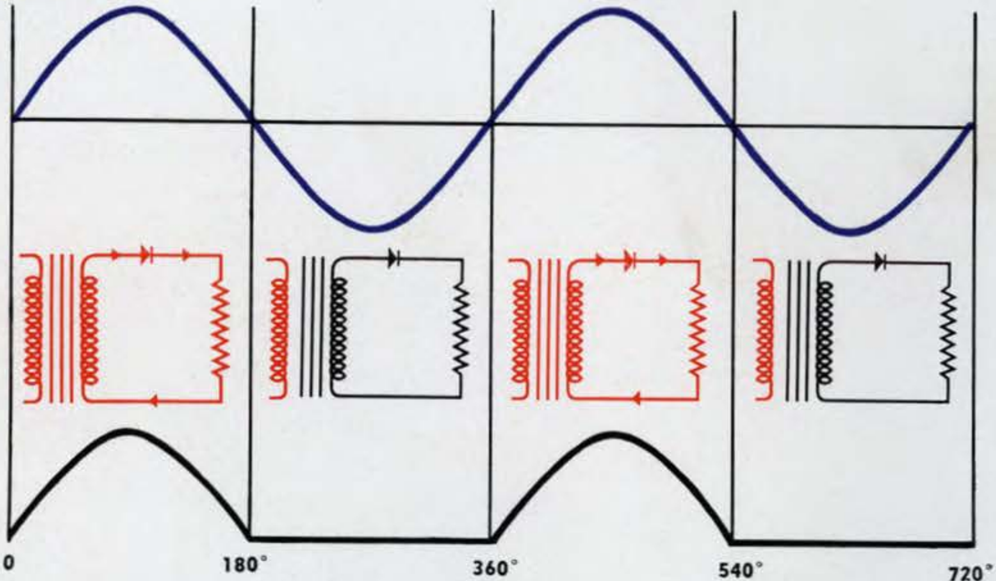
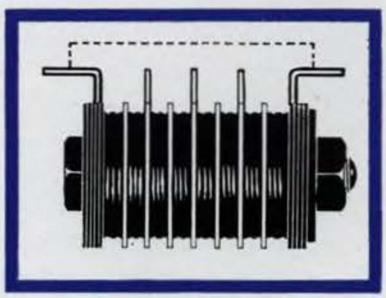


Fig. 22

The purpose of a rectifier is to change an alternating voltage to a pulsating direct voltage. In order to do this, it must be of such a nature that it will pass current in one direction but not in the opposite direction. Films of selenium, copper oxide, copper sulphide, or certain other chemical compounds, when placed between certain types of metal discs or plates possess this property. When alternating voltage is applied to a stack of these elements, known as a dry rectifier, the positive half of the A.C. wave is passed readily, while the negative half of the wave encounters such a high resistance that current flow in the opposite direction is negligible.

Fig. 22 shows the principle of operation of a half-wave dry rectifier. An A.C. source is connected to the unit as shown. During one half of the cycle, or 180°, current flows through the load in the direction indicated. On the next half of the A.C. cycle, the rectifier offers such a high resistance that the current flow is practically zero. In the figure, this action is repeated for another A.C. cycle. The resulting output is a pulsating D.C. across the load due to half-wave rectification.



To rectify both halves of an A.C. wave, two or more rectifier elements are required. Fig. 23 shows the construction of a small copper oxide dry rectifier in which four elements are employed in a bridge circuit and operate as shown in Fig. 24.

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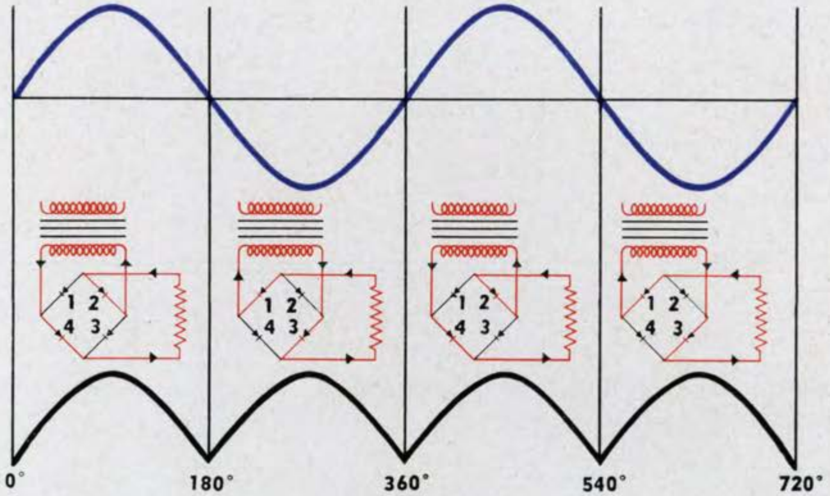

Fig. 24

Referring to Fig. 24, on any given half-cycle, only two of the rectifier elements are being used. From 0° to 180° the current flows in the direction of the black arrows, readily passing through rectifiers 2 and 4. Elements 1 and 3 are not working since their resistance is high to current flow in this direction. On the next half-cycle, the current is still flowing in the direction of the black arrows, although the path through the rectifier elements has changed. Rectifiers 2 and 4 now offer a high resistance to current flow in this direction. The drawing shows this action through two complete cycles.

Across the load, therefore, there appears a pulsating D.C. due to full-wave rectification of twice the frequency of the D.C. pulsations due to half-wave rectification. For some purposes, such as for running motors, the pulsating D.C., either from half-wave or full-wave rectification, is satisfactory as it comes from the rectifier. In other applications, filtering becomes necessary to level off or "smooth out" the pulsations so that a more uniform flow of D.C. is available. A simple filter consists of a condenser across the rectifier output. When the current flows it charges the condenser, and during the time when the D.C. voltage is zero, the condenser discharges into the load. This produces a smoother flow of current through the load. By proper choice of condensers, plus the addition of inductances, or chokes, in series with the load, the output can be made to approach pure D.C. This filtering is necessary if the D.C. is to supply the anode potential for vacuum tube amplifiers.

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A diode (two element) vacuum tube also serves as a rectifier inasmuch as the emission of electrons from the cathode causes a current flow from cathode to anode, but this action is not reversible since the plate is not a source of electrons.

GRID-CONTROLLED RECTIFIERS

If a grid is placed between the cathode and anode of a rectifier tube, the grid can control the starting time of the flow of current and the tube is known as a grid-controlled rectifier. This type of tube is usually filled, after evacuation, with an inert gas at low pressure, which forms a conducting path when ionized. Hence, gas-filled tubes provide much greater current-carrying capacity than do vacuum tubes. (Tubes of the gas-filled variety have been designed to carry hundreds of amperes.)

In a vacuum tube the plate current varies with changes in grid voltage. In a grid-controlled gas-filled rectifier it does not vary. The grid serves only as a "trigger" to start the flow of plate current.

Fig. 25 shows several voltages plotted on a time basis, these voltages representing the principle just explained. In order for the tube to pass current, the plate voltage must be above the ionization potential of the gas, which is indicated (approximately to scale) at V-V′ in the figure. When the voltage on the plate rises above the value at V, it is capable of ionizing the gas and initiating a flow of current, if the grid potential is higher than the value indicated by the critical grid voltage curve at that instant. It can be seen that the critical grid voltage varies with the value of positive plate voltage, a high positive grid voltage being necessary to "trigger" the tube at the beginning or near the end of the cycle, while even if there is small negative grid voltage, the tube may be "triggered" during the major portion of the cycle.

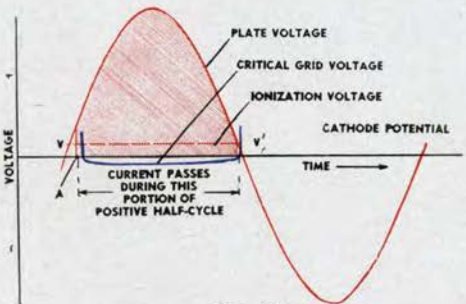

Fig. 25

If the grid is more positive than this critical voltage, for a given value of plate voltage, plate current of the full rated value of the tube will flow, limited only by the amount of load resistance in its plate circuit. As soon as plate current flows, the grid becomes surrounded by a sheath of positive ions from the

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gas, and regardless of how its potential is varied within practical limits, it will not stop the flow of plate current. The only way to stop this flow is to remove the positive plate voltage or reduce it to a value below the ionization voltage of the gas.

In alternating current circuits, the plate is positive for one half cycle and negative the next half. As plate current will flow only when the plate is positive, the current stops every half cycle as the plate voltage drops below the ionization voltage of the gas. During the half-cycle while the plate is negative the grid regains control because the sheath of positive ions drains off in a few millionths of a second.

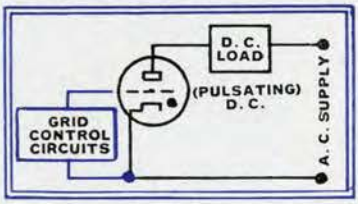

Fig. 26

The tube, therefore, permits the flow of plate current only during the positive half-cycles, and only then (during the positive half-cycle) when the grid potential is allowed to rise above the critical grid voltage. If the grid is at cathode potential, as in Fig. 25, the tube will start conducting at point A where the grid voltage exceeds the value of the critical grid voltage, and will continue to conduct during the shaded portion of the cycle until the plate voltage drops below the ionization voltage at V′.

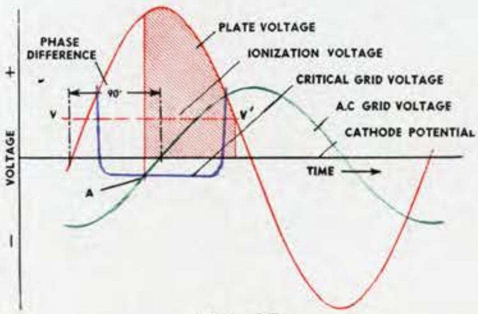

Fig. 27

Fig. 26 shows the fundamental circuit of a grid-controlled rectifier so connected as to operate a load on half-wave rectified A.C. (pulsating D.C.). The dot in the tube diagram is to indicate a gas-filled tube. The circuits in the box marked "grid control circuits" may be manual or automatic, mechanical or electronic, of either a voltage-change or phase-shift type. (Since the operation of certain rectifiers in the Stable Element utilizes electronic control consisting of a combination of voltage-change and phase-shift circuits, the following paragraphs will very briefly explain this type of control.)

Fig. 27 shows several A.C. voltages on a chart of voltage versus time. The red sine wave represents the voltage applied to the plate of a grid-controlled rectifier. The blue curve is the critical grid voltage. As stated before, a grid voltage higher than this value will cause the tube to pass

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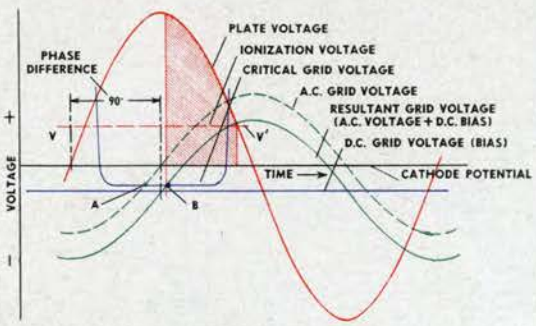

Fig. 28

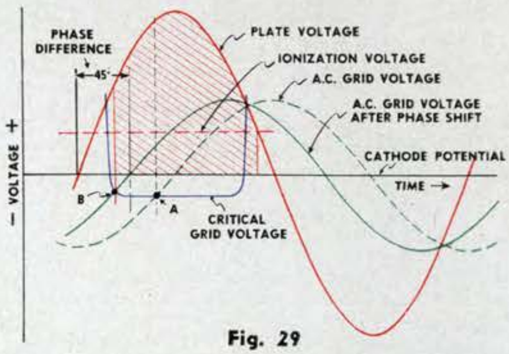

Fig. 29

current during each positive half-cycle, if the plate voltage is greater than the ionization voltage of the gas. If an A.C. voltage as represented by the green wave is applied to the grid, the tube will start passing current during each positive half-cycle at the point A where this wave crosses the critical grid voltage wave. The amount of current passed during this half-cycle is represented by the filled-in portion of the plate voltage wave. To avoid the confusion that would arise if the diagram were drawn to scale, the curves in this figure and in the following diagrams are drawn out of proportion in order to provide readable separation between each other.

There are two methods by which the plate current may be caused to start flowing at a different point in the cycle. One is by applying a D.C. potential (bias) to the grid.

Assuming a negative D.C. bias is applied, as shown in Fig. 28, the applied A.C. grid voltage is caused to exceed the critical grid voltage at a later point B. This allows plate current to flow during a smaller part of the cycle as represented by the smaller shaded portion of the plate voltage cycle. The instantaneous value of the "Resultant Grid Voltage" shown is the algebraic sum of all voltages applied to the grid at that instant.

The other method is by shifting the A.C. grid voltage wave electrically, causing it to cross the critical grid voltage wave sooner or later than shown in Fig. 27. Fig. 29 shows the conditions which exist when the phase of the A.C. grid voltage has been shifted ahead 45 electrical degrees. A combination of these two types of control is used in the Stable Element circuits and is described in the following section on Application.

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APPLICATION OF FUNDAMENTALS

This section describes the specific application to the Stable Element of the units and principles of operation explained generally in the preceding section on Fundamentals.

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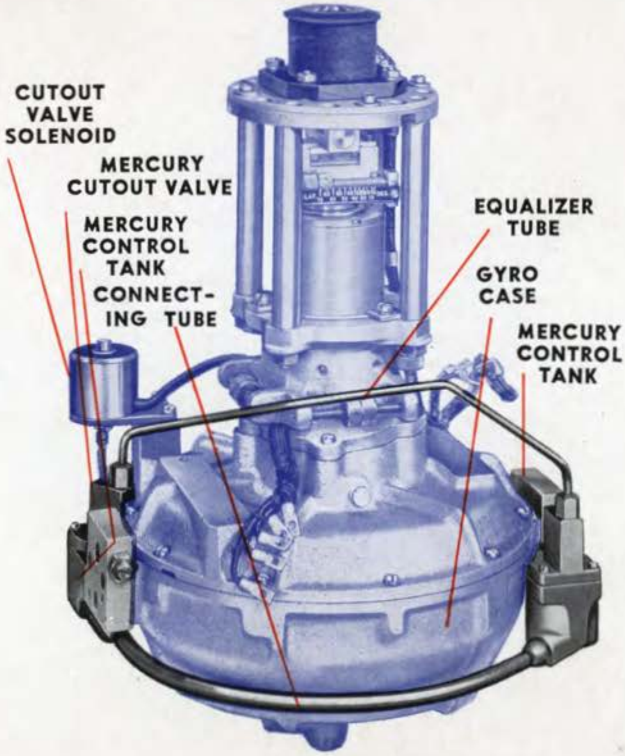

Fig. 30

The application of the gyroscope to the Stable Element consists of the use of a free gyro with its spin axis vertical, such as was described in the section on Fundamentals, together with compensations for all disturbing forces, the gyro providing a true horizontal reference plane from which angles of roll and pitch of a ship can be measured and utilized.

Compensation for various disturbing factors is accomplished as follows:

MERCURY CONTROL

Since free behavior of a gyroscope is affected by friction, acceleration forces, shocks and other disturbances, provision is made in the Stable Element for counteracting any or all of such forces which tend to displace its gyro axis from the vertical. This is accomplished by introducing a righting force which is set up by means of a pair of mercury control tanks and two connecting tubes, as shown in black in Fig. 30. These tanks are diametrically opposite and the lower tube or pipe is to allow for free flow of mercury from either tank to the other. The top tube is merely an air pressure equalizing connection between the two tanks.

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The gyro (including the tanks) and its mountings are rotated within the unit at approximately 18 R.P.M. in the same direction as that of the gyro wheel. When the gyro is displaced from the vertical, the mercury flows from the high tank to the low tank, but not instantaneously. Due to the resistance to flow as determined by the dimensions of the pipe, tanks, and openings between them, as well as friction and rotary motions, the maximum flow occurs at some time after the maximum displacement of the gyro is reached. This flow is about 90° out of phase with (behind) the gyro tilt, and the gravity couple set up by the difference in the amount of mercury in the two tanks is in such a direction (or phase) as to cause the gyro to precess back into the vertical.

The couple, or righting force, introduced by the mercury control depends only upon a displacement of the gyro axis from the vertical, regardless of the cause of the displacement. Therefore, in starting up the Sensitive Element, if the gyro axis is not vertical, the mercury control will bring it to the vertical and tend to maintain it in that position.

MERCURY CONTROL CUTOUT VALVE

Any disturbance in the natural mercury flow would tend to displace the gyro from the vertical rather than to right it. Such a disturbance can be introduced by a centrifugal force caused by the ship's turning at a high enough speed or at a small enough radius, or by mercury surging due to its inertia when the ship accelerates or slows down rapidly. Therefore provision is made to stop the flow of mercury under these conditions by energizing (closing) the electric solenoid valve shown in Fig. 30, through motor-operated contacts on the Control Panel. The operation of this control is described in the following paragraphs:

CUTOUT VALVE CONTROL

The control is divided into two units, one of which (So unit) consists essentially of a small A.C. auxiliary motor and a Synchro-motor which is excited by the ship's Pitometer Log at 1 speed. The other (Co Unit) consists essentially of a small D.C. motor and a Synchro-motor excited from the ship's Gyro Compass at 36 speed. (*On DD's 421-436, BB's 55-56, AO's 22-23, AD-15 and AV-5 there is only one control unit, that excited by the ship's Gyro Compass,*

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so that the cutout is affected only by a change in course (Co). On all other ships, there are two control motor units as described in these paragraphs.)

So UNIT The purpose of this unit is to stop the flow of mercury if it tends to

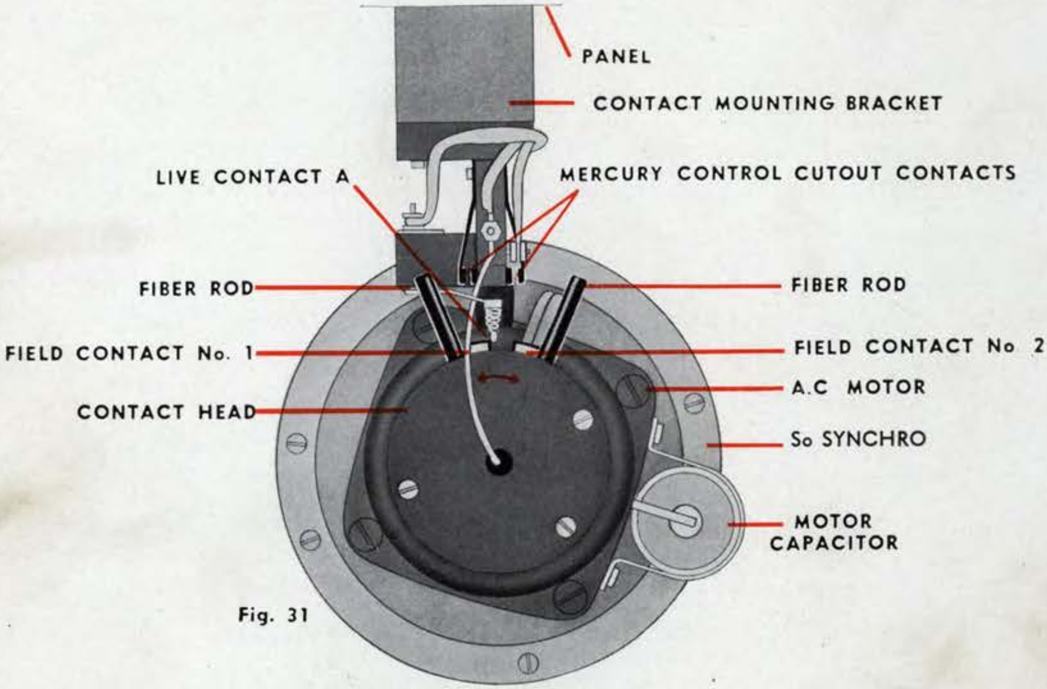

Fig. 31

be too greatly disturbed by linear acceleration of the ship (change in Own Ship's Speed).

The A.C. motor is so mounted (pivoted) that its frame (or stator) is free to rotate within certain fixed limits. On its armature shaft is a friction coupling and a small spur gear which meshes with a similar spur gear on the rotor shaft of the Synchro receiver. This Synchro indicates Own Ship's Speed and hence the rate of turning of the Synchro is proportional to Own Ship's Acceleration. The R.P.M. of the A.C. motor is dependent on the number of degrees the So Synchro turns per knot of Own Ship's Speed. Thus the R.P.M. of the A.C. motor varies with different Pitometer Logs. See Chart C under Information for relationship between Own Ship's Speed and the speed of the A.C. motor.

The A.C. motor is of the reversible split-phase type, one field winding terminating in Field Contact 1 and the other terminating in Field Contact 2 with a capacitor connected between the two. Refer to Fig. 31. On a stationary bracket

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in alignment with these terminals is a spring-loaded live silver contact A which is energized from the ship's 115 volt A.C. supply. The stator of the A.C. motor also carries 2 projecting arms (fiber rods) which operate the mercury control cutout magnet contacts. When the ship is moving at a constant speed the So unit is in equilibrium, neither field contact touching the live terminal. Thus the A.C. motor is not energized, and the rotor of the So Synchro receiver is held stationary at a given point by the Pitometer Log input, this position depending upon the actual speed of the ship. However, when the ship accelerates or decelerates the rotor of the Synchro receiver is displaced. Since the A.C. motor is not energized, its stator is carried about on its pivots by the rotation of the Synchro rotor until one or the other of its field contacts touches the live contact. This energizes the motor in such a direction as to cause its stator to turn away from the live terminal and thereby break the circuit. (Since the armature shaft is geared to the rotor of the Synchro, any relative motion between armature and stator must be taken up by movement of the stator.) This action—contacting and backing away—continues in rapid sequence as long as the change in ship's speed is not too great.

If, however, the rate of change of speed is so great that the Synchro rotor is being displaced faster than the rated R.P.M. of the A.C. motor, the entire A.C. motor will be carried onward faster than its own rotation can back its stator—and field contact—away. The spring-loaded live contact takes up this extra rotation until finally the projecting arm closes one of the pairs of mercury control contacts. This energizes the mercury cutout valve magnet on the Sensitive Element, provided the Mercury Control Switch on the Control Panel is in the "Automatic" position. Energizing this magnet closes the cutout valve, thus halting the flow of mercury. This condition continues until the disturbing force subsides and the control contacts are no longer held closed by the stator of the A.C. motor. If the acceleration persists after the control contacts are closed, the friction clutch (coupling the motor to the Synchro) slips and prevents damage to the unit.

Co UNIT The purpose of this unit is to stop the flow of mercury if it tends to be too greatly disturbed by angular acceleration (rate of change of Own Ship's Course). The construction of the Own Ship's Course Co Mercury Control cutout assembly is quite similar to that just described for the Own Ship's Speed So unit with the exception of the arrangement of the contacts and

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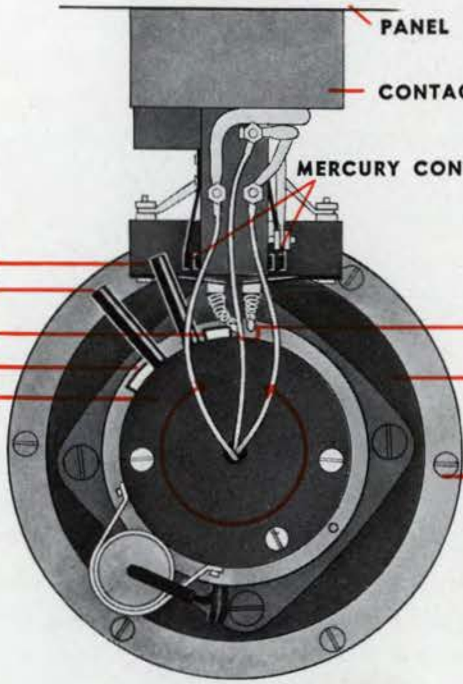

Fig. 32

the limits of rotation of the auxiliary motor. See Fig. 32. The Synchro receiver in this case is connected to the output of the Gyro Compass transmitter and the auxiliary motor is D.C. operated, being internally geared to produce a maximum output of a little less than 2 R.P.M. As in the So unit, the stator of the auxiliary motor operates a set of mercury control contacts which are electrically in parallel with those of the So unit. If the change in Own Ship's Course causes the Synchro rotor to turn faster than the D.C. motor, this auxiliary motor will not be able to overcome the turning of the Synchro, and will close the mercury control contacts, thereby energizing the cutout magnet on the Sensitive Element and halting the flow of mercury.

The angular acceleration of own ship depends upon both the radius of turn and the speed of the ship. The R.P.M. of the Co Synchro varies inversely with the radius of turn for any given speed of the ship. In other words for a given ship's speed, the more acute the turn the greater the R.P.M. of the Co Synchro. Likewise the R.P.M. of the D.C. auxiliary motor is caused to vary inversely with Own Ship's Speed. This is brought about by having the armature

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current of the motor pass through a voltage divider, the movable contact of which is positioned by the rotor of the So Synchro.

Therefore, for a given speed of the ship, and hence for a given R.P.M. of the D.C.motor, the mercury control contacts will be actuated depending upon the acuteness of the turn. Similarly, since the R.P.M. of the D.C. motor varies inversely with the speed of the ship, for a greater speed of own ship than formerly, less acute turns than formerly will close the Co unit's contacts, since the slower R.P.M. of the D.C. motor will not allow it to back away as rapidly. The design is such that the contacts will close when the angular acceleration of the ship exerts too great a disturbing force on the mercury.

This action is assumed to take place when the Mercury Control circuit is in proper operation. The circuit to the cutout magnet is completed through the "Mercury Control Switch" located on the Control Panel. This switch has two positions, marked "On" and "Automatic." In the "On" position the circuit through the magnet is always open and the cutout valve remains open, allowing free flow of the mercury between tanks regardless of the position of the contacts on the control motors just described.

This "On" position is used whenever it is desired to prevent closing of the mercury control valve. Reference will be made to it later in the section under Adjustments.

The "Automatic" position is used when the Sensitive Element is settled, both at anchor and at sea, and when in this position, the contact points of the control motors just described will operate the cutout valve when conditions of speed and turning warrant the cessation of the flow of mercury.

LATITUDE CORRECTION

It has been shown how the mercury control brings the spin axis of the gyro to the vertical, but that effective operation of this control depends upon a definite displacement of the gyro from the vertical. If the mercury control were acting alone, the gyro would deviate slightly from the vertical due to apparent tilt caused by the earth's rotation. To compensate for this, a correcting force must be applied in such a manner that the rate of precession eastward about a north-south axis due to this applied force will be exactly equal to the rate of apparent tilt of the gyro caused by the earth's rotation. This correcting force must be

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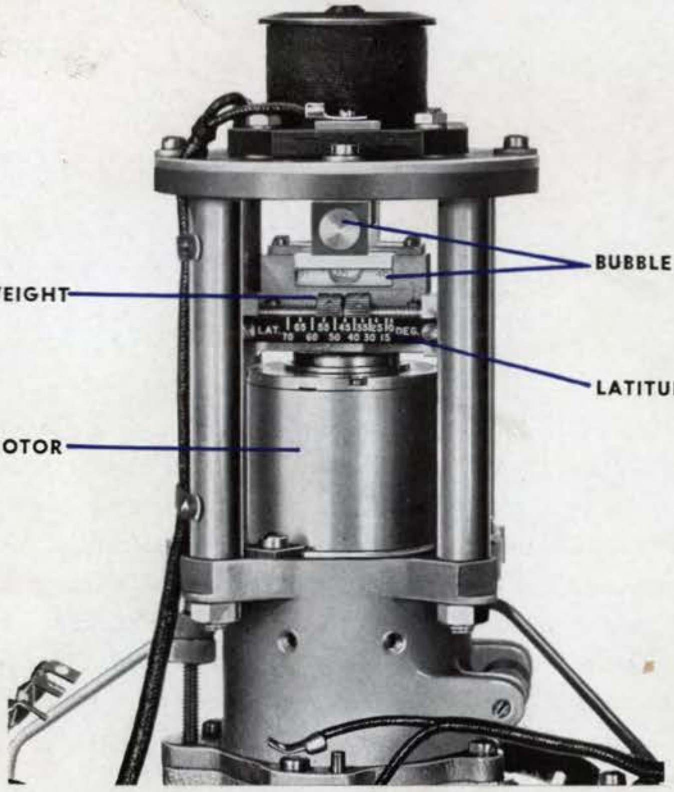

Fig. 33

adjustable, its value or position depending at any time upon the latitude of the gyro at that time.

In the Stable Element, this correction is accomplished by applying a torque or couple about an east-west axis which causes the desired precession eastward about a north-south axis. This couple is set up by means of a weight which can be adjustably positioned on a screw.

Fig. 33 shows the horizontal screw and adjustable weight. The position of the weight is determined by a scale parallel with the screw and calibrated in degrees latitude. This weight is positioned by hand, and must be set to the correct latitude of the ship's position within plus or minus one thirty-second (1/32") of an inch on the scale each time the Stable Element is started up.

In order for the precession caused by the latitude correction weight to be toward the east, the weight must always be maintained on the same side of the gyro. The direction of rotation of the gyro is such that, to cause this eastward precession, the mounting screw upon which the weight is positioned must lie in a north-south direction. This positioning is accomplished as follows:

Since the gyro case, its gimbals and its supports are rotating at approximately 18 R.P.M., as explained in the preceding paragraphs on the Mercury Control System, and since the whole assembly rotates with the training gear during changes in Target Bearing (Director Train) input, the latitude correction weight assembly cannot be mounted directly on the gyro case. Therefore, it is secured to the rotor of a small Synchro-motor which is clamped to the gyro case. This receiver is energized by a transmitter on the ship's Gyro Compass through two differential Synchros in series. One of these differential Synchros is driven by the training gear at 1 to 1 ratio and "takes out" the motion due to change of director train angle; the other is geared 1 to 1 to the mechanism which turns the gyro and its mountings at 18 R.P.M. and "takes out" the angle generated by this rotation.

Thus, since all rotatory motions imparted to the gyro case are counteracted by differential Synchros, the rotor of the latitude correction Synchro-motor appears to remain stationary within the rotating system, and the screw carrying the latitude correction weight always lies in the meridian—as long as the latitude correction motor is energized by the Gyro Compass transmitter.

APPLICATION OF THE SYNCHRO SYSTEM

The Stable Element utilizes Synchro Transmission systems in several ways, two of which have been described in the preceding pages of this section, to wit:

1. Synchro-motors are used in the Cutout Valve Control to reproduce at the Control Panel Own Ship's Course from the Gyro Compass and Own Ship's Speed from the Pitometer Log.
2. A Synchro-motor and two differential Synchros are used in the Latitude Correction system in the Stable Element to reproduce Own Ship's Course at the gyro Latitude Correction assembly.

Another use of Synchro-systems is found in the transmission of Level and Cross Level angles as measured by the Stable Element. Synchro-generators are geared to one or more mechanical outputs of the instrument (depending upon the Mark and Mod.) and provide electrical positioning for remote devices which utilize the angles generated by the Stable Element.

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Inasmuch as the electronic principles utilized in the Stable Element are so closely associated with the remaining electrical circuits, the entire electrical system, including the Control Panel, Follow-up Panel and Stable Element proper, is shown diagrammatically on the following three pages (52A, 54A and 56A) for ready reference with respect to the ensuing explanation of its operation.

STABLE ELEMENT

This circuit diagram represents the Mark 6 only. Circuit differences between this instrument and the Mark 5 and Mark 6 Mod. 1 are in the electrical transmission (Synchro) systems only.

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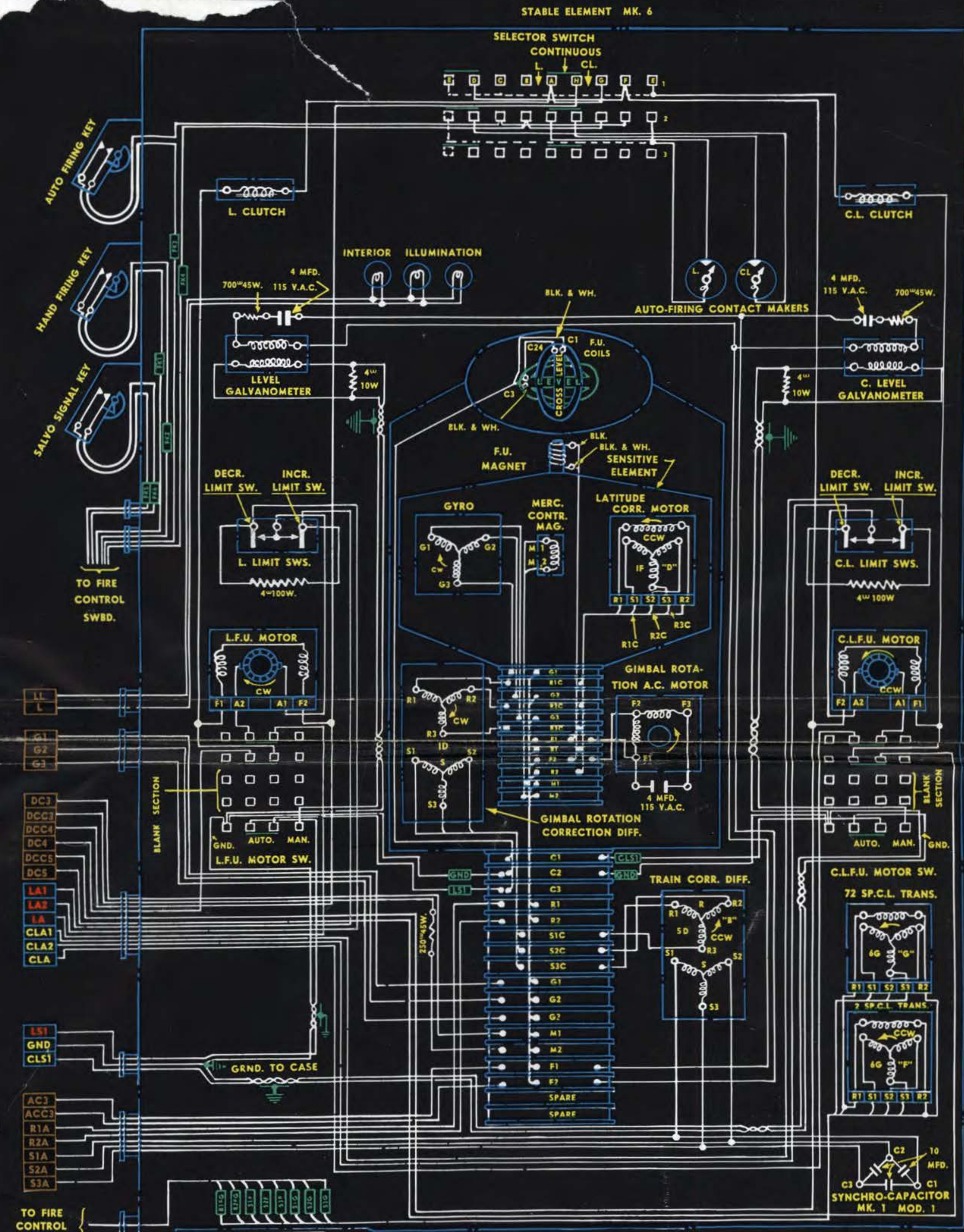
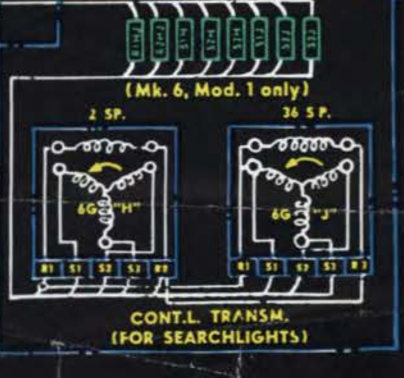
STABLE ELEMENT — ELEMENTARY WIRING DIAGRAM

Fig. 34





LEGEND:
- Shielding
- O Terminal on Unit
- NO Terminal on Main Terminal Block
- NO Terminal on Control Panel
- NO Terminal on Follow-up Panel

NOTES:

1. Switches shown as viewed from front; No. 1 Section is nearest handle.
2. Arrows on Level Follow-up Motor and Continuous Level Synchros (Mk. 6, Mod. 1 only) indicate direction of rotation for increasing Level angle (optics up).
3. Arrows on Cross Level Follow-up Motor and Synchros indicate direction of rotation for increasing Cross Level angle (left side of optics up, facing target).
4. Arrows on Latitude Correction Motor, Gimbal Rotation Motor and Gimbal Rotation Correction differential Synchro are for clockwise rotation of the Sensitive Element and Gyro as viewed from top.
5. Arrow on Train Correction differential Synchro is for clockwise rotation of Line of Sight.
6. Rotation on Synchros and motors are indicated as viewed from shaft extension end.
7. For external, schematic and elementary wiring diagram numbers pertaining to the particular installation, refer to list of drawing numbers on Chart (A) under Information.

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CONTROL PANEL

The circuit shown represents that of the Mark 7, Mods. 2 and 5 Control Panel, similar to the Control Panel pictured on page 107, which is a simplex panel used for controlling one Stable Element. All Mark 7 panels are simplex panels, while all Mark 8 panels are duplex, designed to operate two Stable Elements.

The various modifications of each Mark type are based on:

1. The maximum speed of own ship
2. The Control Valve Control system inputs
3. Shock test
4. Spare Mods.

These modifications are listed in page Chart C under Information, but the electrical circuits differ but slightly from the one shown here, the major difference being in the switching of the gyro supply.

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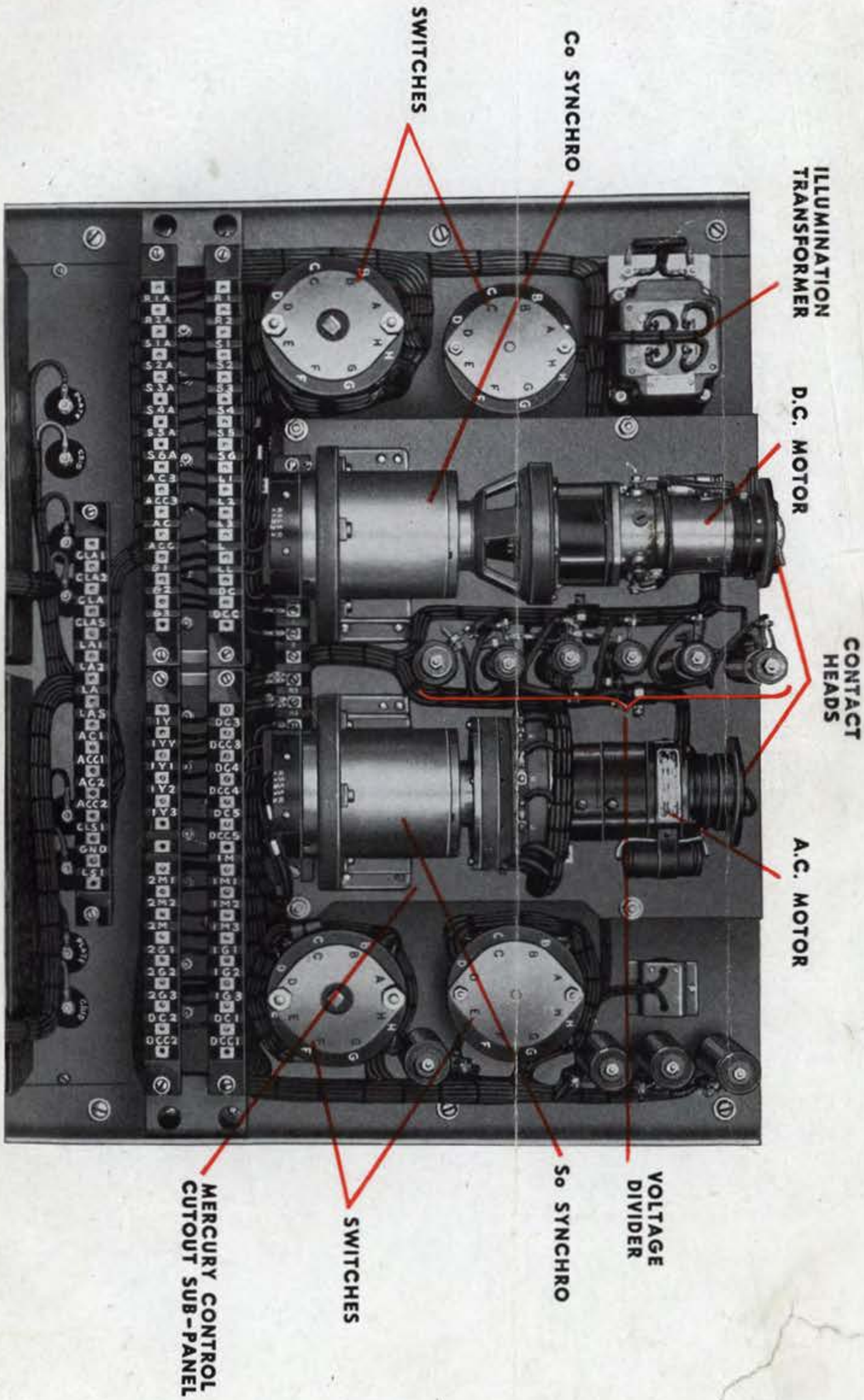

Fig. 35

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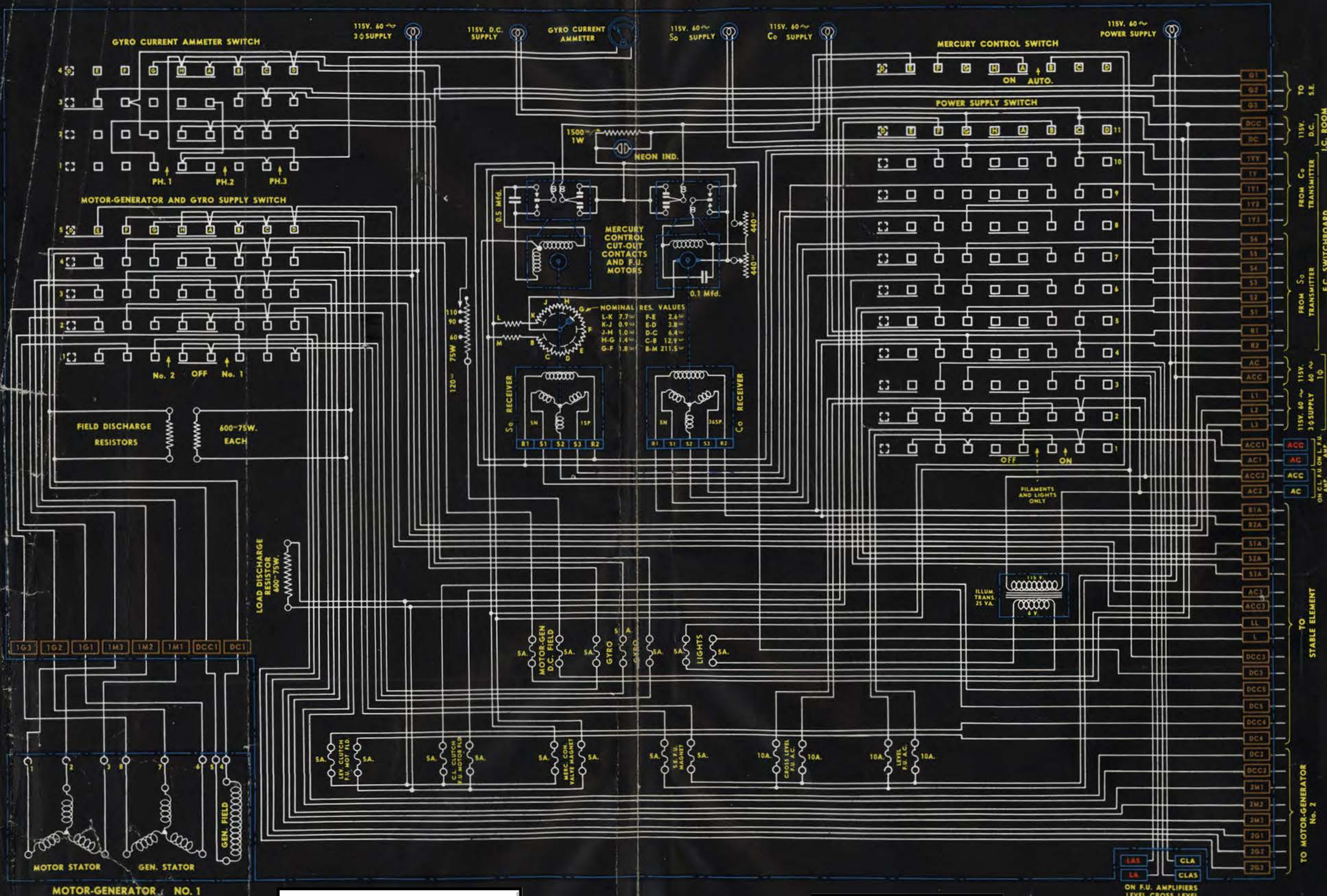
CONTROL PANEL ELEMENTARY WIRING DIAGRAM, MK. 7, MODS. 2 and 5

Fig. 36



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FOLLOW-UP AMPLIFIERS

Shown here is one follow-up circuit only, since both the Level and Cross Level follow-up amplifiers and associated circuits are identical. The terminals numbered in red are those found on the Level system, while yellow numbers on the same terminals represent the corresponding terminals when referring to the Cross Level circuits.

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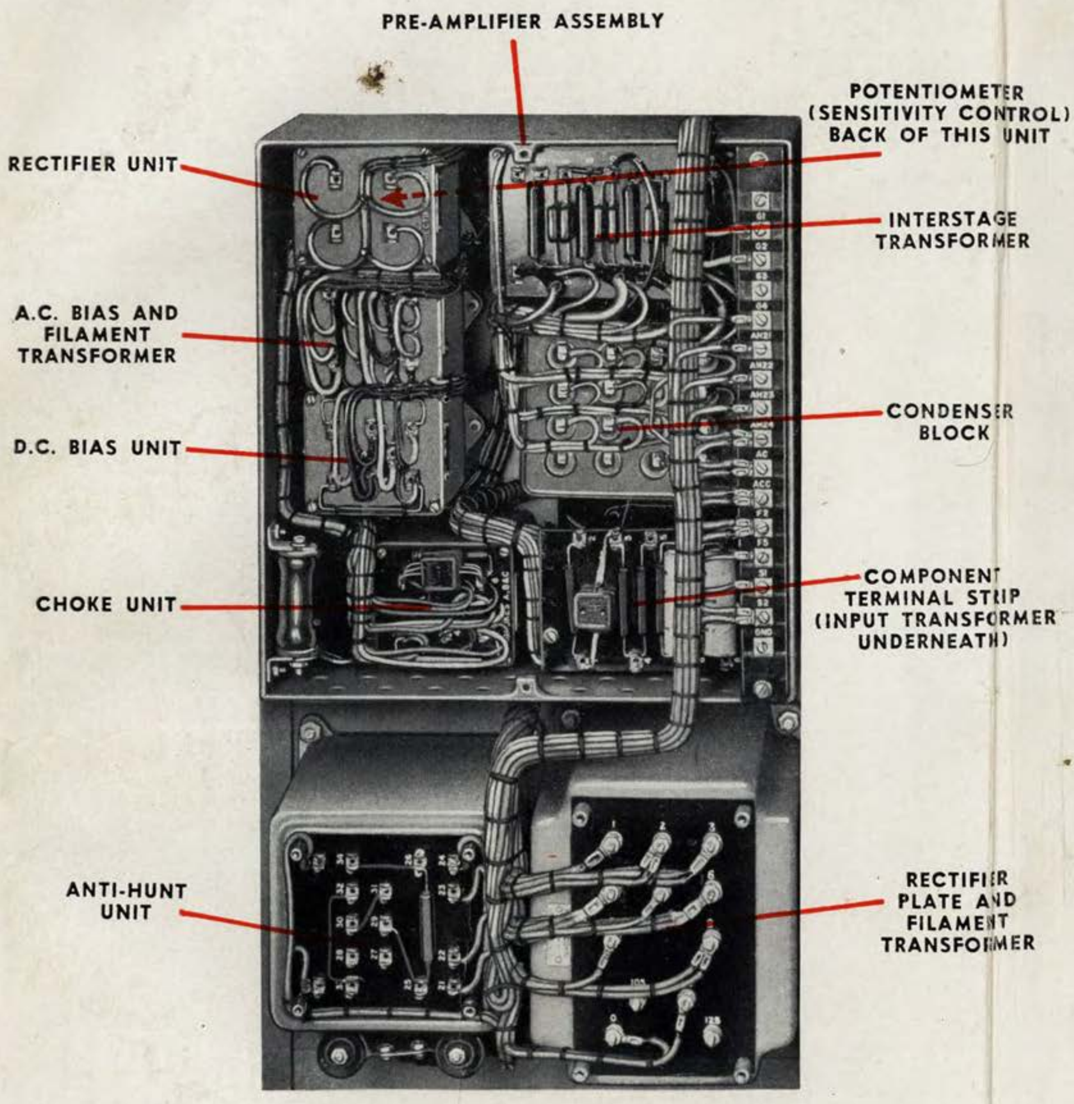

Fig. 37

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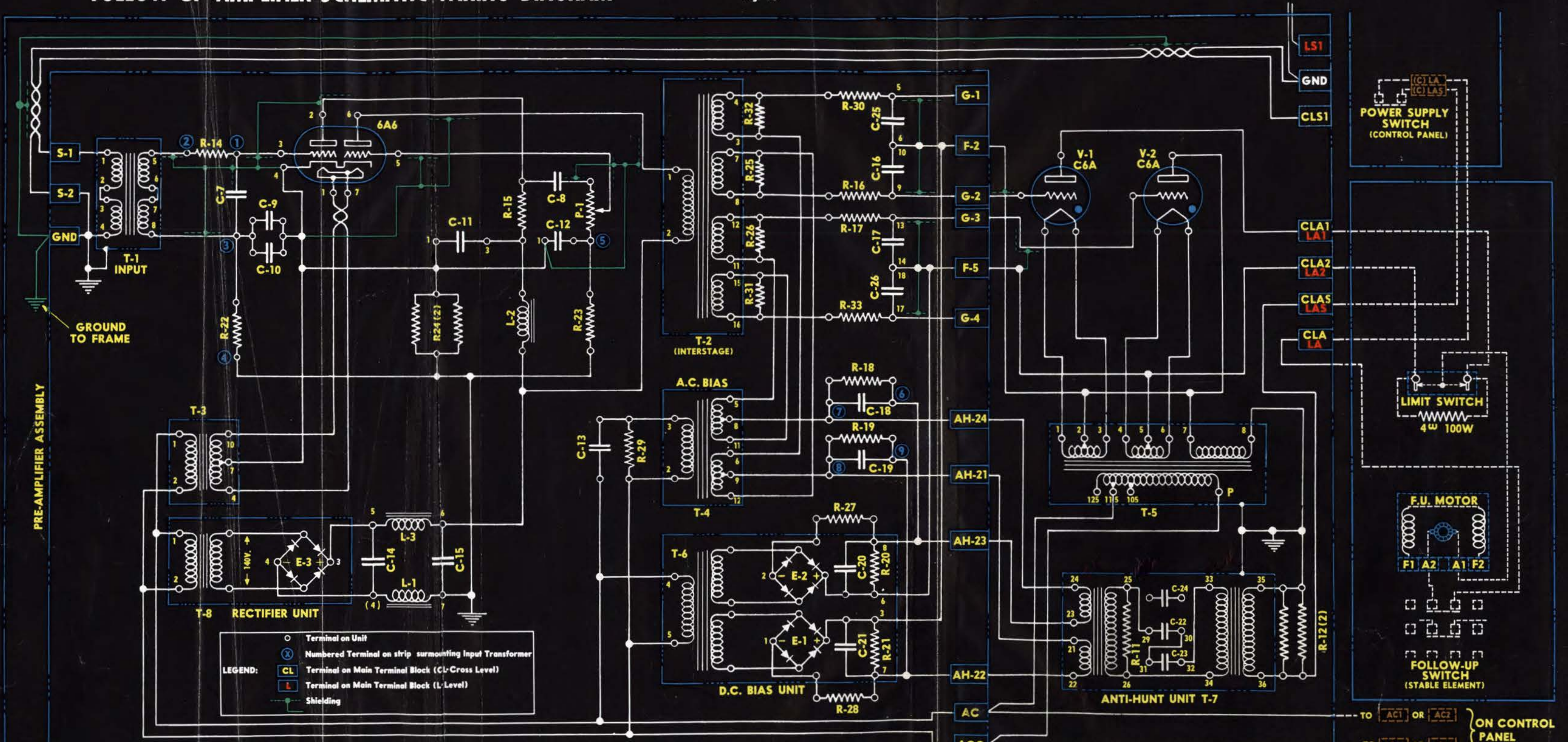
FOLLOW-UP AMPLIFIER SCHEMATIC WIRING DIAGRAM

Fig. 38



Note: Tube V-1 (left) type C6A carries current for increasing Level or Cross Level.

The principle of operation of the Stable Element may be expressed as follows:

1. The gyroscope continuously maintains an A.C. electromagnet in a fixed position with its axis vertical.
2. Above the magnet are two sets of follow-up coils, the fields of which are at right angles to each other, one for Level and the other for Cross Level control. Both are supported on the inner of two follow-up gimbals.
3. Rolling or pitching of the ship causes a slight movement of the coils in relation to the follow-up magnet.
4. The follow-up system, by means of electronically controlled motors, moves the Level and Cross Level gimbals in such a direction as to maintain the coils directly over the magnet.
5. The mechanism which causes the gimbals to maintain the position above mentioned actuates other mechanisms which transmit the same motions to the Director and Computer for the control of optics, etc., in order to keep them stabilized in both Level and Cross Level.

Two follow-up systems are used in the Stable Element, one for Level and one for Cross Level. Each system consists of six parts, namely: an A.C. follow-up electromagnet, a follow-up coil, a vacuum-tube amplifier, a grid-controlled rectifier circuit, an anti-hunt unit, and a follow-up motor. The A.C. magnet is common to both systems, and the construction and operation of the two systems are identical. The following explanation, therefore, applies to either system. The follow-up system derives its name from the operation in which the coils "follow" the magnet in response to signals generated by the most minute displacement of the coils.

FOLLOW-UP COILS AND MAGNET

The Level and Cross Level follow-up coils are mounted one above the other and with their fields at right angles to each other. The intersection of their fields at the center of the mount is the neutral point which is to be maintained directly over the pole piece of the follow-up magnet. The follow-up magnet is energized from the ship's 115 volt 60-cycle A.C. supply, and is capable of inducing small 60-cycle voltages in these coils, but the coils are so wound that the voltages induced in the two halves of either coil are equal and opposite when there is no displacement of the neutral point in relation to the axis of the magnet. The net voltage at the output of the coil is, therefore, zero. However, if the coil is moved, the voltages induced in the two halves of the coil are unequal,

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and a voltage appears across the output terminals of that coil. The coils are so wound that the voltage induced in them when they are displaced in one direction from their normal position is opposite in phase from that induced when the displacement is in the other direction.

The output of each coil is conducted through a shielded cable to its respective amplifier, which, after amplification of the signal voltage, operates grid-controlled rectifiers which in turn cause the follow-up motor to restore the coil to its normal position.

FOLLOW-UP AMPLIFIERS

The amplifier (Fig. 39) for each follow-up system is a two-stage unit in which a 6A6 dual-triode serves as both stages. As can be seen in the circuit diagram on page 56A, the signal voltage from the follow-up coil is conducted to the grid of the first section of the tube through a shielded cable, a step-up input transformer T-1 (which is electrostatically and magnetically shielded) and a phase shifting network consisting of condenser C-7 and resistor R-14. (This phase shift causes the amplified signal appearing at the grids of the rectifier tubes to lag the incoming signal by about 10 degrees, which results in optimum performance of the rectifier tube control circuits.) The two sections of the 6A6 tube are resistance-capacitance coupled through condenser C-8 with a potentiometer P-1 serving to regulate the voltage applied to the grid of the second section. This is the "Sensitivity Control" which adjusts the overall amplification of the signal to secure the optimum sensitivity of the follow-up system. The output of the second stage is coupled to the grids of the grid-controlled rectifier tubes through transformer T-2. R-24 provides the grid bias for the 6A6. R-22 and R-23 are the D.C. return resistors for the first and second stages respectively, corresponding to the resistors A and A′ in Fig. 21, pg. 37. C-9 and C-10 in the first stage, and C-12 in the second stage, provide a path for the A.C. signal but prevent short-circuiting the D.C. bias voltage. R-15 for the first stage, and the primary wind-

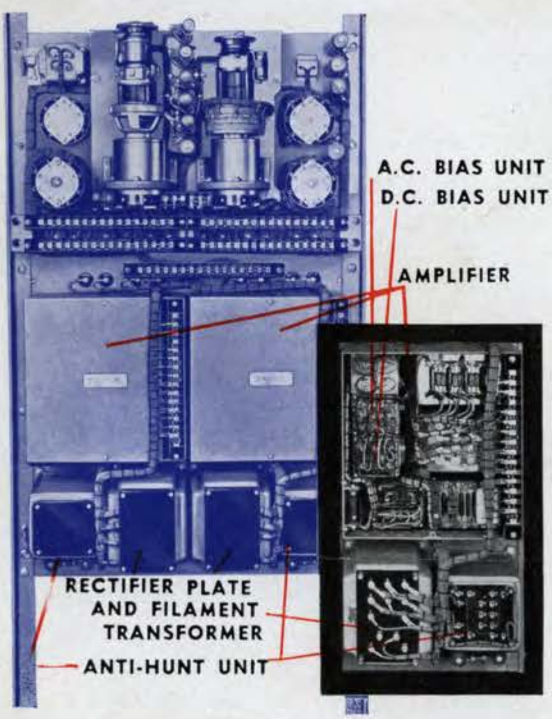

Fig. 38

ing of transformer T-2 for the second stage, serve as plate loads corresponding to resistor R and the transformer primary respectively in Fig. 21, pg. 37.

The amplifier is entirely operated from ship's 115 volt 60-cycle A.C. supply. The plate voltage supply (B+) is obtained from a copper oxide rectifier and two section filter (E-3, L-1, L-3, C-14, C-15), with L-2 and C-11 providing a third section of filtering for the first stage only. The 6.3 volt heater supply is obtained from transformer T-3. The overall gain of the amplifier is approximately 5000. (For example a .001 volt input would be amplified to 5 volts at the output.)

DRY RECTIFIERS

Both types of rectifiers described in the section on Fundamentals are used in the follow-up system. Copper oxide rectifiers supply the B+ voltage for the amplifier tube plates and the D.C. bias voltage for the grids of the grid-controlled rectifier tubes, which are to be described in the following paragraphs.

GRID-CONTROLLED RECTIFIERS

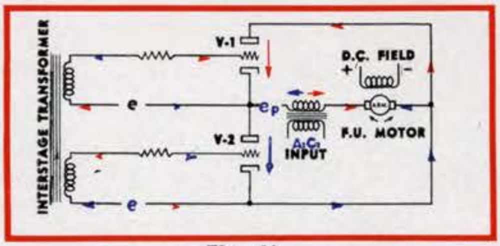

Fig. 40

Each follow-up motor is controlled by two grid-controlled rectifiers, type C6A, which are gas-filled tubes. These two tubes are connected with the armature of the follow-up motor in such a manner that when one tube is passing current the motor will run in one direction, and when the other tube is passing current the motor will run in the opposite direction. The tube which will pass current at any given time is selected or determined by the phase of the input signal voltage from the follow-up coil (depending upon direction of displacement), and the amount of current it will pass depends upon the amplitude of the signal voltage (determined by amount of displacement).

The two rectifier grid and plate circuits are alike, but are 180 degrees out of phase with each other. The simplified circuit of Fig. 40 shows the electrical location of the motor armature with respect to the two rectifier tubes, and the colored arrows indicate the relation between incoming signal and direction of motor rotation. In the figure (e_p) is the plate voltage, while (e) is the vector sum of the D.C. grid bias, the A.C. grid bias and the anti-hunt unit grid voltages.

BIASING—To obtain more stable control over the action of the grid-controlled rectifier tubes, the amplified signal voltage is modified by the addition of a D.C. bias, an A.C. bias, and an anti-hunt control voltage.

On page 40, under Fundamentals of grid-controlled rectifiers, the effect of D.C. and A.C. voltages applied to the grid was explained. If now we consider both of these voltages as bias voltages, and superimpose a signal voltage on them, we can obtain phase-shift control of the rectifiers as follows:

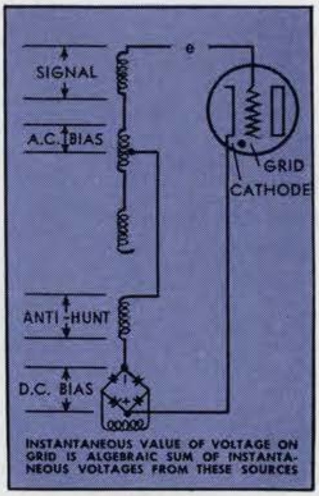

Fig. 41

In the circuit diagram on page 56A of this section it is seen that the grid of one tube (V-1, for instance) receives its signal from one of the secondary windings of transformer T-2. (This transformer is a standard stock unit complete with resistors and condensers, used on several types of equipment, and actually has 5 secondaries, only two of which are used in this application.) The signal voltage for tube V-1 comes from the secondary having terminal numbers 7 and 8. In series with this secondary is one winding of the A.C. bias transformer T-4. The center tap of this winding connects to one winding of the anti-hunt unit T-7, thence to a copper oxide rectifier E-1, which, with its filter circuit (R-21 and C-21), provides a negative 4 volts of D.C. bias. The return is to the rectifier cathode through center tap 2 of the filament winding on transformer T-5. The return could not be made to terminals 1 or 3 since the A.C. filament voltage would then be added to the grid voltage. However, by returning to the mid-tap of this filament winding, the voltages on either side are equal and opposite; thus the filament voltage has no effect on the grid. Fig. 41 is a simplified grid circuit showing how the various voltages are applied to the grid.

Condenser C-13 and shunt resistor R-29 (page 56A) act together as a phase shift circuit for the A.C. bias. These components are of such values that the A.C. bias causes both rectifier tubes to pass current during a small portion of each positive half-cycle. (This provides more stable operation of the follow-up motor as explained in the next paragraph.) Since the load currents in both tubes under no-signal conditions are equal and opposite (bucking each other) there is no tendency for the follow-up motor to turn as there is no current flow in its armature.

When either follow-up coil is displaced from its neutral position, the voltage induced in the coil is amplified and is applied to the grids of its rectifier tubes. This voltage added to the A.C. bias potential has the effect of shifting the phase and changing the magnitude of the latter, as illustrated in Figs. 42 and 43.

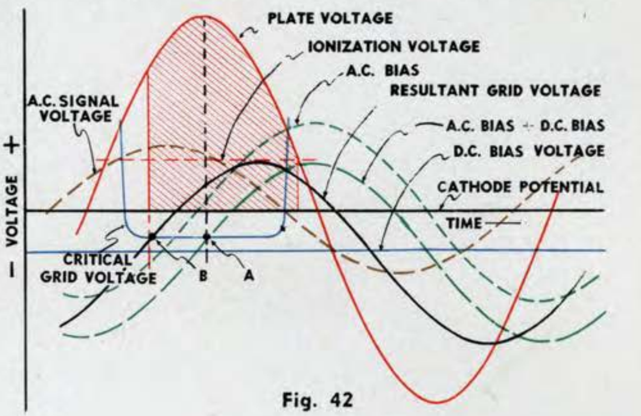

Fig. 42

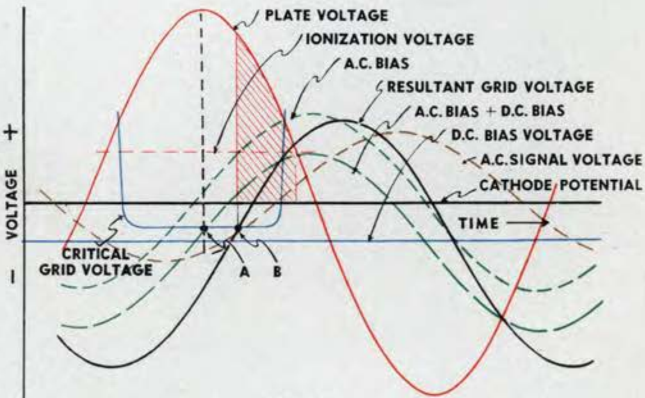

Fig. 43

Due to the 180 degree out-of-phase relationship of the plates of the two tubes, the effect is to advance the phase of one grid potential, causing that tube to pass more current, and to retard the phase of the potential on the other grid, causing that tube to pass less or no current. These figures illustrate both cases, the resultant grid voltage causing the tube to start passing current at B in each case. The point A in both cases represents the firing point of the tube under no-signal conditions.

The reverse is true when the follow-up coil displacement is in the opposite direction. The entire sequence then applies to tube V-2 and its associated electrical components. Thus the motor will turn in the proper direction to restore the follow-up coil to its normal neutral position, regardless of the direction in which the coil was displaced.

The resistors R-16 and R-17 (page 56A), one in the grid lead of each rectifier tube, are to limit the grid current when the tubes are operating. The small condensers C-16 and C-17 are to prevent transient voltages at the grid of one tube from affecting the grid of the other tube through inductive interaction between the two secondary windings of transformer T-2, which could cause undesirable cross-firing.

The sensitivity of the follow-up circuit is adjusted by changing the amplification ratio of the amplifier by means of the "Sensitivity Control" potentiometer. If the sensitivity is low, the follow-up coil must be displaced from its neutral

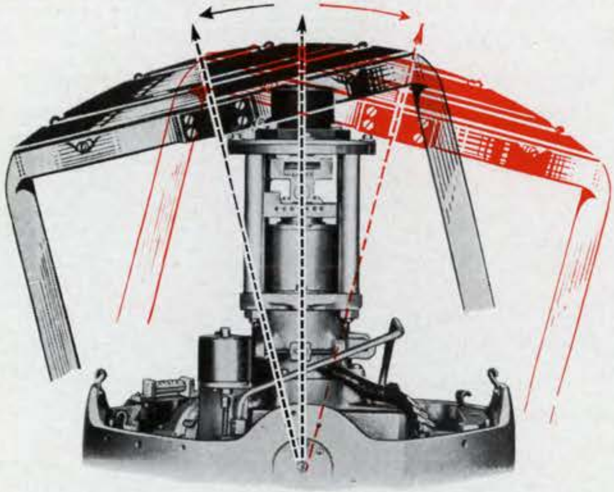

Fig. 44

position by an appreciable angle before the signal voltage is sufficient to cause the follow-up system to work. Increasing the amplification (sensitivity) reduces this angle of "dead space", but if it is reduced too much, the follow-up mechanism will start to oscillate, or hunt, as illustrated by Fig. 44.

This is caused by the inherent time lag in the electrical circuits, the effect of which is to cause the motor operation to lag the actuating signal by a small increment of time. The driving force on the follow-up coil, therefore, continues for just a fraction of a second after the neutral position of the coil cuts off the signal to the amplifier. This plus the inertia of the mechanism causes the coil to over-shoot just enough to start the firing of the tube which will run the motor in the reverse direction, where the same thing happens as it again reaches the neutral position. This can be illustrated as follows:

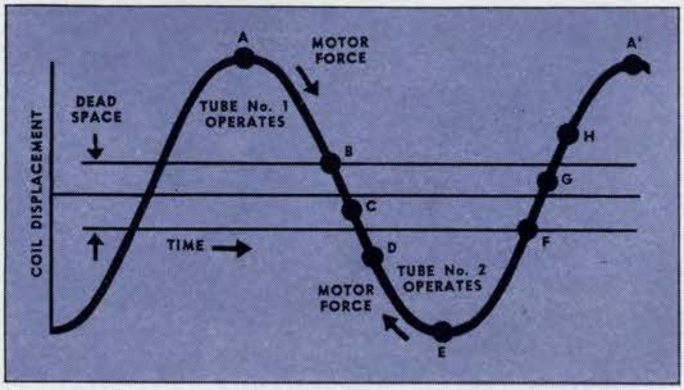

Fig. 45

Fig. 45 shows a curve representing oscillation of the follow-up coil back and forth across its neutral position when the dead space has been reduced to a very

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small value by increasing the sensitivity of the amplifier. At position A the coil is displaced from its neutral position. Plate current flows through tube No. 1, turning the follow-up motor, which drives the coil along curve A B toward its neutral position. When the coil reaches B it enters the very narrow dead space *where the voltage induced in the follow-up coil is insufficient to cause operation of the follow-up motor*. However, due to the time lag in the amplifier and rectifier circuits, the motor will continue to be energized and will drive the coil until it reaches point C. Due to inertia, the coil will overshoot point C. Just as there is a lag in the cut-off point of tube No. 1, there is also a lag in the starting of tube No. 2. Therefore tube No. 2 does not start operating until the coil has reached point D, where it starts to oppose the inertia force of the follow-up mechanism until point E is reached and the coil has been brought to a stop. The follow-up motor now drives the coil back toward its neutral position, where the same sequence is repeated in the opposite direction.

In comparing curves A B C and D E, it is apparent that more energy was added to the follow-up mechanism when it moved from A to C than was subtracted when it slowed down through the shorter distance D E. The difference in these two amounts of energy is what maintains the oscillation against the friction loss of the system.

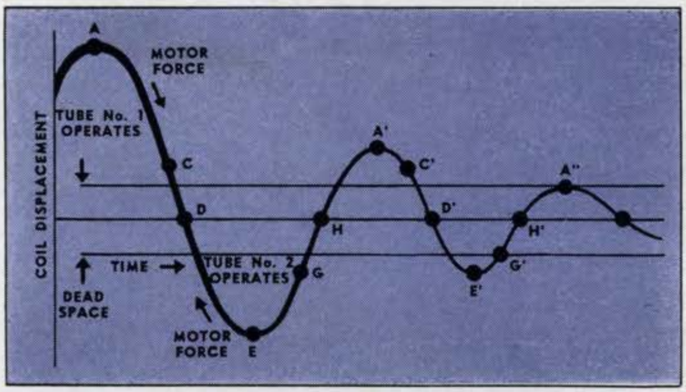

Fig. 46

The oscillation can be stopped by reducing the sensitivity to widen the dead space to a value such that the energy absorbed by friction is greater than the net supplied energy. This however, impairs the accuracy of the instrument. Therefore, an anti-hunt circuit is incorporated in the control which damps the oscillations while permitting the sensitivity to remain at its optimum point.

The effect of the unit in operation is to shift the "cut-off" and "cut-on" points C and D as shown in Fig. 46, so that at each swing of the follow-up coil past the neutral position the amplitude of swing is reduced. This is accomplished by

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changing the value of the D.C. bias on the rectifier tubes as follows:

As can be seen in the circuit diagram on page 56A, the follow-up motor armature current passes through a resistance R-12 which is shunted by the primary of a transformer, causing a voltage in these components which varies in magnitude with the displacement of the follow-up coil, and which is at a maximum when the coil is farthest from its mean position. Thus an alternating voltage of the same frequency as, and in phase with, the mechanical oscillation frequency is applied to the transformer.

The secondary of this transformer feeds the primary of a second transformer through a phase-shifting network (C-22 and C-23 and R-11) which shifts the phase of the output voltage of the second transformer 90 degrees from the input voltage of the first transformer. (C-24 is a spare condenser.) The varying voltage produced by this unit is applied to the grid circuit (90 degrees out of phase with the coil displacement) so that as the coil nears its neutral position the grid bias of the driving tube is made more negative, causing that tube to become inoperative sooner than it would otherwise. At the same time the bias voltage on the grid of the second rectifier tube becomes *less* negative and the tube becomes operative sooner than it would otherwise. Thus the point C of Fig. 45 is shifted to the position shown in Fig. 46, and the "cut-in" point D is also shifted the same amount in the same direction, as shown. In Fig. 46 it is apparent that the energy added to the follow-up mechanism from A to C is less than that subtracted from D to E. This condition results in a rapid damping of the oscillation, and permits the "dead space" to be reduced to a very narrow value.

The "dead space" may be reduced to zero under these conditions, if that were possible, without resultant oscillation. However, if the sensitivity is increased far beyond the value which effectively eliminates the dead space, the system is so responsive to displacement of the follow-up coil that the most minute vibration of the coil, such as might result from the ship's normal vibration, causes the rectifier tubes to operate. Thus, the tubes are continually under load, placing an unnecessary strain on the system. In addition, interference picked up by the coil is amplified to such an extent that it may become troublesome. For these reasons there is a practical limit to the sensitivity which may be used to advantage.

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In the light of the foregoing circuit explanations, the Follow-up Theory is repeated here with additional statements which can now be more readily understood. Since the function of each follow-up system (Level or Cross Level) is to maintain its respective follow-up coil in alignment with the A.C. magnet on the Sensitive Element, the following sequence of operations takes place when a change occurs in the position of the ship's deck due to roll and pitch of the ship.

1. The Stable Element housing moves with the ship, carrying or tending to carry with it the Level and Cross Level gimbals.  2. Since the follow-up coils are mounted in the gimbal assembly, a displacement  between them and the A.C. magnet occurs. 3. This shift of either follow-up coil  results in a voltage across its terminals. 4. This voltage is conducted to the proper amplifier,  where it is greatly amplified. 5. The amplified voltage is then applied to the grids of two grid-controlled rectifier  tubes. 6. The phase of this voltage determines which one of the rectifier  tubes will operate and allow current to flow in the follow-up motor circuit.  The direction of flow of this current (and therefore the direction of motor rotation) is determined by whichever rectifier tube is operating. 7. If the follow-up coil had been displaced in the opposite direction  the other rectifier tube  would have operated and the follow-up motor  would have turned in the opposite direction. 8. The follow-up motor operates the mechanism which moves the respective

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gimbal  in the Sensitive Element in the proper direction to restore the follow-up coil  to its normal position with respect to the magnet. 9. The angle through which the gimbal  moves is indicated by dials  on the Stable Element, and at the same time this motion is transmitted through proper gearing to other units on the ship which are to be stabilized against the continuous rolling and pitching of the deck. 10. If the change in ship's motion  had involved both Level and Cross Level angles, both the Level and Cross Level follow-up systems would have operated simultaneously.  

The foregoing outline may be more clearly understood if it is assumed that considerable displacement had occurred before the follow-up circuits were energized. The greater the displacement, the greater the speed of the follow-up motor.

It can be seen that the operation as outlined depends upon a definite displacement between A.C. magnet and follow-up coil. The more sensitive the amplifier circuit can be made, the less displacement it will tolerate before operating the follow-up mechanism.

In the Stable Element this sensitivity is adjusted to the point where 3 to 4 minutes of arc (1/20 to 1/15 of a degree) displacement is sufficient to cause the follow-up sequence to occur. Thus, even under continuous rolling and pitching of the ship, the Level and Cross Level coils (as well as the optics, rangefinder and other controlled elements) are continuously being stabilized and are never more than 3 or 4 minutes displaced from a horizontal plane. The sensitivity can be brought down to ½ minute but the dead space at this sensitivity is usually so small that hunting will start.

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CONSTRUCTION

The constructional description of the Stable Element and its associated equipment as set forth in this section is accompanied by numerous identifying photographs and drawings referring particularly to the Mark 6 Stable Element and the Mark 7 Mod. 3 Control and Follow-up Panel. Any differences between the Mark 6 and the other two Stable Elements, Mark 5 and Mark 6 Mod. 1, and between the Marks 7 and 8 (and Mods.) Control Panels, will be explained in footnotes and can be checked (functionally) by reference to the Mod. Chart on page 24 under Function. Weights and dimensions and other pertinent data will be found in the section on Information.

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CONSTRUCTION OF STABLE ELEMENT EXTERIOR

RIGHT AND BACK

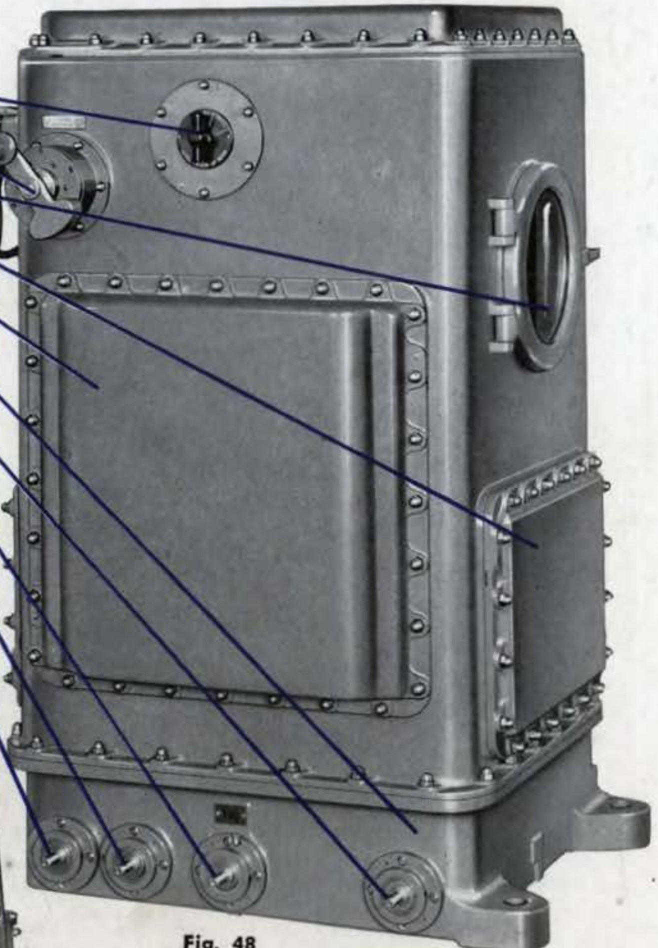

Fig. 48

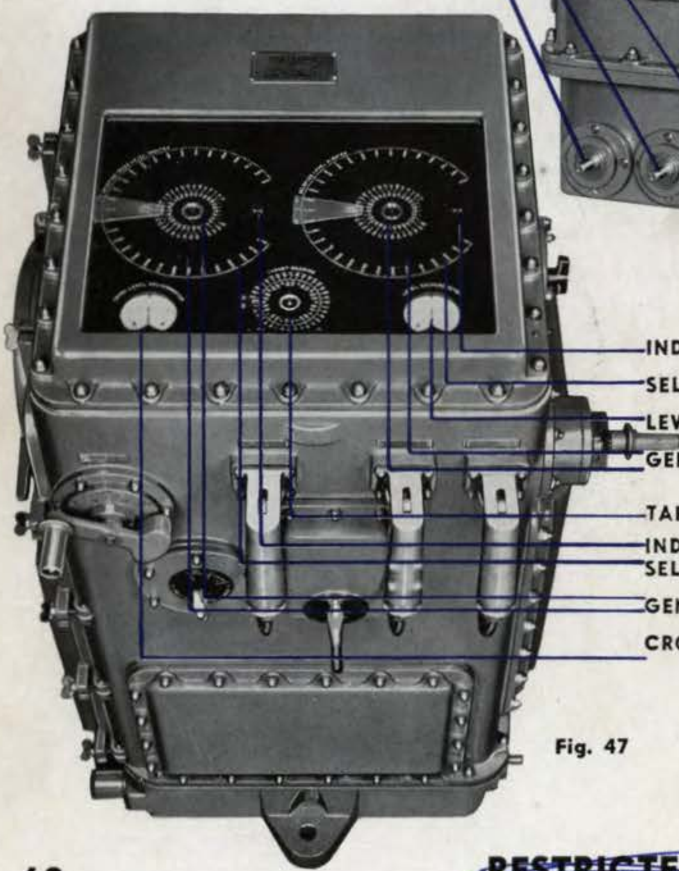

Fig. 47

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The instrument is built into a weatherproof metal housing consisting of an upper section and a lower section, the two being held together by bolts as shown in Figs. 48 and 49. The nomenclature accompanying each of these figures will serve to locate the various elements of the unit which are visible from the outside.

LEFT AND FRONT

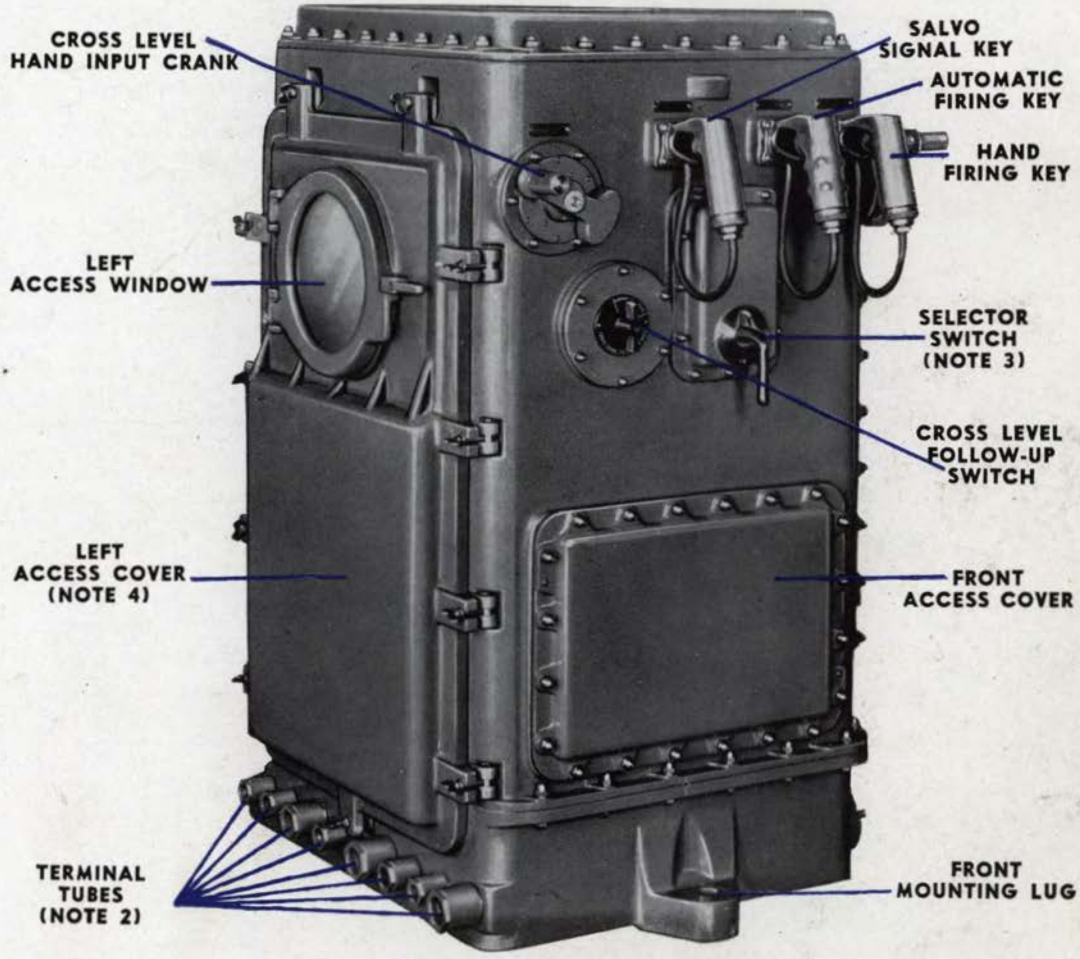

Fig. 49

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NOTES applying to Figs. 47, 48 and 49.

1. The Mark 5 does not have this "Level plus 1/30 Cross Level" mechanical output shaft, but rather transmits this function electrically by means of a Synchro-generator.

2. Terminal tubes, through which all electrical wiring enters the instrument, are located as shown when installation is made on a ship having no false deck. On a ship which does have a false deck, the terminal tubes are in the bottom of the case on the left side.

3. This Selector Switch mechanically operates synchronized clutches in the bottom chassis of the instrument, and is also geared to a rotary electrical switch which serves to control the follow-up motors, the firing circuits and the magnetic clutches associated with the hand input cranks. This control system is explained on page 124 under the heading "Automatic Firing."

4. This cover is fitted with pivoted studs and wing nuts such that it may be swung open as a door, or entirely removed, as desired.

5. On the Mark 6 Mod. 1 Stable Element, this cover is several inches deeper as it covers two Synchro-generators which electrically transmit Continuous Level at 2 and 36 speeds.

6. Firing contacts are located immediately under these index points and are actuated by cams secured to the rings upon which the dials are mounted.

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CONSTRUCTION OF STABLE ELEMENT INTERIOR

With but few exceptions, most of the mechanism of the instrument is installed as removable sections or units, to be described in ensuing paragraphs. These exceptions consist of certain gearing and individual shafts mounted in brackets attached to or integral with the main upper section casting (Refer to Figure 50), as follows:

A and B. The shafts and associated gears which actuate the dial mechanisms in the top of the instrument, said shafts extending to separable couplings on the bottom chassis.

X. All counter-shafts and gears associated with the dials and firing contact cams on the mechanism plate under the top cover. These are not visible in this illustration, but are located at a point behind X.

L and C. The shafts which are connected to the Level and Cross Level hand input cranks.

R. The Selected Level and Cross Level stops, not visible in this figure, but which are shown on page 141, at R in Fig. 139.

D and E. The five ball bearing roller guides for the training gear, two of which are visible.

T. The shaft (and its pinion which is driven by the training gear) which runs up the inside front of the instrument to the Target Bearing dials.

S. The Selector Switch handle, shaft and geared electrical switch.

G and H. The Level and Cross Level follow-up switches.

The shaft and associated pinion which drives the training gear from a coupling on the bottom chassis. Not visible in this figure, but are shown in Fig. 144, page 143 in Section 9, Disassembly.

NOTES applying to Figure 50:

1. This "lubberline" is in alignment with the engraved line "F" on the training gear when the Sensitive Element is trained to 0°.
2. Socket for 6 volt light for general interior illumination. Two more are mounted inside the upper section casting, one on each side of the large left side access door.
3. The follow-up motors are removable individually or as part of the bottom chassis. The pedestal, which is the main support for the Sensitive Element, can only be removed when the bottom chassis is out of the instrument.

NOTES applying to Figure 51:

1. The action of these limit switches is to protect the mechanism by reducing the speed and power of the follow-up motors when faulty operation of the follow-up system or excessive roll or pitch of the ship causes motions in Level or Cross Level in excess of plus or minus 22½°.

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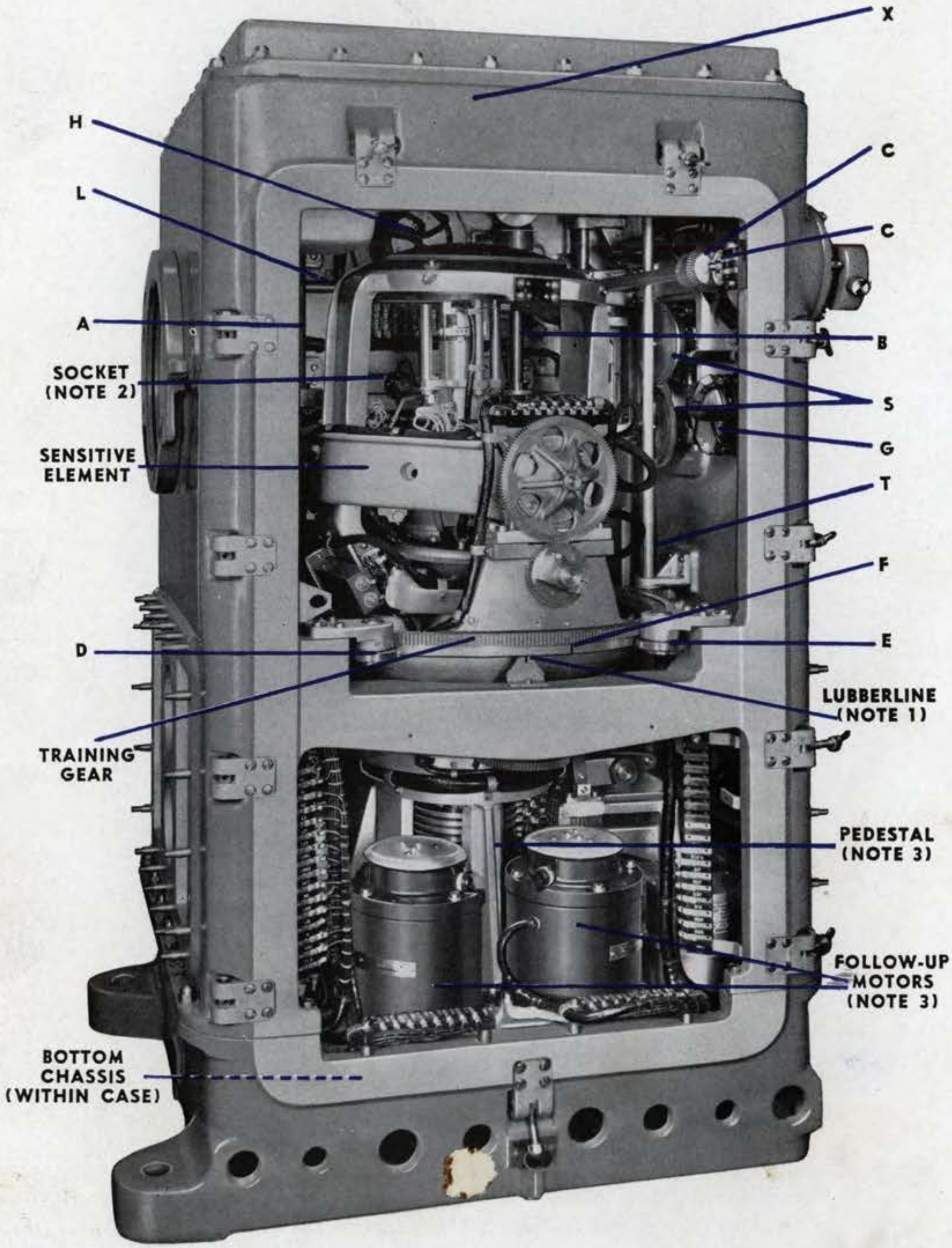

Fig. 50

STABLE ELEMENTS MK 6 MODS 7 & 9 ARE EACH EQUIPPED WITH A TRAIN TRANSMITTING UNIT. (SEE FIG. 78 B)

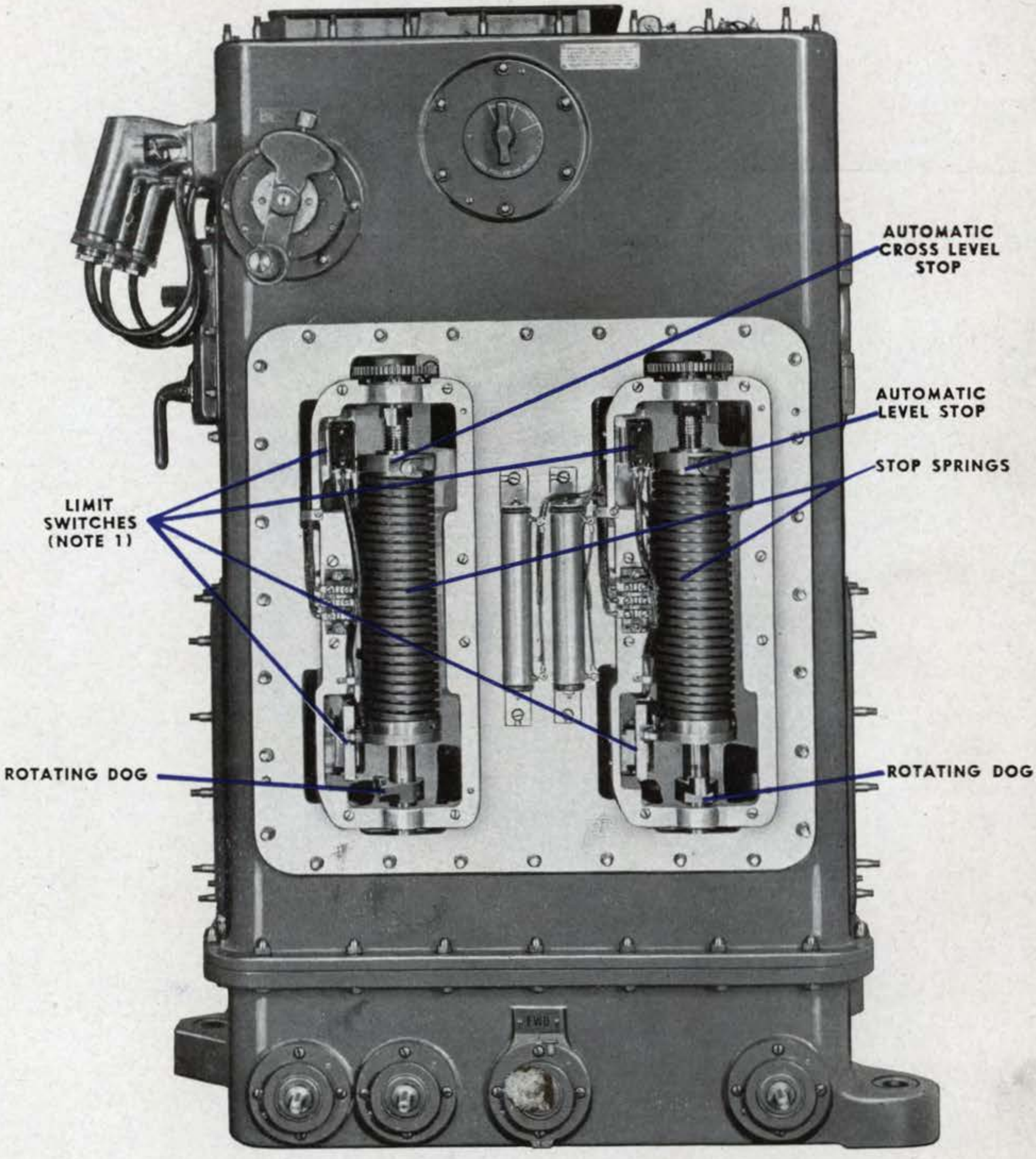
AUTOMATIC
CROSS LEVEL
STOP
AUTOMATIC
LEVEL STOP
STOP SPRINGS
LIMIT
SWITCHES
(NOTE 1)
ROTATING DOG
ROTATING DOG

Fig. 51

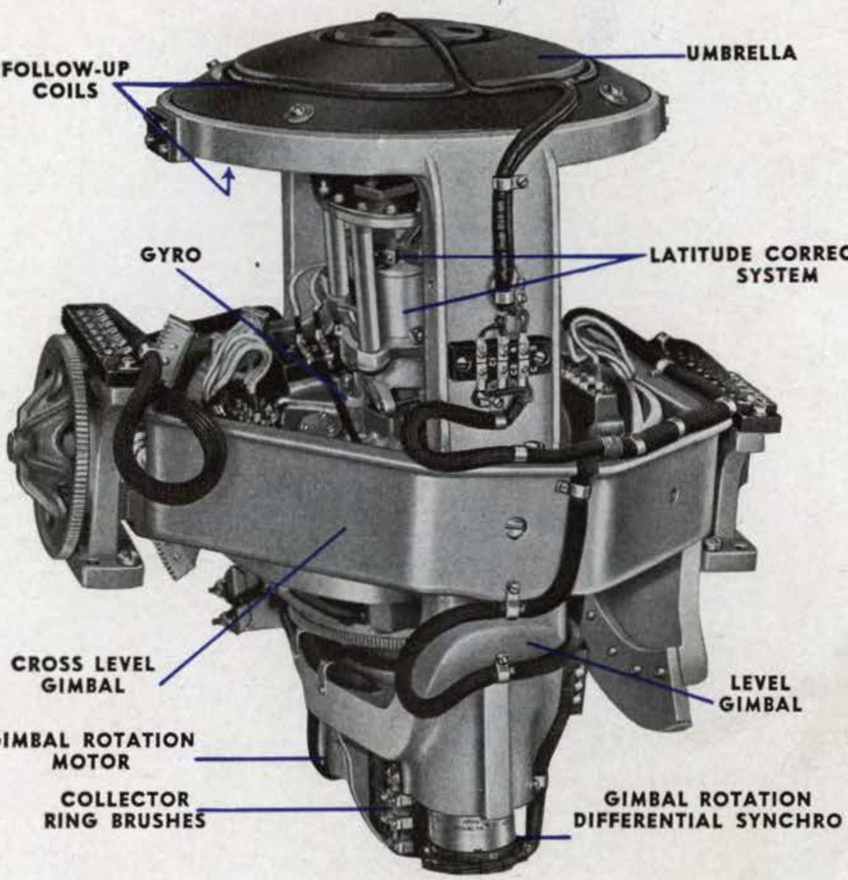

Fig. 52

THE SENSITIVE ELEMENT

Fig. 52 is a view of the "Sensitive Element" after removal from the training ring in the Stable Element. Its location in the instrument is shown in Fig. 50. (Fig. 68 on page 87 shows the Sensitive Element from another angle.)

In general, the Sensitive Element consists of a gyroscope mounted in gimbals, which assembly rotates within another pair of gimbals. This entire unit is then mounted within the rotatably mounted training gear casting. The following paragraphs, together with photographs and nomenclature, describe in the order just named each unit or sub-element of the Sensitive Element, its function and its relationship to the other units.

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THE GYROSCOPE

The free gyroscope described in the section on Fundamentals is the heart of the Sensitive Element. In this instrument, such a gyro is mounted so that when it is running and settled its spin axis will remain vertical.

Fig. 53 shows the gyro assembly. The wheel itself is the rotor of a three-phase 146 cycle electric motor, the stator winding of which is built upon the gyro case as shown in the cutaway portion of the figure.

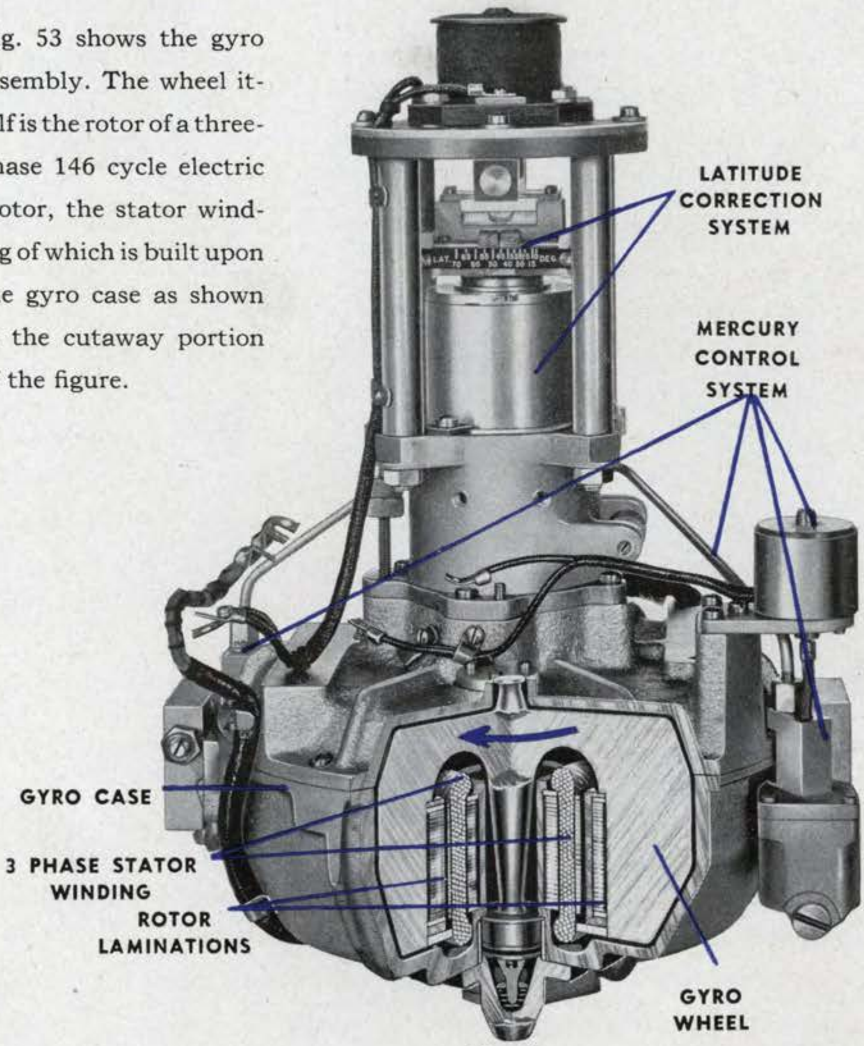

Fig. 53

The speed of the gyro when settled is approximately 8,500 R.P.M. in the direction shown by the arrow. In operation, the gyro supplies a horizontal reference plane from which angles of tilt of the ship's deck can be measured and transmitted by the rest of the mechanism of the Stable Element.

LATITUDE CORRECTION SYSTEM

Figure 54 shows the essential units of the latitude correction system mounted on the gyro. The 1F Synchro-motor is secured to the upper casting of the gyro case by three clamps. On the output shaft is secured a platform upon which are mounted the adjustable latitude correction weight and scale, balancing weights (not visible in this view) and two bubble levels at right angles to each other.

The adjustable latitude weight is in reality two knurled nuts mounted on a threaded rod. They are positioned by hand by rotating them to the desired position and tightening against each other to lock them in place. (The V-groove formed by the beveled edges on their adjacent faces is the reference point which should be set opposite the correct latitude reading on the scale.)

The object of the bubble levels is to provide references for aligning and adjusting the unit after disassembly for any reason, and to check the accuracy of the horizontal plane which the gyro provides as reference for all motions of the instrument. Their function will be apparent when assembling, adjusting, or "trouble-shooting" as outlined in the sections on Disassembly and Casualties.

FOLLOW-UP MAGNET

This unit, the location of which can be seen in Fig. 54 is shown more in detail in Fig. 55. It consists of a coil of wire wound about a single steel stud which is positioned so that its axis is vertical when the gyro is running and settled. This magnet is energized from the ship's 115 volt 60 cycle A.C. supply, and sets up an alternating magnetic field which is capable of inducing small A.C. voltages in a group of follow-up coils centered directly above the magnet.

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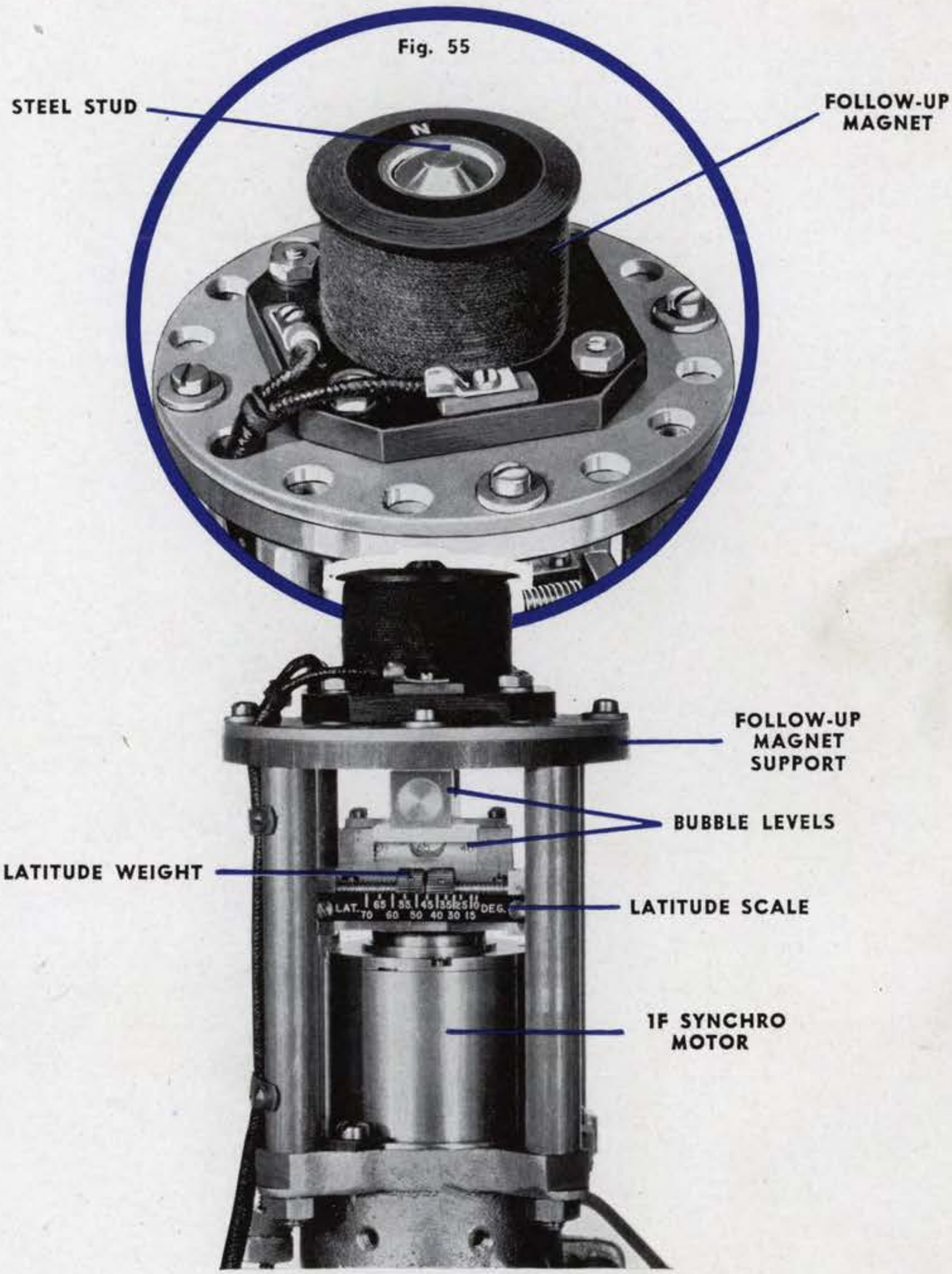
STEEL STUD
FOLLOW-UP MAGNET
FOLLOW-UP MAGNET SUPPORT
BUBBLE LEVELS
LATITUDE WEIGHT
LATITUDE SCALE
1F SYNCHRO MOTOR

Fig. 55

Fig. 54

GIMBAL MOUNTING AND ROTATING FORK

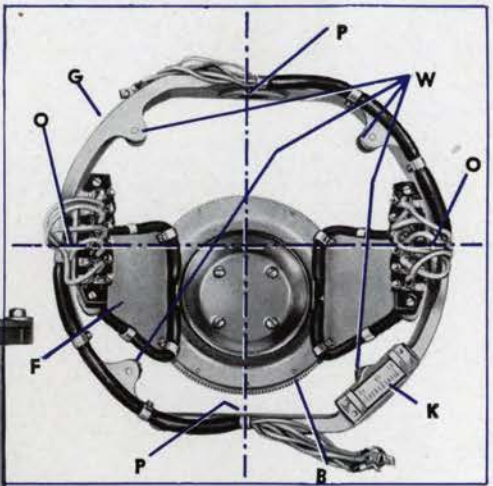

Fig. 56

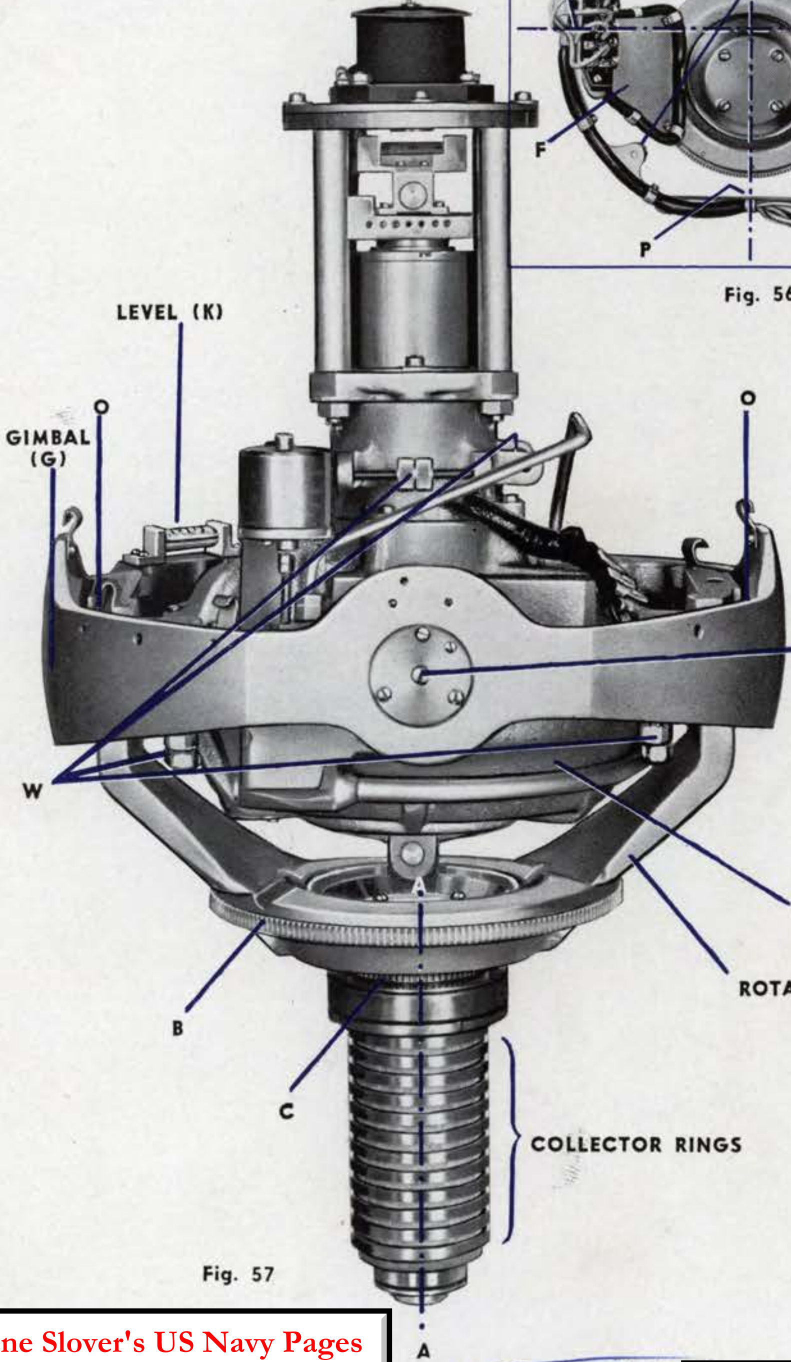

Fig. 57

GIMBAL MOUNTING

The entire assembly of elements on the gyro case (just described) must be free to maintain a vertical position to provide a horizontal reference plane. The gyro case is therefore pivoted at points P-P (Figs. 56 and 57) in a gimbal ring G. This ring is in turn pivoted at points O-O, at right angles to the axis P-P, in a fork-shaped mounting F. Thus the gyro case may be positioned at any angle about a horizontal plane, or conversely it can maintain a horizontal position regardless of any motion imparted to the fork F. The balancing weights W and the bubble level K on the gimbal are for balancing the gyro case and its associated equipment within the fork when at rest, this adjustment being explained on page 173 under Neutral Equilibrium.

ROTATING FORK

In order to provide the righting force explained under Mercury Control (page 44) the construction of the rotating fork F is such as to allow rotation about the axis A-A in bearings in the bottom frame of the Level Gimbal. The gear B is driven at 18 R.P.M. by the "Gimbal Rotation Motor" while gear C drives the Synchro differential which "takes out" the gimbal rotation in the latitude correction motor circuit.

Twelve collector rings are wired through the base of the rotating fork to terminal blocks on the gyro case and provide electrical connections to the gyro motor, the latitude correction motor, the mercury cutout valve, and the follow-up magnet from twelve sliding contacts or brushes which are mounted on the bottom frame of the Level Gimbal.

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LEVEL GIMBAL

Figs. 58 and 59 show the construction of the Level Gimbal, so called because it measures the angle about the Level axis for use in the optics, rangefinders, etc.

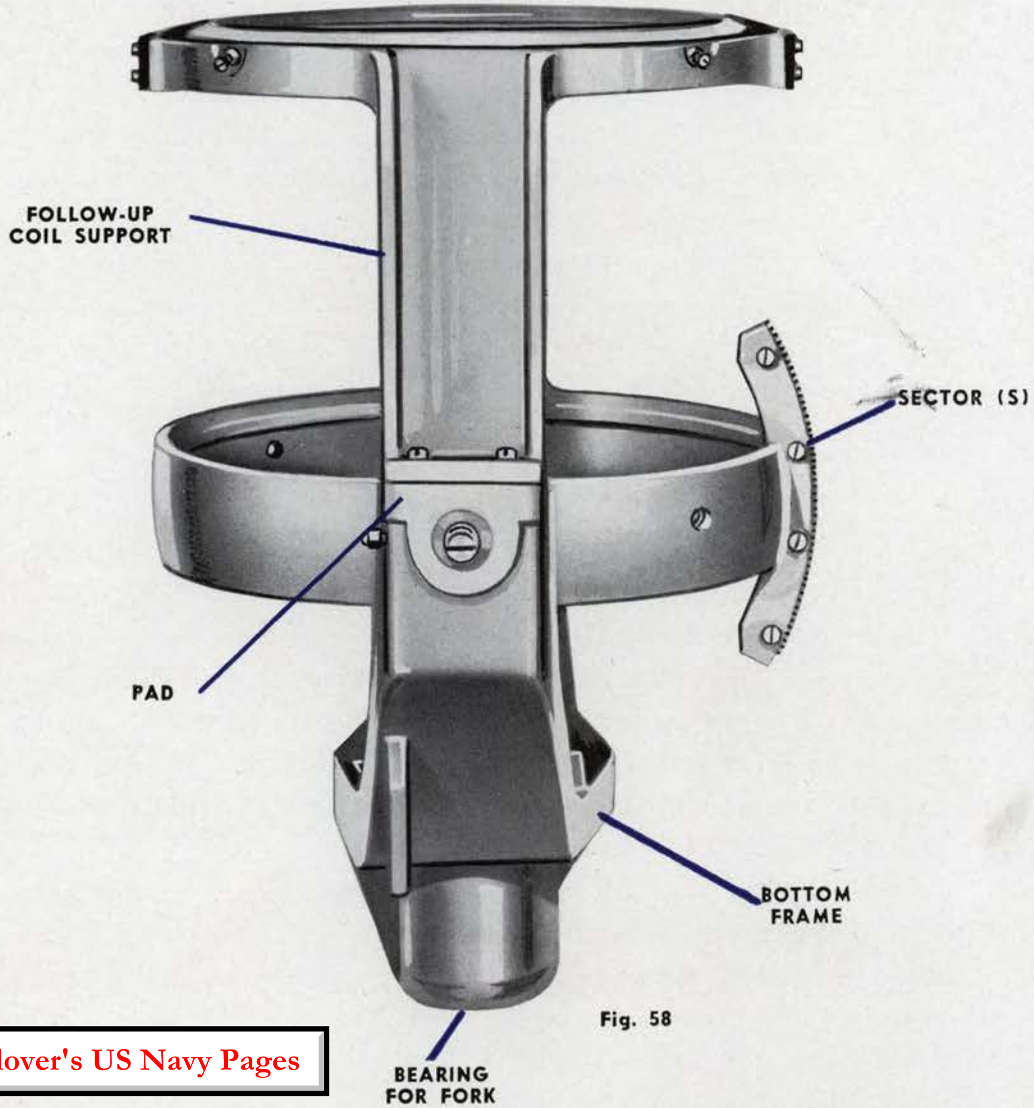

Fig. 58

The Level Gimbal is cast as a ring with pads on its top edge for mounting the follow-up coil support, and with a bottom frame below its center line in which are located bearings for mounting the rotating fork assembly just described. The figures also show where the Gimbal Rotation Motor, the differential Synchro, and the brush blocks and contacts mentioned in the preceding paragraphs are mounted when assembled upon the Level Gimbal.

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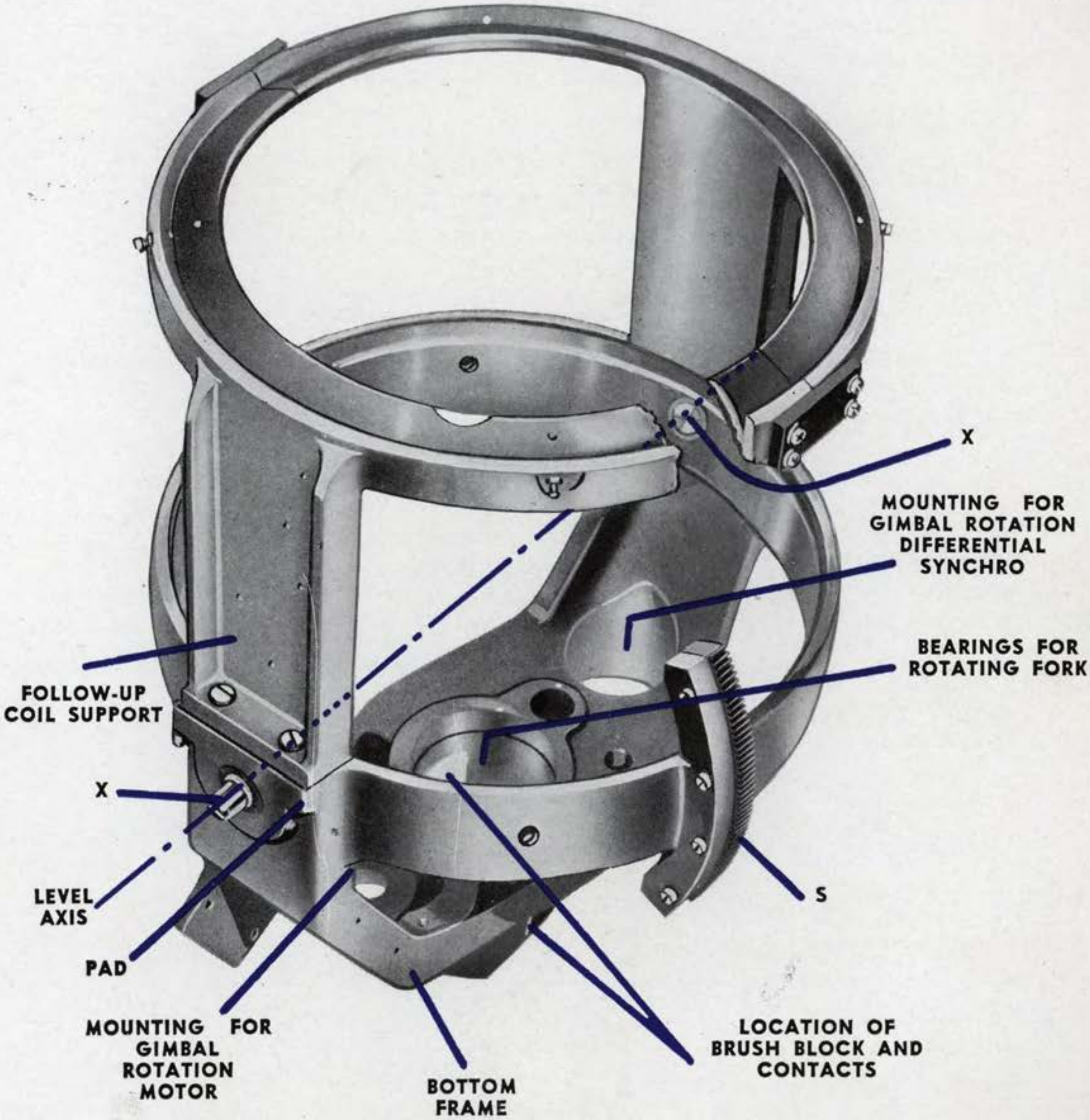

Fig. 59

The Level Gimbal is pivoted in ball bearings at points X-X in the Cross Level Gimbal. The gear sector shown at S meshes with a pinion mounted on the Gross Level Gimbal, so that the Level Gimbal may be moved a maximum of 25 degrees in either direction about its axis X-X by the Level follow-up motor in response to the proper signals from the Level follow-up coils.

Fig. 60

FOLLOW-UP COIL SUPPORT

The "umbrella," which carries the Level and Cross Level follow-up coils, is mounted on an aluminum support ring, which is in turn fastened to the Level Gimbal by means of two integrally cast upright supports, as shown in Fig. 60. The follow-up coils are mounted in grooves, the Level coil on top and the Cross Level coil on the underneath side of the umbrella, which is made of an insulating material. Each coil is astatically wound as shown in the insert, Fig. 60. Aligning screws are provided to accurately position the umbrella over the follow-up magnet. (See adjustment No. 7 in the section on Adjustments).

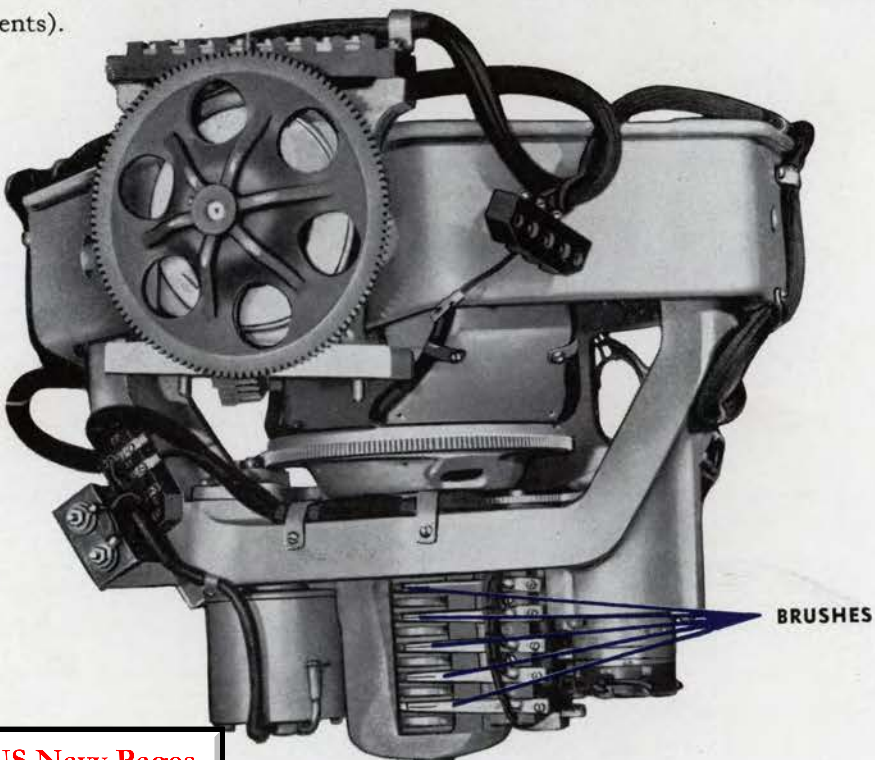

Fig. 61

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All electrical circuits to the rotating fork assembly are completed through the brushes shown in Fig. 61, of which there are 6 mounted on an insulating block on each side of the casting.

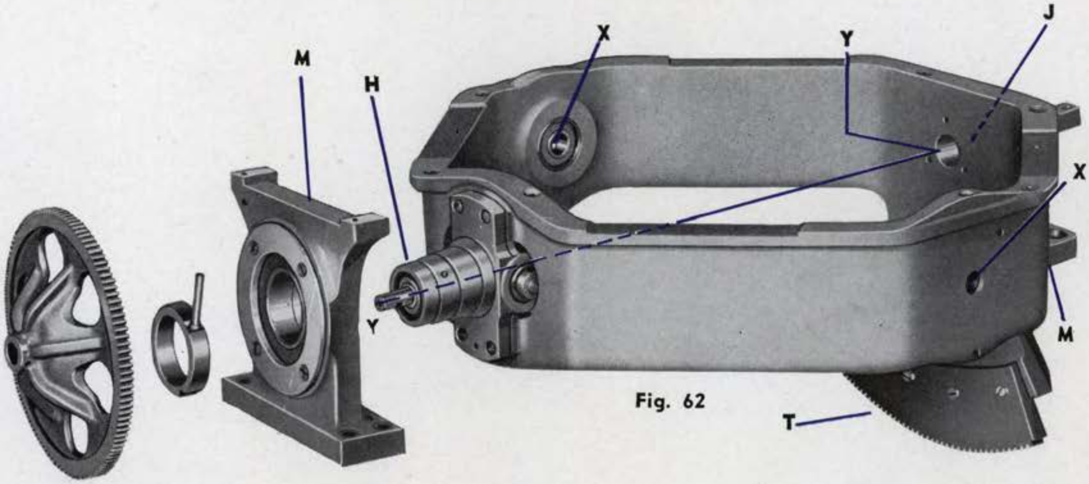

Fig. 62

CROSS LEVEL GIMBAL

Fig. 62 shows the Cross Level Gimbal, and Fig. 63 shows the Cross Level Gimbal and mounted within it the Level Gimbal previously described. The Cross Level Gimbal is so named because it measures the angle about the Cross Level axis for use in the optics, rangefinder, etc. The mounting blocks M are fastened to the rotating base of the training gear, and the axis Y-Y of the Cross Level Gimbal is always in the vertical plane containing the line of sight.

The construction of the Cross Level Gimbal is self-evident from the figures. It is supported or swung by means of the trunnion bearings H-J at right angles to the pivot bearings X of the Level Gimbal. The gear sector T meshes with a pinion on the training gear casting so that the gimbal can be moved a maximum of 25 degrees from the horizontal in either direction about its axis Y-Y.

LEVEL GEAR

The Level Gear shown in Fig. 62 is driven by the Level follow-up motor through gearing explained in subsequent paragraphs, and it, in turn, drives a set of gears in the Cross Level Gimbal by means of a shaft through trunnion bearing H. This set of gears moves the Level Gimbal through the meshing of one of them with the sector shown in Figs. 58 and 59.

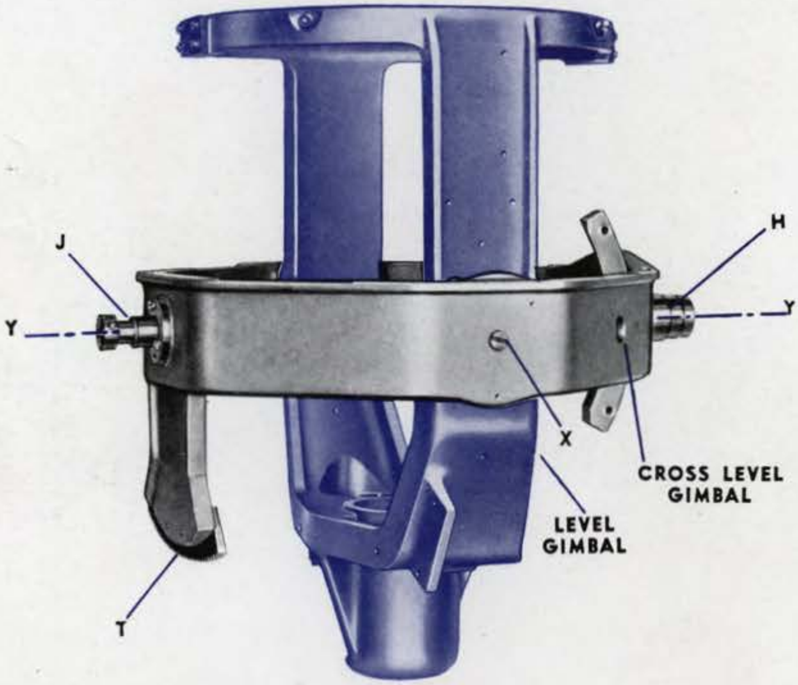

Fig. 63

CROSS LEVEL EFFECT ON LEVEL

In other sections of this manual references are made to "Level plus a function of Cross Level." The explanation of this notation is as follows:

The mountings and output gearings of the gimbal system are such that a movement of the Cross Level Gimbal will result in a small movement of the Level Gimbal as well. By referring to Fig. 65, this effect can be visualized and followed. The gimbal shown at 1 represents a Cross Level Gimbal, and gear 2 is the Level Gear mounted on an input shaft passing through the trunnion bearing of the gimbal. Gear 2 drives gear 3, which, through suitable additional gearing, moves the inner or Level Gimbal (not shown). Now if there is no Level motion, and gear 2 is held stationary, a Cross Level motion applied to gimbal 1 will move this gimbal to the position indicated in blue in the sketch.

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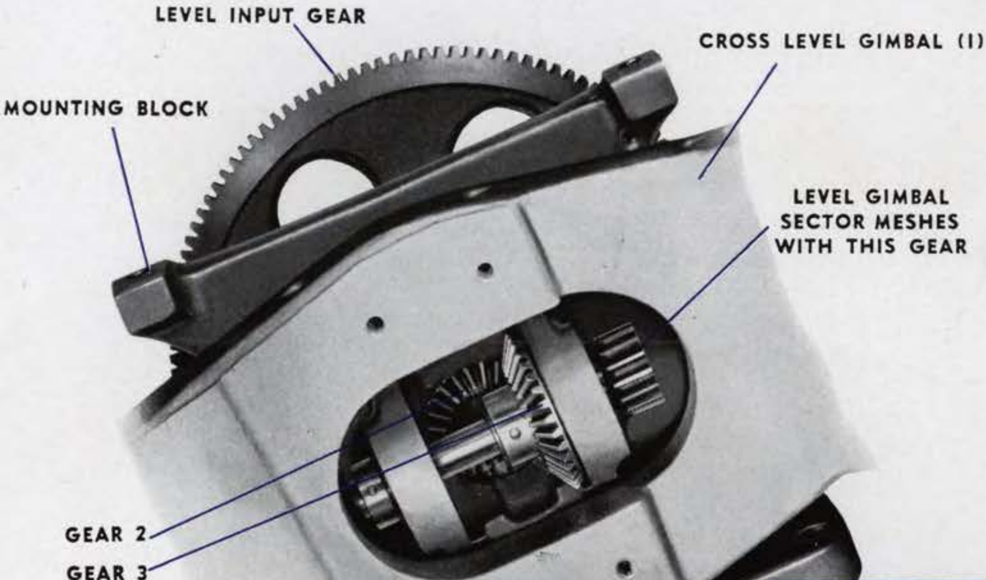

Fig. 64

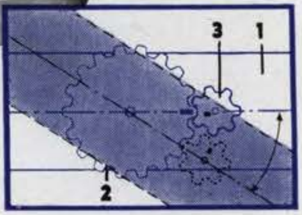

Fig. 65

Since gear 3 is mounted on a shaft whose bearings are integral with the gimbal 1, the gear 3 moves with the gimbal, "rolling" or turning about gear 2 and assuming the new position shown. This turning action results in movement of the Level Gimbal which gear 3 operates, although no Level function was transmitted through gear 2.

Thus any motion of the Level Gimbal will have superimposed upon it a function of Cross Level. In the Stable Element, this effect of Cross Level on Level is handled as explained on page 95.

(This interaction also obtains in the mountings of the optics. The Level input to the optics, therefore, normally must be corrected to offset this Level rotational effect due to a Cross Level input. By making the outputs from the Stable Element (1) Cross Level and (2) Level plus a function of Cross Level, these outputs can be connected directly to the inputs to the optics and give exact stabilization of the line of sight in both Level and Cross Level. This is accomplished by using a gimbal construction in the Stable Element similar to that of the optics and with the same ratio of gearing between Level Gear and the sector it is to drive. Fig. 64 shows the actual arrangement of the gear train between the Level Gear and the gear sector on the Level Gimbal. How the correction for true Level output of the Stable Element is obtained is explained on page 95 under "Continuous Level.")

GIMBAL RELATIONSHIPS

These two figures show the location of the gyro, gyro gimbal and Level and Cross Level Gimbals with respect to each other. When all gimbals are horizontally aligned their respective bearings all lie in a common horizontal plane. This entire assembly rotates with the training gear, and the arrow indicates the direction of the target or Director.

Fig. 66

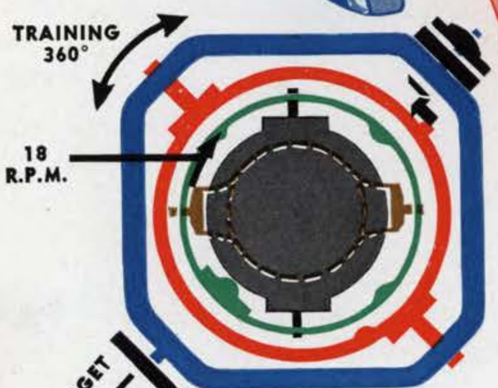

Fig. 67

- CROSS LEVEL GIMBAL
- LEVEL GIMBAL
- ROTATING FORK
- GYRO GIMBAL
- GYRO CASE

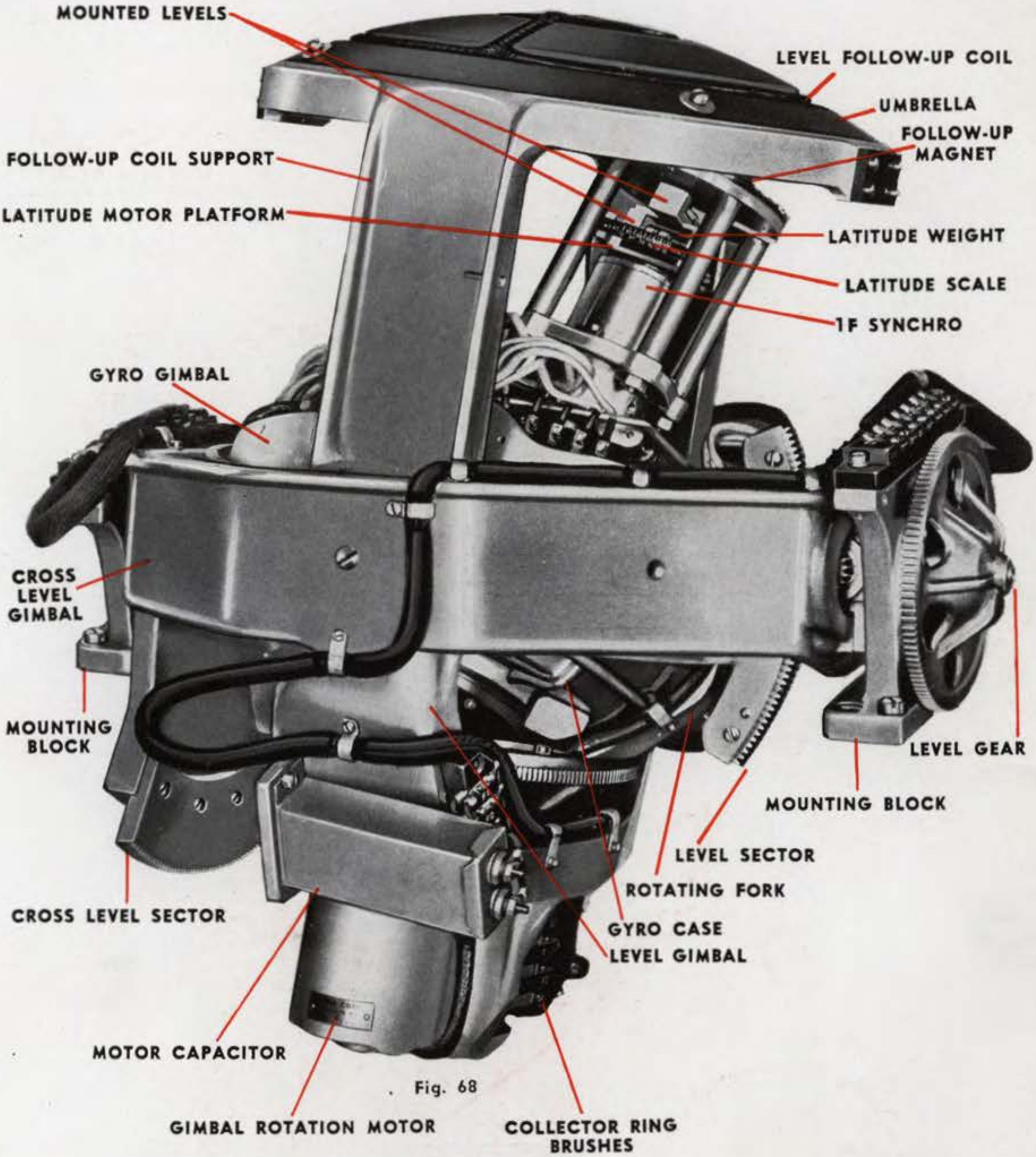

Fig. 68

SENSITIVE ELEMENT ASSEMBLY

Fig. 68 is another view of the Sensitive Element as an assembly of the various units just described. The gyro and all gimbals are pivoted in ball bearings to allow the gyro the utmost freedom in performing its function.

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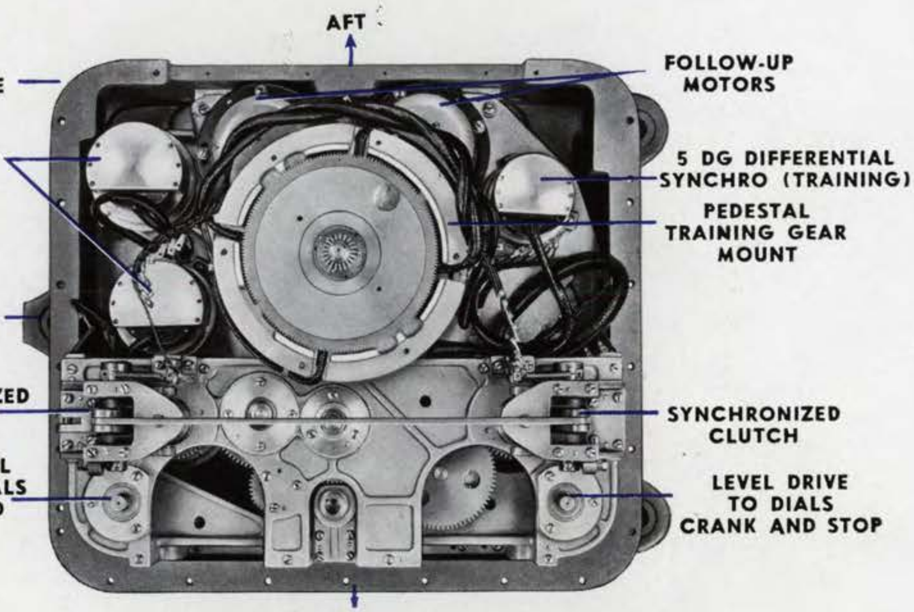

Fig. 69 TOP VIEW IN CASE

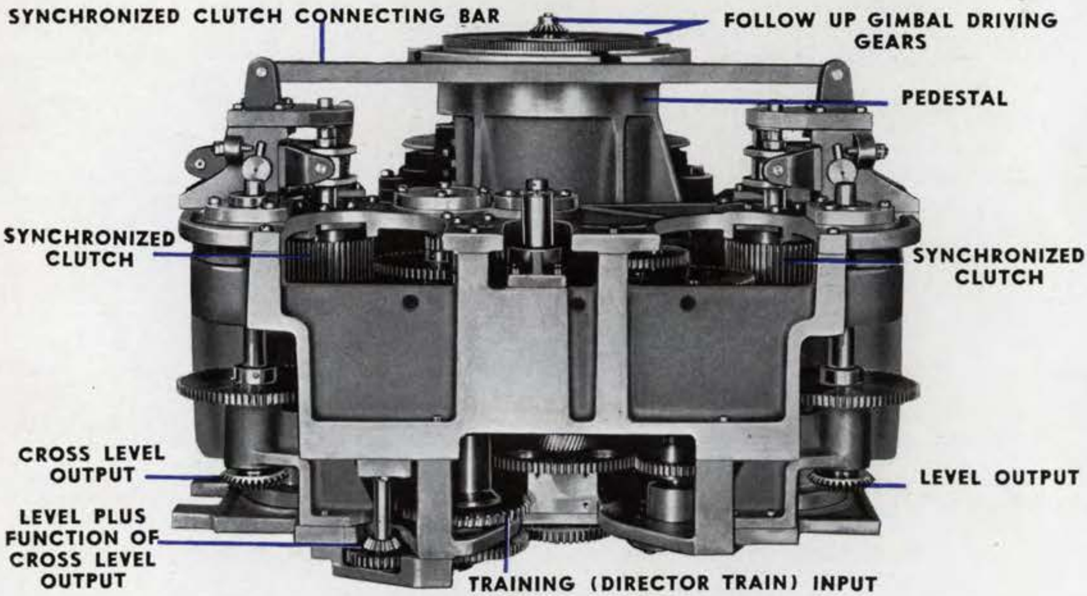

Fig. 70 RIGHT SIDE VIEW

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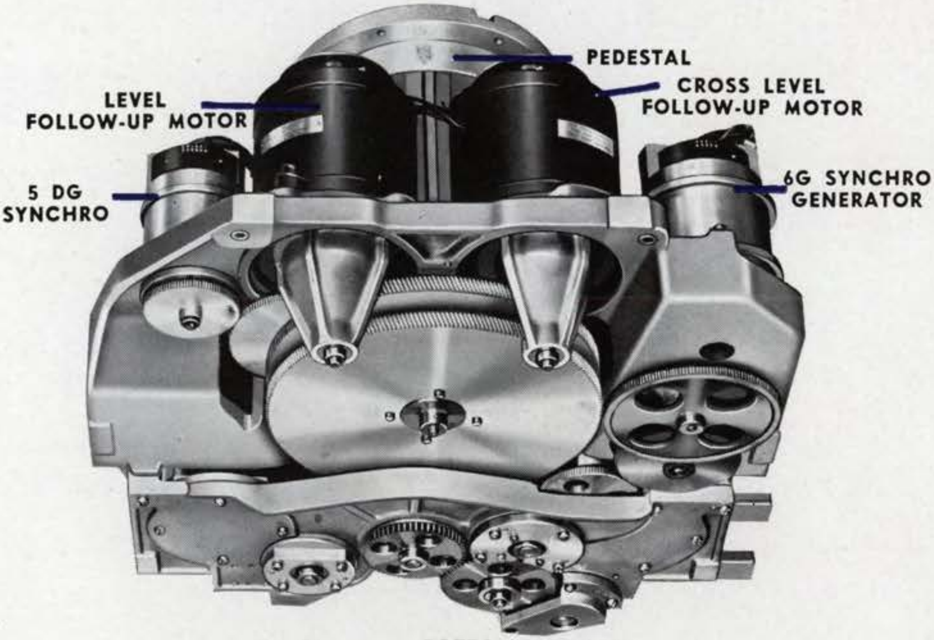

Fig. 71 BOTTOM AND LEFT

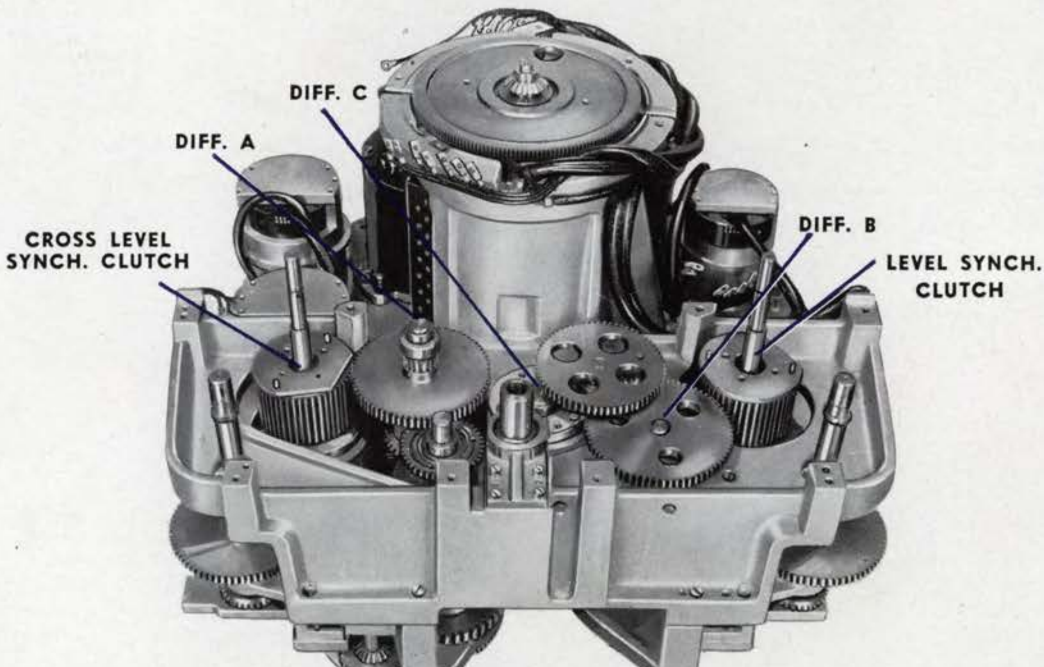

Fig. 72 TOP PLATE REMOVED

FOLLOW-UP MOTORS

The two follow-up motors, one for Level and one for Cross Level, are mounted on the Bottom Chassis as shown in Fig. 73. Each motor, rated at ¼ H.P., obtains its armature current from its respective follow-up amplifier and rectifier circuits. The armature is rated at 55 volts D.C., 5000 R.P.M. no load speed.

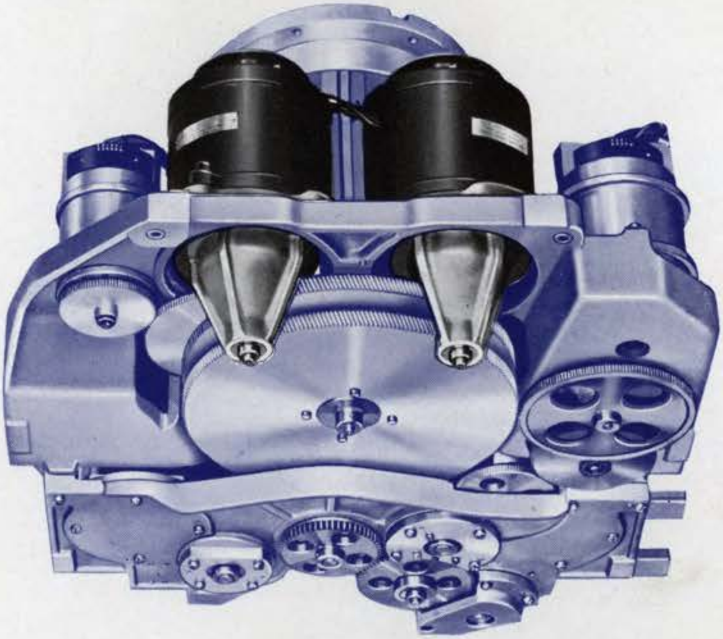

Fig. 73

Both motors have 115 volt D.C. fields, supplied from the ship's 115 volt D. C. system through the Control Panel.

Fig. 74 is an exploded view of a follow-up motor showing the location and construction of a slip-clutch which acts to protect the mechanism as well as the motor in the event of mechanical casualty in the operation of the Stable Element.

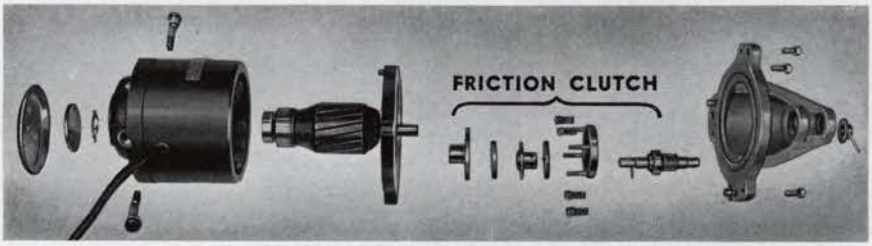

Fig. 74 EXPLODED VIEW OF FOLLOW-UP MOTOR

SYNCHRONIZED CLUTCHES

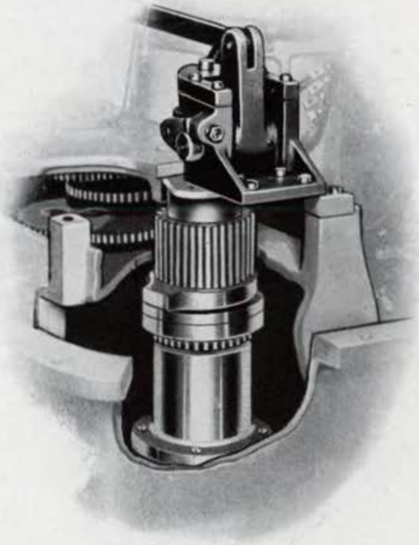

Fig. 75

These clutches are operated by the Selector Switch on the front of the instrument and are interlocked in such a way that both may be engaged at once or either one (but not both at once) may be disengaged. When the Selector Switch is in the "Continuous Fire" position, both clutches are engaged and connect the Level and Cross Level output shafts to their respective follow-up mechanisms in the bottom chassis. At the same time the switch electrically disengages magnetic clutches on both the Level and Cross Level manual input cranks (when they are in "Automatic" position) so that the instrument continuously and automatically stabilizes in both Level and Cross Level. If the Selector Switch is moved to either "Level Fire" or "Cross Level Fire," it mechanically disengages the corresponding synchronized clutch and electrically engages the magnetic clutch on the corresponding manual input crank so that that output can then be controlled by hand.

Fig. 75 shows one of these clutches in place in the bottom chassis, and Fig. 76 is an exploded view showing the various parts. It is essentially a planetary differential, operating on the principle as described under Fundamentals. The input gear A is slidably mounted on the sun gear shaft S and carries a pin B which, when the clutch is engaged, fits through notch C in the ring gear E and notch D in the spider mounting F of the planet gear P respectively, locking the two "ends" of the differential together so they turn as one. The

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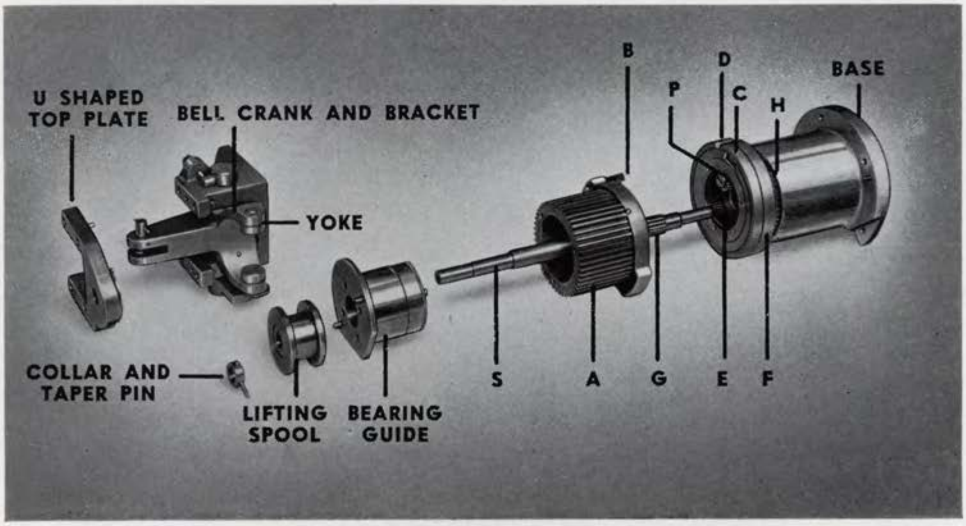

Fig. 76

follow-up mechanism drives (through gear A) the sun gear G, while the output shaft is in turn driven by the gear H on the spider F.

To disengage the clutch, the gear A and pin B are lifted so that the pin disengages from the notches C and D, allowing the two end members freedom to rotate with respect to each other. Thus, when disengaged, either input or output can move freely and the ring gear E can rotate to take up the difference between their relative motions.

The gear ratio of the clutch members is such that there is only one relative position for each of the three members in which the pin B will engage both notches and lock the clutch in direct drive. In any other relationship, even though the pin B is lined up with either notch D or C, the other notch is out of line and prevents the pin from dropping into engagement. This correct position can be found by turning the manual input crank until the angle generated by its corresponding output shaft equals the indicated angle of the corresponding gimbal on the Sensitive Element. In other words, this occurs only when the generated dials and selected dial of that particular system indicate the same angle (arrow heads together). See Fig. 77.

The relationship between synchronized clutch positions and other functions of the follow-up system may be checked by reference to the Functional Check Chart on page 99.

PRINCIPLE

As the ship pitches and rolls, the Stable Element is continuously stabilizing the optics in both Level and Cross Level. This means that, in effect, the Level Gimbal of the Sensitive Element is maintained in a horizontal plane as long as follow-up is occurring, regardless of the relative motion of the case around the Sensitive Element. The angle through which each gimbal moves to maintain this relationship is the angle which is transmitted to the Director, Computer, etc. These angles are indicated on the Level and Cross Level dials on the top of the Stable Element. Fig. 77 is a photograph of one of these sets of dials. Each set consists of three dials, the inner (high speed) generated dial, the outer (low speed) generated dial, and the selected dial.

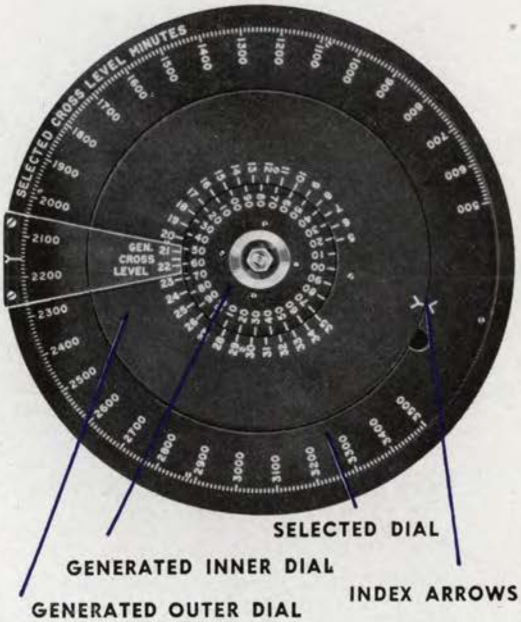

Fig. 77

GENERATED DIALS

As either follow-up mechanism operates it turns its respective pair of generated dials so that the angle of deviation can be read under the index plate. The inner dial is geared to make one revolution for every 300 minutes (5 degrees) of stabilization. The outer generated dial is calibrated in minutes from 500 to 3500, 2000 minutes being the center of roll or pitch, or zero angle of deviation. Its travel is limited to plus or minus 135 degrees from the reference point, which angles correspond to plus or minus 22½ degrees of correction (since the dial rotates at 6 speed). Thus the total angle of deviation in minutes is the sum of the readings on both generated dials, with 2000 minutes representing the zero angle or reference point. Both sets of dials (Level and Cross Level) are identical, but indicate angles about two axes 90 degrees apart.

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SELECTED DIAL

The selected dial for either system is also calibrated in minutes from 500 to 3500 and is geared to the corresponding output shaft at the same gear ratio as that of the outer generated dial. The arrow heads on these two dials indicate firing contact position, and when the synchronized clutch in the corresponding follow-up system is engaged, the arrow heads (and firing contacts) remain—and move—together. When firing the guns in "Level Fire" or "Cross Level Fire," the corresponding selected dial (and output shaft) is positioned by turning the manual input crank, and indicates the angle of deviation from a horizontal deck position at which the guns will fire.

The relationship between dial operation and control functions of the instrument may be checked by reference to the Functional Check Chart on page 99, and the interpretation of the dial indications is further explained under Methods of Follow-up on pages 122 and 123.

ELECTRICAL TRANSMISSION

The motions of the follow-up systems in maintaining the follow-up coils in alignment with the magnet are imparted through proper gearing to Synchro-generators for electrical transmission, as explained on page 32 under Fundamentals. In the case of the Mark 6 one function only, Cross Level, is transmitted by this means.* Two Synchro-generators are mounted on the bottom chassis and are geared to the follow-up mechanism, one at 2 speed and one at 72 speed.

*In the case of the Mark 5, Level plus 1/30 Cross Level is also transmitted electrically at 72 speed by one Synchro-generator, while in the case of the Mark 6, Mod. 1, Cross Level is transmitted as in the Mark 6 and in addition Continuous Level is transmitted at 2 and 36 speeds by two Synchro-generators mounted on the rear of the housing.

MECHANICAL TRANSMISSION

Fig. 78

The angles generated by the follow-up systems are also transmitted mechanically by shafts which are coupled directly to the adjacent Computer. These outputs terminate in adapter shafts as shown in Fig. 78 and transmit, in the case of the Mark 6 and Mark 6 Mod. 1, Level, Cross Level, and Level plus 1/30 Cross Level, all at 120 speed. (In the case of the Mark 5, Level plus 1/30 Cross Level is transmitted electrically, as explained above, but not mechanically.)

OUTPUTS OF STABLE ELEMENT

CROSS LEVEL

The gearing of this shaft may be followed by means of the gear train diagrams on pages 103 and 106, and by reference to the Functional Diagram on page 98.

TRAIN TRANSMITTING UNIT

Installation of a Train Transmitting Unit, as directed by OrdAlt 2807A, permits transmitting Stable Element Train at 1-speed and 36-speed. When Stable Element Mark 6 Mod. 1 is so equipped, it becomes Mark 6 Mod 7; when Stable Element Mark 6 Mod. 8 is so equipped, it becomes Mark 6 Mod. 9.

Fig. 78A illustrates the circuitry of the Stable Element Mark 6 Mod. 7. The Train Transmitting Unit is shown just below and to the left of the Stable Element. The Train Transmitting Unit (Dwg. 698283) consists of two 1G Synchro-generators Mark 5 Mod. 1 (Dwg. 213036) which are mounted with a gearing arrangement (fig. 78B). The gearing arrangement is such that one of the generators delivers at 1-speed and the other is driven through an epicyclic gear train so that its output is delivered at 36-speed (fig. 78C). The Train Transmitting Unit is mounted just inside the front access cover on a metal assembly inserted between the top and bottom surfaces of the front access opening (fig. 78B). It then derives train mechanically from the Stable Element by means of a gear drive which meshes with the Stable Element Training Gear.

ADJUSTMENT - The Train Transmitting Unit is adjusted as follows:

1. Connect a 1F test motor with a 1-speed train dial and a fixed index to the 1-speed generator leads R1KL, R2KL, S1K, S2K and S3K; connect another 1F test motor with a 36-speed train dial and a fixed index to the 36-speed generator leads R1KL, R2KL, S1L, S2L and S3L.
2. Energize the generators from a 115-volt single-phase 60 cycle A. C. source (See OP 1303).
3. Align the Training Gear index line with the fixed index plate line (under center of left access door).
4. Loosen the Train Transmitting Unit input gear setscrew. (See fig. 78B).
5. Rotate the Train Transmitting Unit input shaft (fig. 78B) until test motor dials read zero degrees. The 36-speed generator may have to be set to electrical zero as follows:
    A. Loosen friction clamp (See fig. 78B).
    B. Hold the 1-speed generator rotor gear at zero and position the 36-speed motor hub (with a screw driver held in the hub slots) to zero on the 36-speed test motor dial.
    C. Tighten friction clamp.
6. Mesh input gear centrally with Training Gear and tighten input gear setscrew.
7. Disconnect the 1F test motors.

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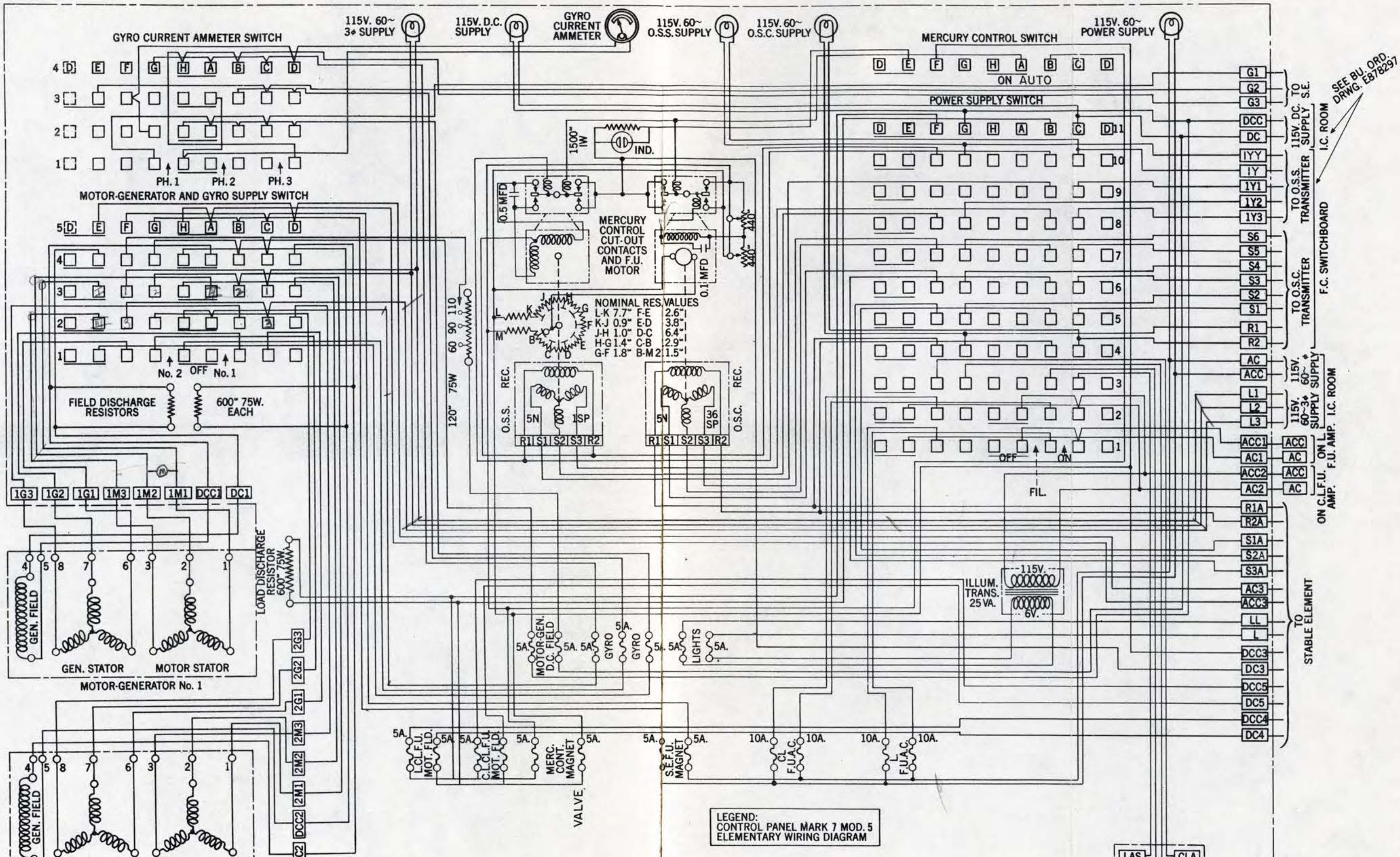

Fig. 78A (Part 1)

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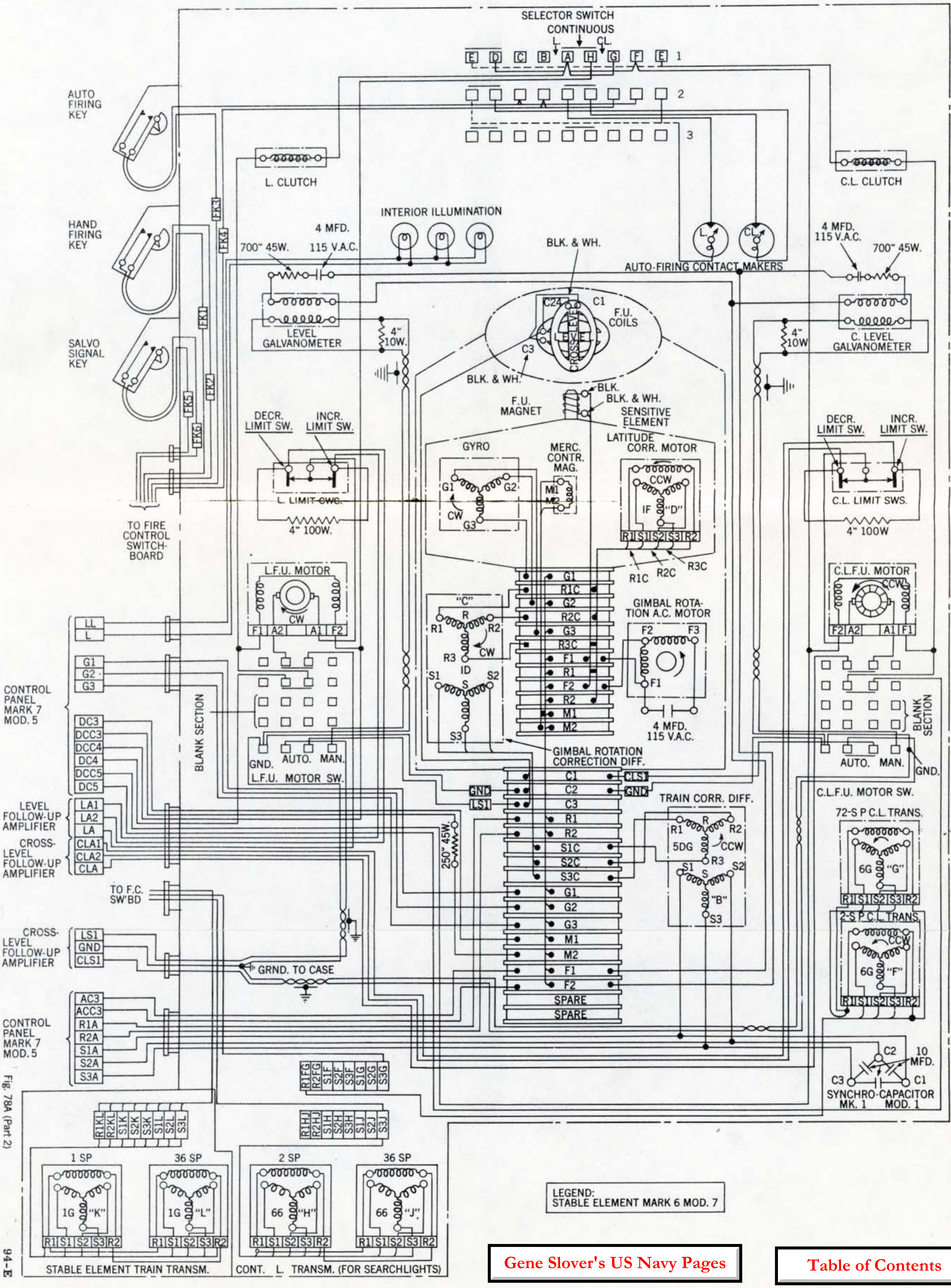

Fig. 78A (Part 2)

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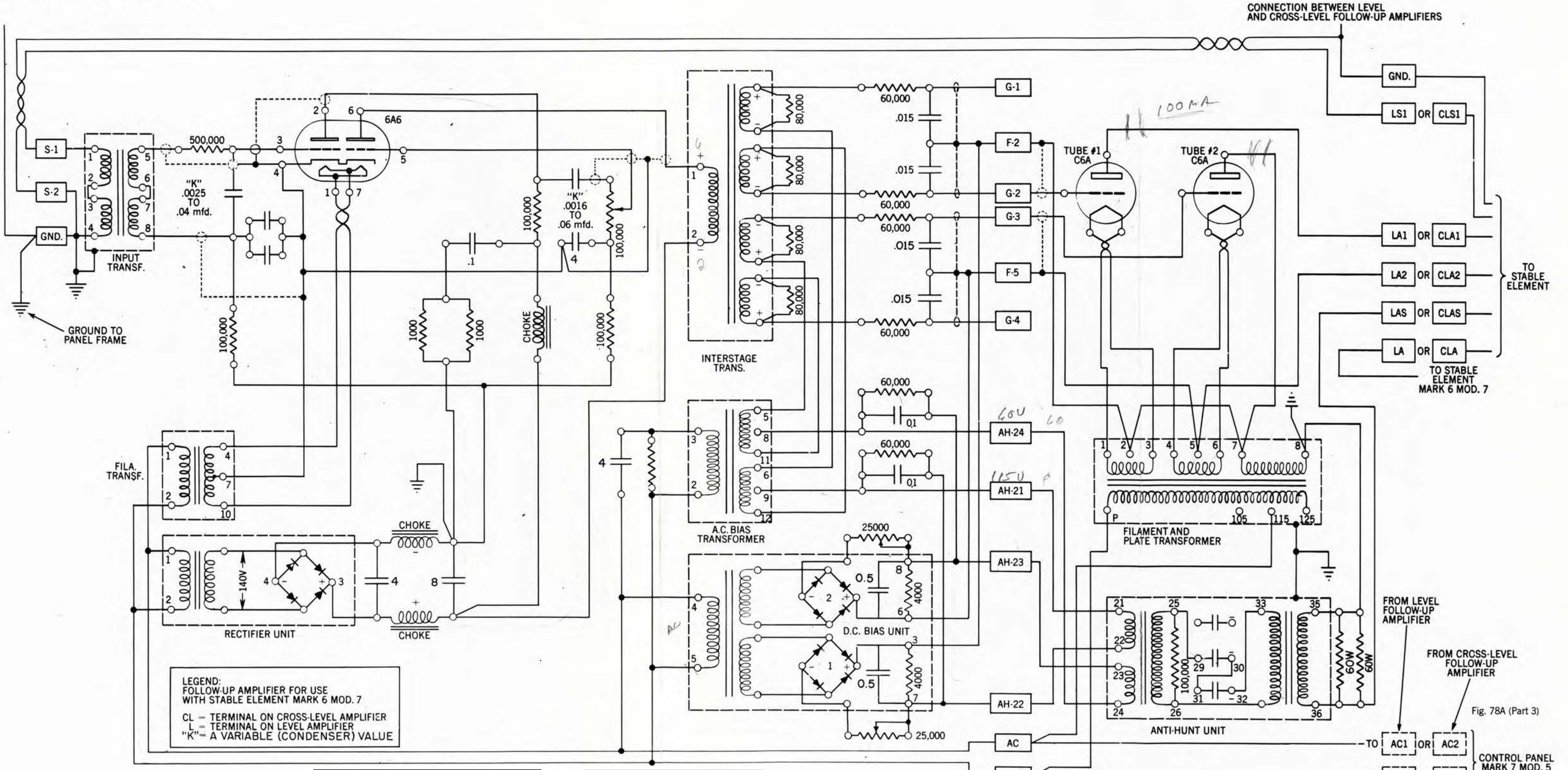

Fig. 78A (Part 3)

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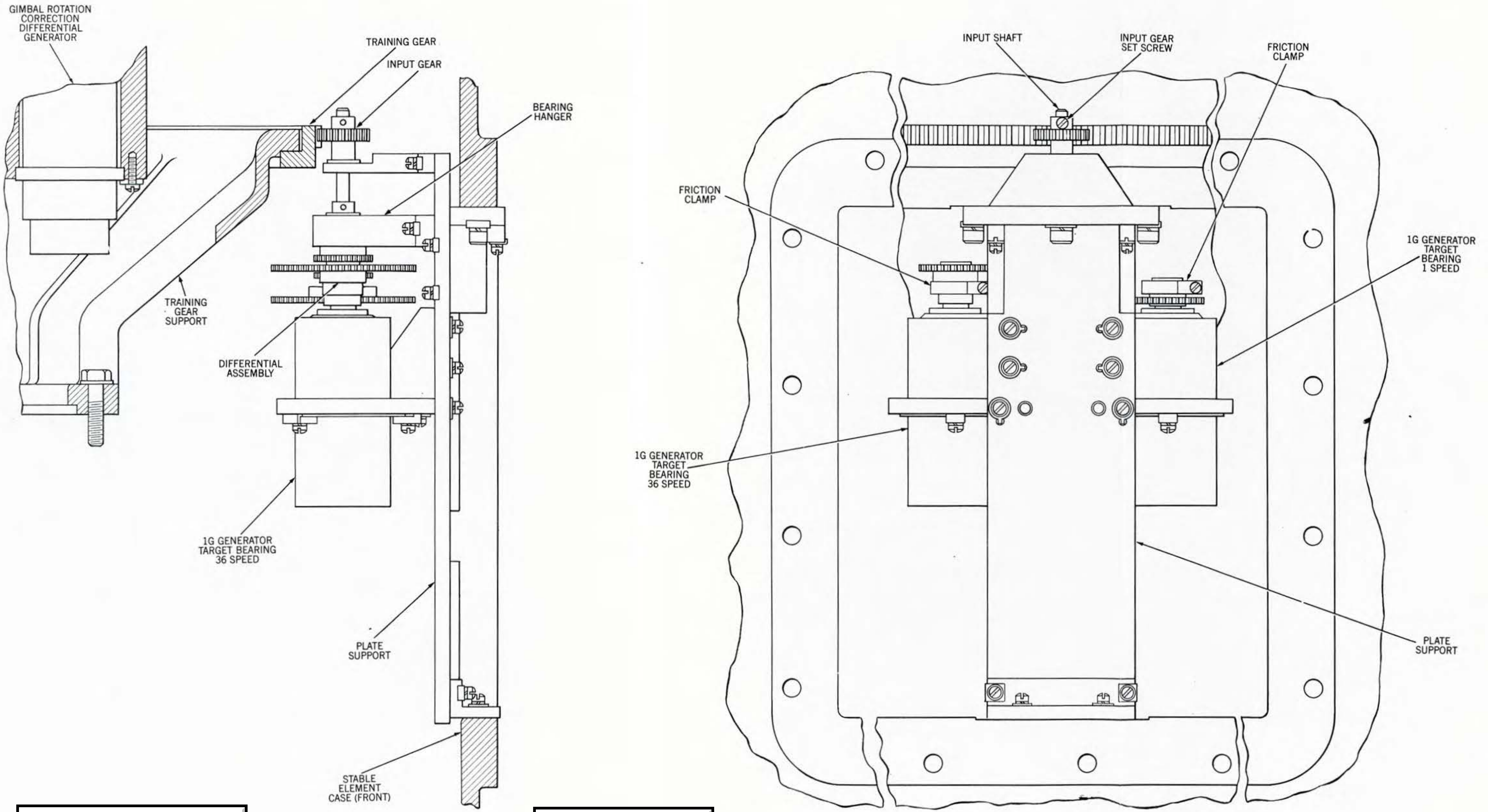

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Fig. 78B

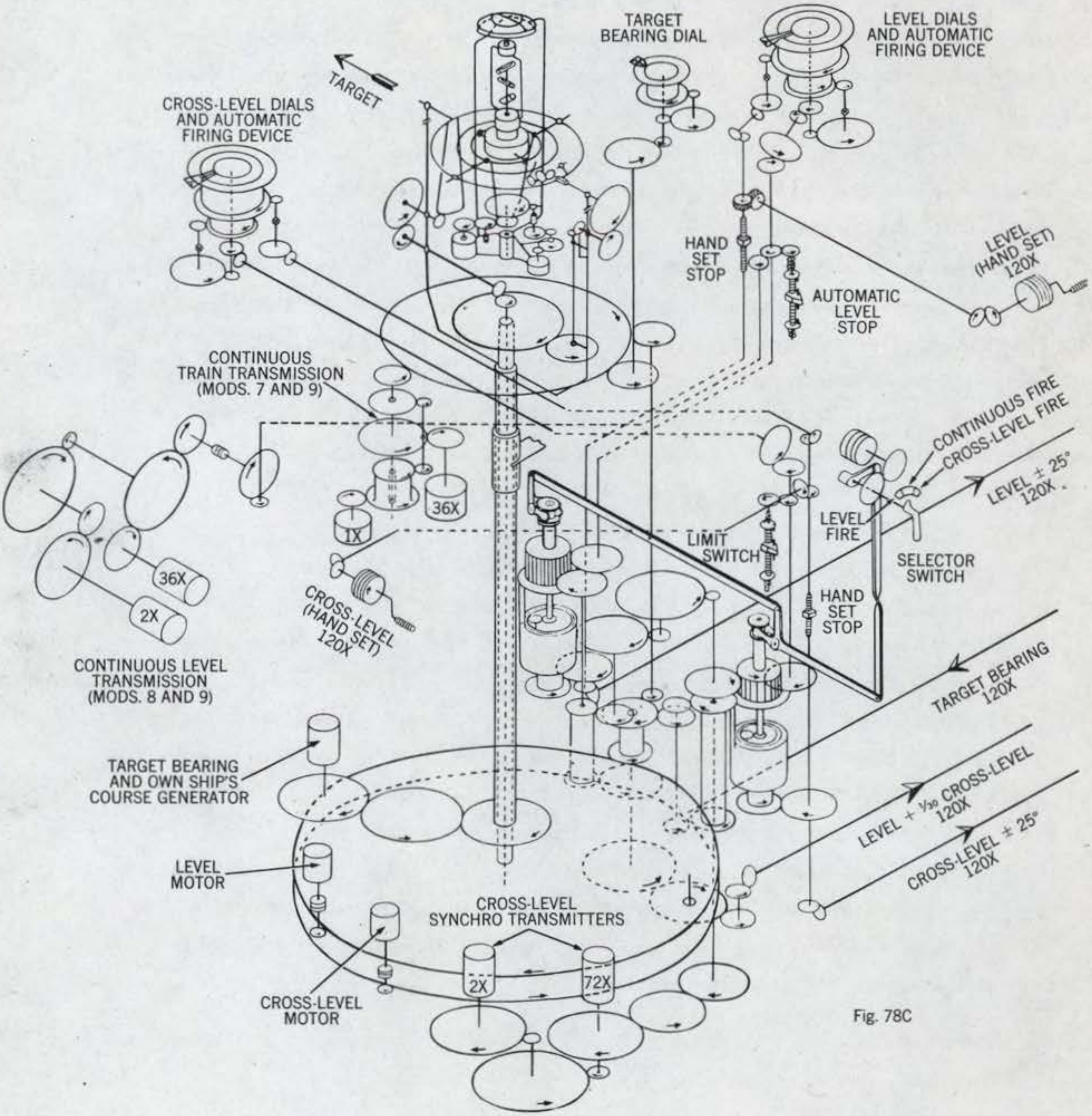

Fig. 78C

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CONTINUOUS LEVEL TRANSMITTING UNIT

Installation of the Continuous Level Transmitting Unit, as directed by OrdAlt 2906, permits transmitting Continuous Level at 2-speed and 36-speed for use in the underwater fire control system. The Unit is added to the Stable Element Mark 6 Mod. 0 making it Mark 6 Mod. 8.

Figure 78C shows the Stable Element Mark 6 Mod. 9 gearing arrangement including the Continuous Level Transmitting Unit. Figure 78F shows the wiring diagram of the Stable Element with the Continuous Level Transmitting Unit installed. This unit is built on a metal plate which is mounted just inside the rear access opening between the top and bottom surfaces of this opening (fig. 78E). The Continuous Level Transmitting Unit (Dwg. 698727) consists of two 5G Synchro-generators Mark 1 (Dwg. 561792) mounted with a gear arrangement which derives continuous level from the Stable Element (fig. 78E) and delivers it to one of the generators at 2-speed and to the other generator at 36-speed. The gear arrangement of this unit derives continuous level through an Oldham-type coupling which connects the unit to the level-dial gearing (fig. 78C). This is in contrast to the Stable Element Mark 6 Mod. 1 which delivers continuous level at 2-speed and 36-speed electrically but which derives this function by mechanically coupling its Synchro-generators to the "B" differential connected to the Training Gear (fig. 91, OP 1063). The physical orientation of the Synchro-generators in the one Continuous Level Transmitting Unit is opposite to that in the other transmitting arrangement (fig. 78E and fig. 147).

ADJUSTMENT - The Continuous Level Transmitting Unit is adjusted as follows:

1. Connect a No. 5 test synchro motor having a 0-360° dial and a fixed index to 5G synchro generator assembly terminal board leads R1HJ, R2HJ, S1H, S2H and S3H; connect another No. 5 test synchro motor having a 0-360° dial and a fixed index to 5G synchro generator assembly terminal board leads R1HJ, R2HJ, S1J, S2J and S3J.
2. Energize the generators from a 115-volt single phase 60 cycle A. C. source. (See OP 1303.)
3. Set Stable Element Generated Level Dials at 2000'. Adjust both test motor dials to a reading of zero degrees by either of the following means:

   A. Loosen setscrew on Continuous Level Transmitting Unit input gear (fig. 78E); rotate input shaft until test motor dials read zero degrees; tighten input gear set screw or,

   B. Loosen each generator shaft nut (fig. 78E); rotate each generator rotor (with a screw driver) until each test motor dial reads zero degrees; tighten each generator shaft nut.
4. Disconnect No. 5 test synchro motors.

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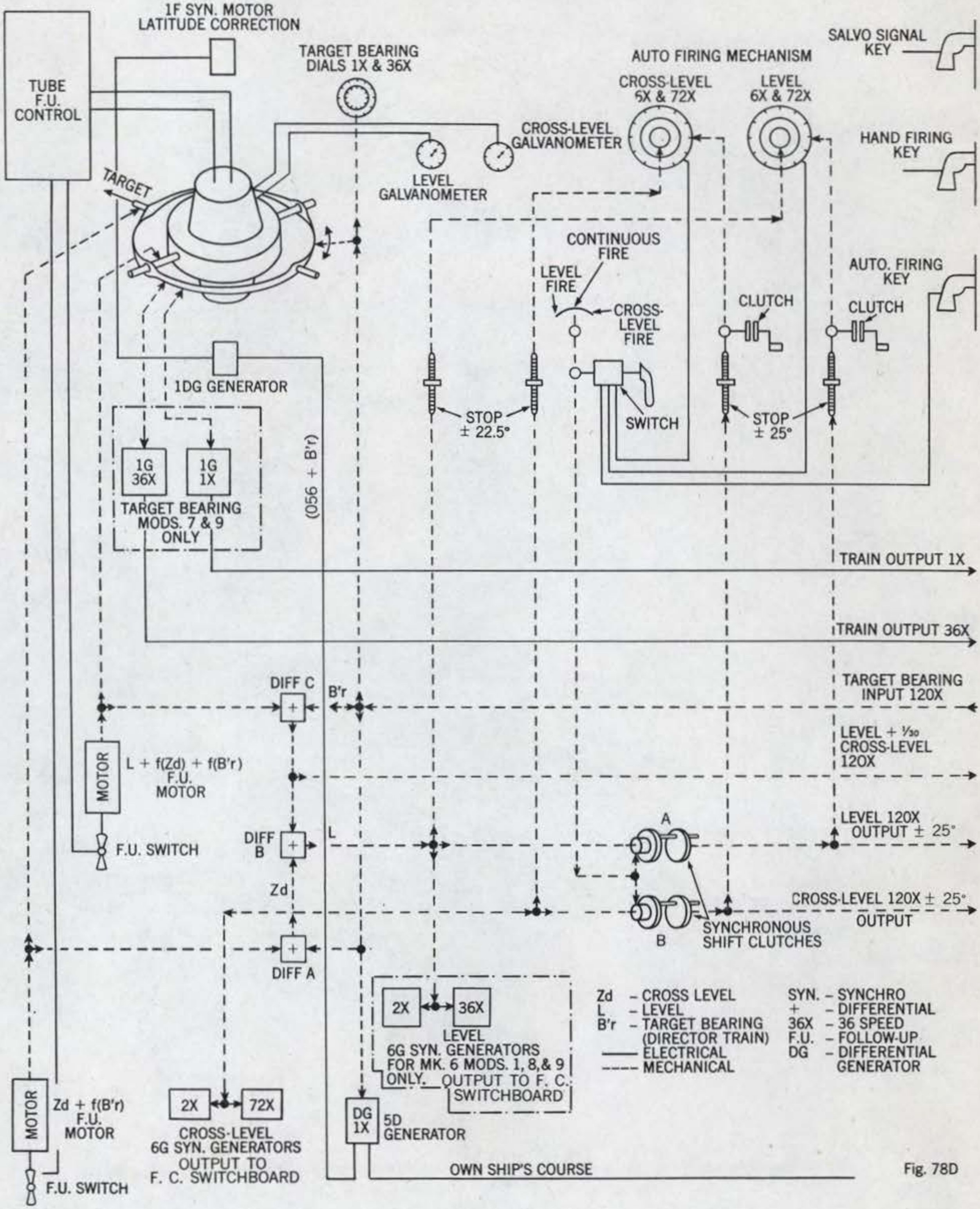

Fig. 78D

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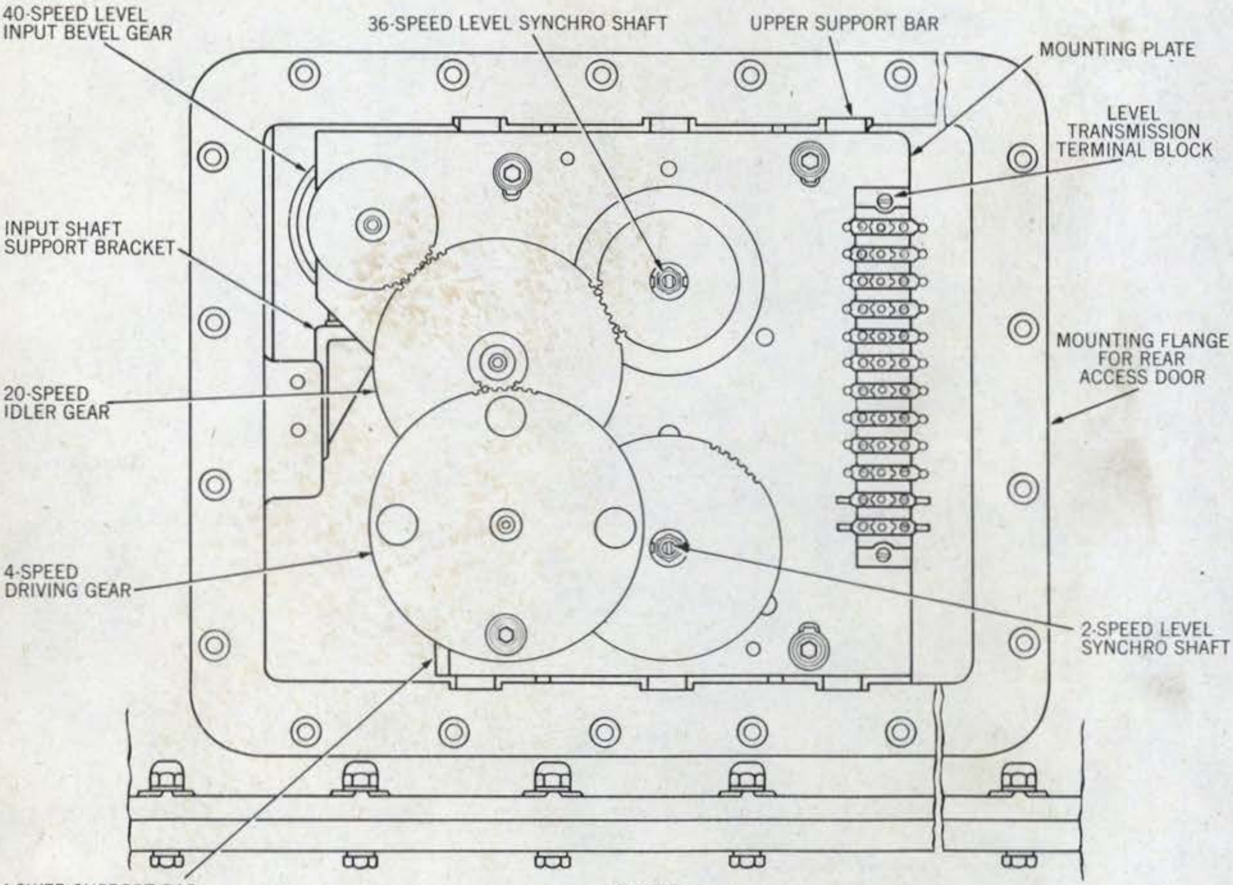

Fig. 78E

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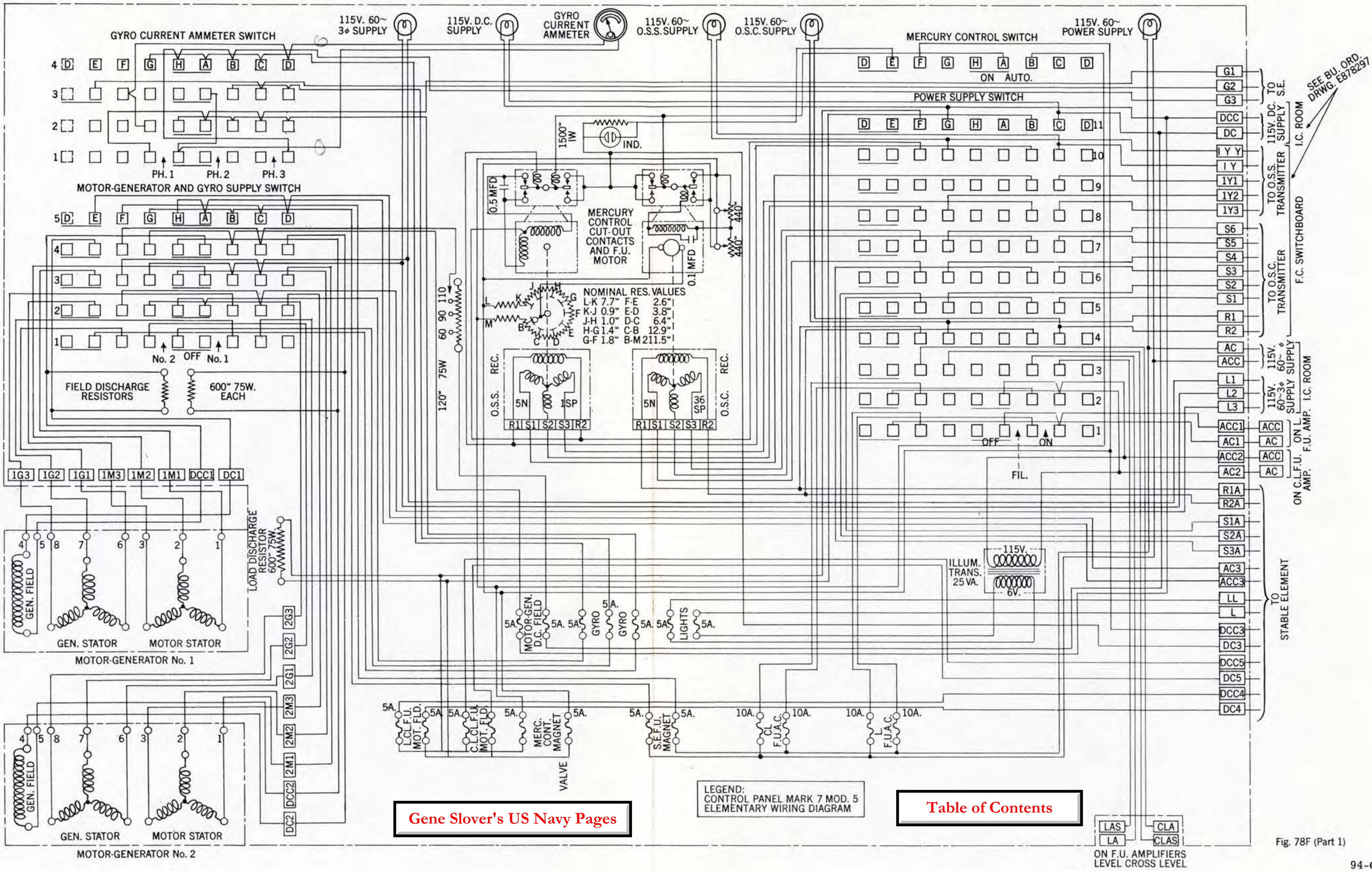

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Fig. 78F (Part 1)

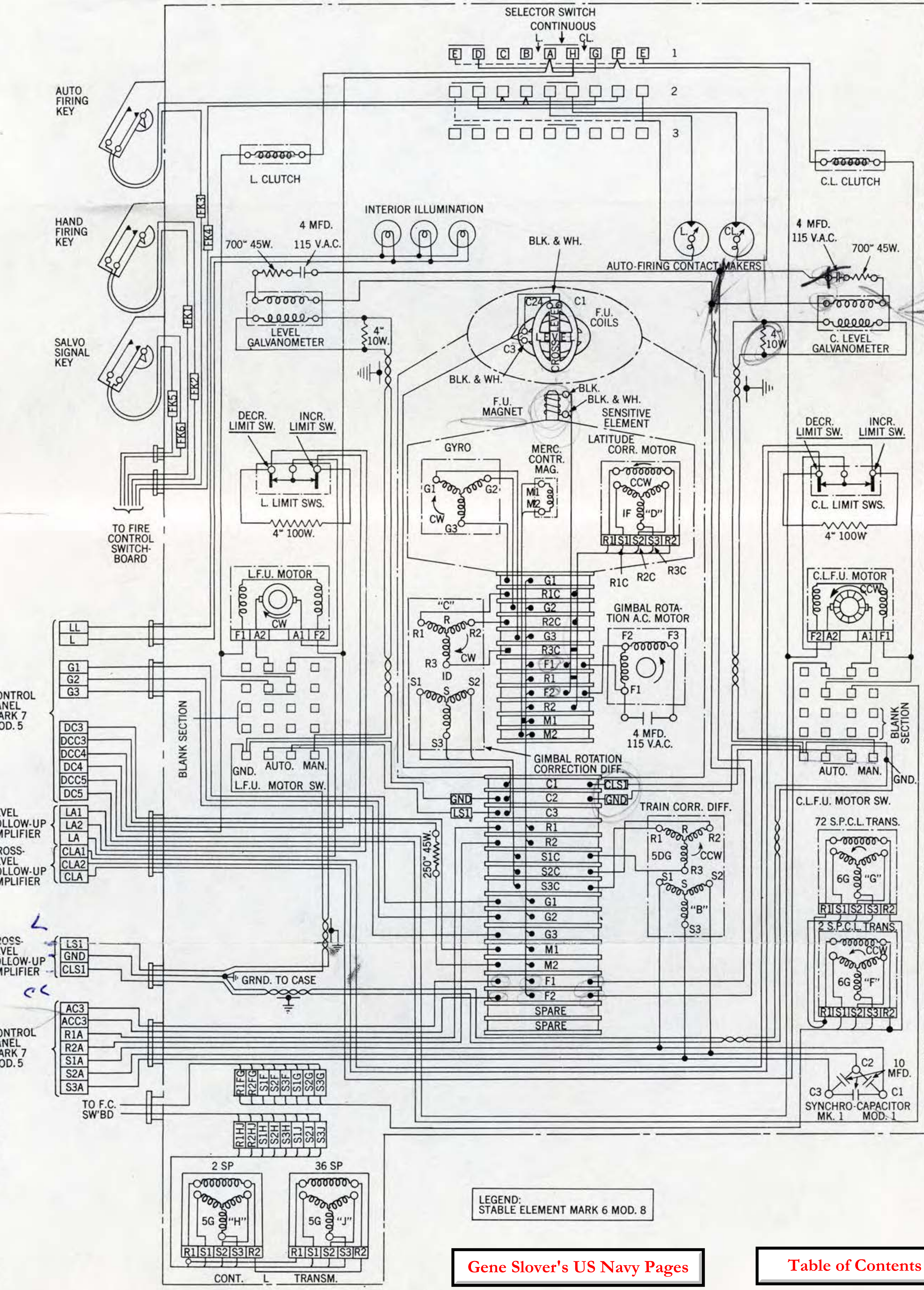

Fig. 78F (Part 2)

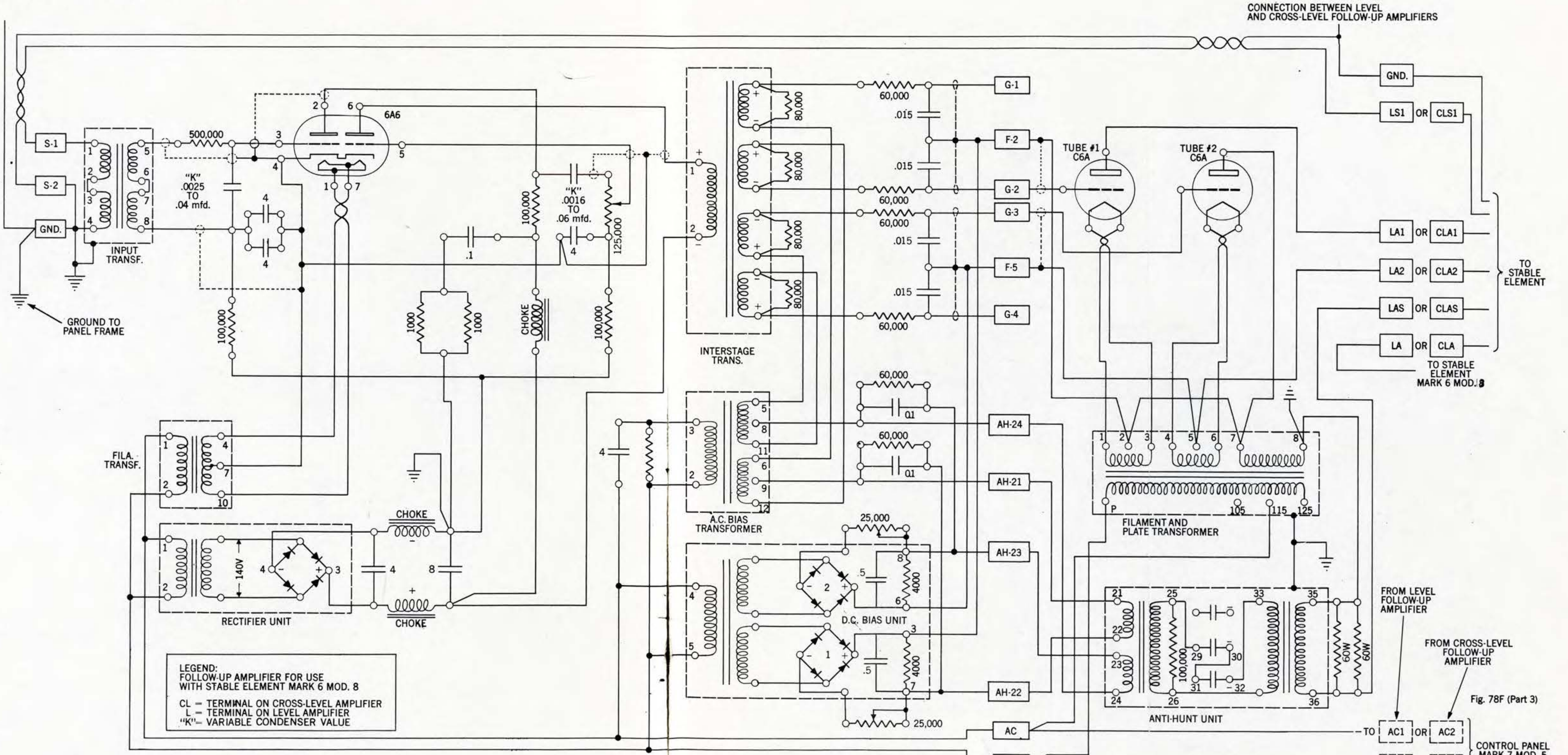

Fig. 78F (Part 3)

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LEVEL PLUS 1/30 CROSS LEVEL

As was brought out in a preceding paragraph (page 84), any movement of the Cross Level Gimbal in its bearings (which are 90 degrees from the Level Gimbal bearings) will cause the Level Gimbal, and all of the units mounted on it, to turn about the axis of the Cross Level gimbal bearings. (Since the Level driving gear is locked in position, unless being driven by the Level follow-up motor, the Level driven gear will roll about its driving gear and cause a motion of the Level Gimbal about the Level axis.) This movement causes a displacement of the Level follow-up coils with respect to the follow-up magnet, thus energizing the Level follow-up motor, which then drives the Level Gear and Gimbal (and output shafts) until the displacement of the Level follow-up coil is eliminated. The operation of the Level follow-up system, due to a motion in Cross Level, introduces this function of Cross Level in the Level output. The tooth ratio of the gear train between the Level driving gear and the Level Gimbal gear sector is 1 to 30; thus the value of this function is 1/30 of the Cross Level motion.

This modified output and the Cross Level output are used in stabilizing the optics or any other instrument which is mounted in similar gimbals and which requires this correction in its Level input. These gear relationships may be followed by means of the gear train diagrams on pages 105 and 106 and the Functional Diagram on page 98.

CONTINUOUS LEVEL

Where true Level is desired, unmodified by the Cross Level function, steps must be taken to eliminate this Cross Level effect on Level. In the Stable Element, this is accomplished as follows:

As explained in the preceding paragraphs, the motion of the Level follow-up gimbal, due to a motion in Cross Level, is counteracted by the operation of the Level follow-up motor, which brings the Level follow-up coil back into alignment with the magnet. This counter-motion is also applied to a mechanical differential (Diff. B as shown in the Functional Diagram, page 98), which "refers" it to the Cross Level motion which caused the original Level Gimbal displacement. The differential "takes out" the 1/30 Cross Level function, and its output is true Continuous Level, which is then made available at the Level adapter shaft, shown in Fig. 78. This function may be more easily understood by referring to the Functional Diagram, and can be followed in detail by tracing through the gear train diagrams on pages 101 and 106.

EFFECT OF TRAINING

Due to the construction of the gimbal assembly wherein the motion of both follow-up gimbals is transmitted through gearing in the pedestal of the bottom chassis, the rotation of the training gear will also cause motion of both gimbals. The follow-up motors, therefore, operate to restore the follow-up coils to their neutral positions, and their outputs thus contain a function of training, as can be seen by referring to the Functional Diagram on page 98. In order to eliminate this function in the outputs, the Level and Cross Level motor outputs are applied to two differentials (Diff. C and Diff. A respectively). The other input to each differential is Target Bearing (Director Train.) The differentials thus "take out" the training function and leave unmodified Cross Level and Level plus 1/30 Cross Level, this latter function (Zd/30) being "taken out" of the Continuous Level output by differential B as explained in the preceding paragraph.

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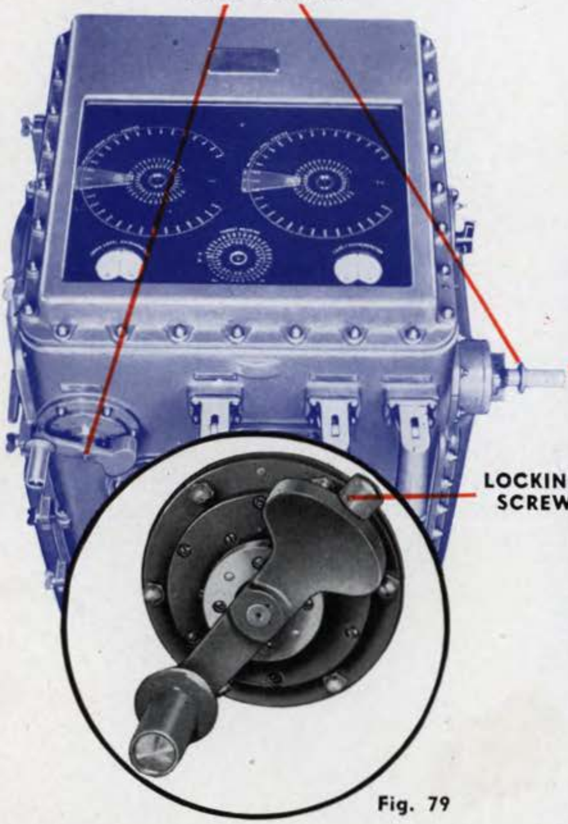

Fig. 79

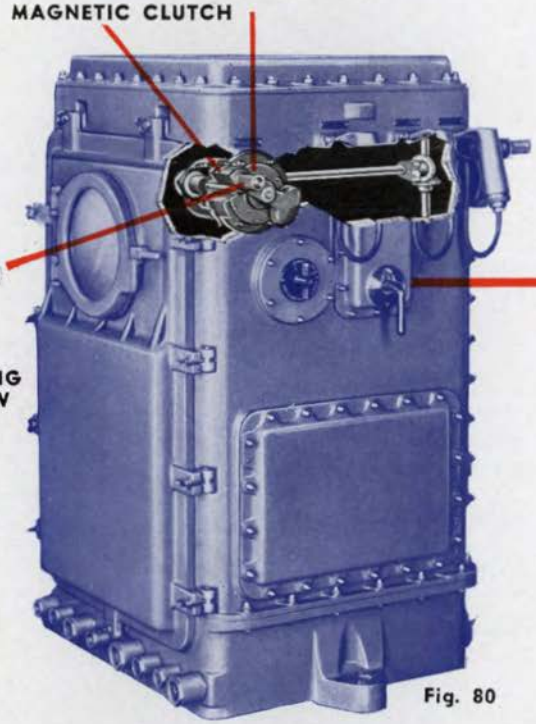

Fig. 80

Normally, automatic follow-up is used for both the Level and Cross Level systems, but in the event either or both of these systems fail to operate properly, or when conditions otherwise warrant it, (see Operation, page 122) the Stable Element may be operated manually.

HAND CRANKS

The manual input for Level control is the hand crank on the right side of the instrument, while the Cross Level hand input crank is on the front of the case, as shown in Fig. 79. On each crank is a locking screw which should be kept tight to prevent feed-back of either function from the Computer when it is in operation and the Stable Element is not. The use of these cranks is explained on page 122 under Operation.

MAGNETIC CLUTCHES

Mounted inside the case directly behind each hand crank is a magnetic clutch, one of which is shown in Fig. 80. When energized, the spring-loaded friction plates are *disengaged,* preventing coupling between the crank and its associated gearing. The

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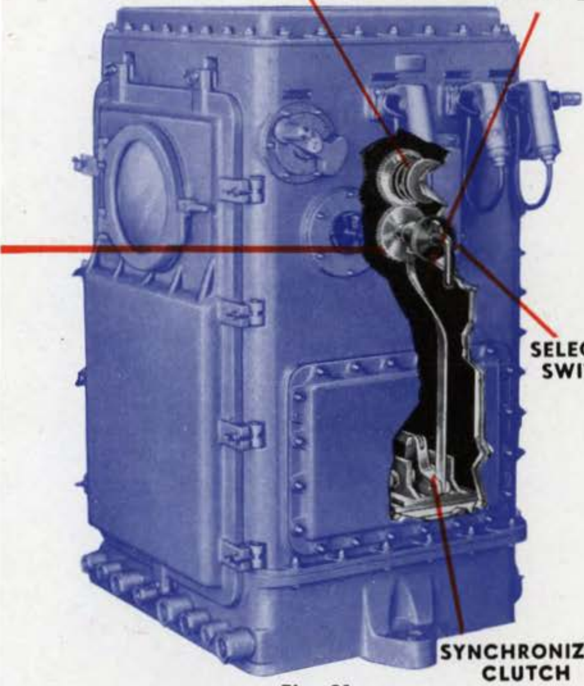

Fig. 81

conditions under which either clutch is de-energized, thus engaging its shafts, are explained under Operation, page 123, and are also shown in the Functional Check Chart on page 99.

SELECTOR SWITCH

While not exactly a manual input, this switch does determine when manual inputs can be used. It is located on the front of the instrument, Figs. 80 and 81, and performs both mechanical and electrical functions. It mechanically controls the synchronized clutches described on page 91, engaging one or the other or both (Level and Cross Level) and at the same time controls electrically the action of the magnetic clutches on the hand cranks. See Section 7, Operation, for further explanation of the use of this switch.

DIALS

The dials, similarly, are not manual inputs, but they do indicate what is happening when manual (or automatic) operation is occurring. The selected dial of either system indicates the angle at which the guns will fire, and is set by its respective hand crank when the Selector Switch is in the corresponding Level Fire or Cross Level Fire position.

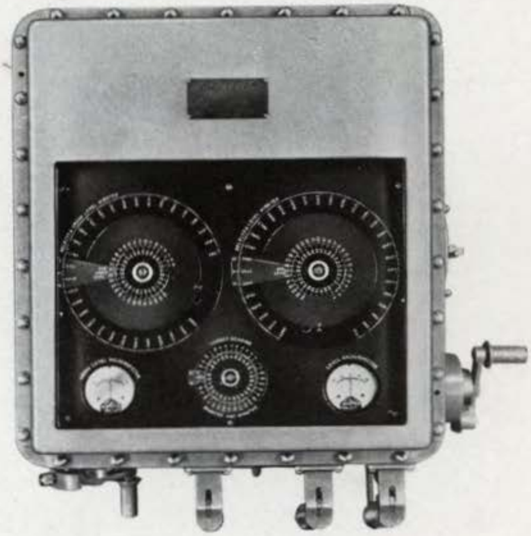
Fig. 82

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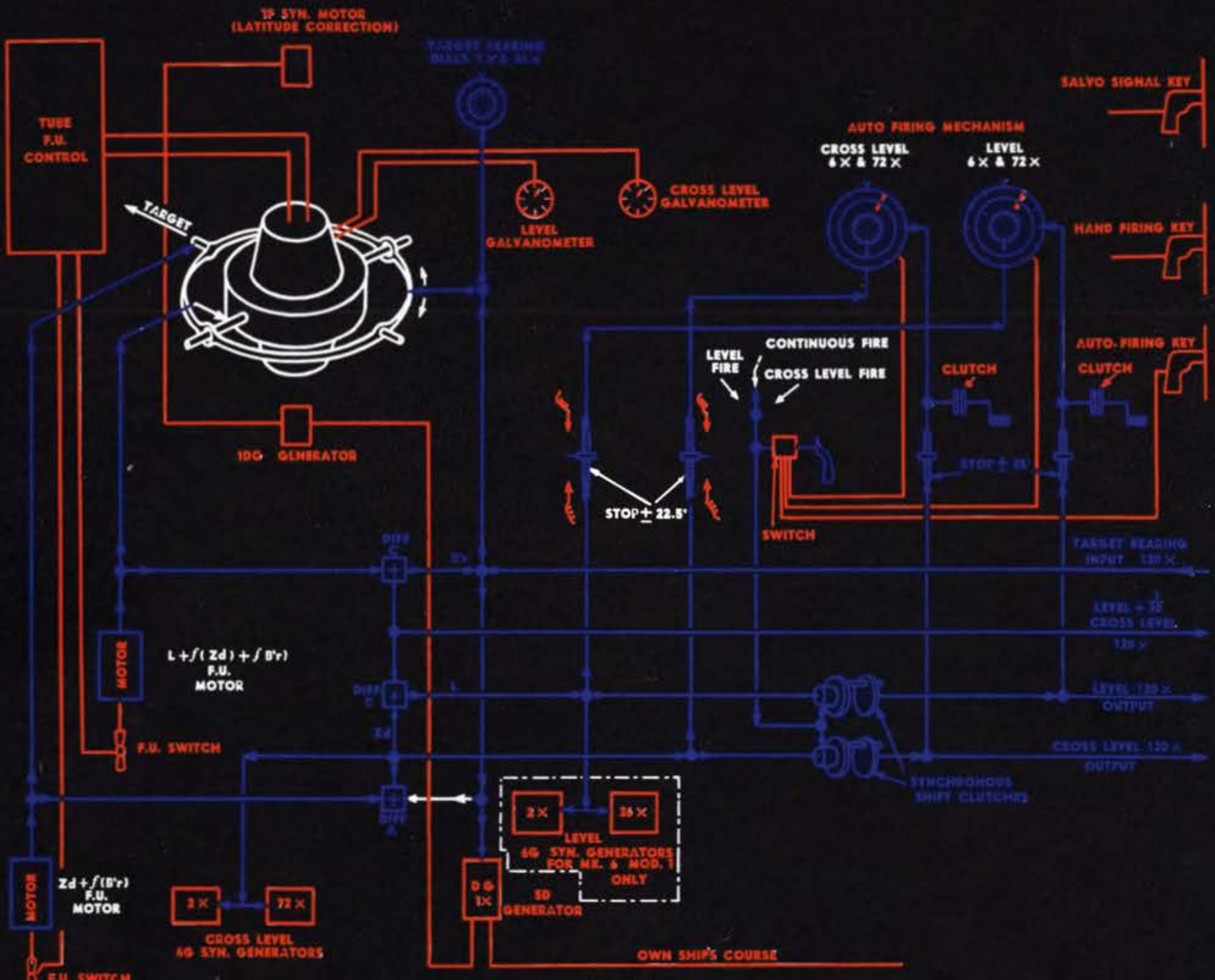

Fig. 83

Zd — CROSS LEVEL
L — LEVEL
B'r — TARGET BEARING (DIRECTOR TRAIN)
—— ELECTRICAL
—— MECHANICAL

SYN. — SYNCHRO
+ — DIFFERENTIAL
36 × — 36 SPEED
F.U. — FOLLOW-UP
D G — DIFFERENTIAL GENERATOR

This diagram is purposely simplified in block form to show merely the functional location of each of the various units of the Stable Element in the overall operation of the instrument. Lines in blue indicate mechanical functions, shafts and gearing, while the red lines represent electrical functions.

The Functional Diagram has been elaborated upon, function by function, in the gear train diagrams on the following pages.

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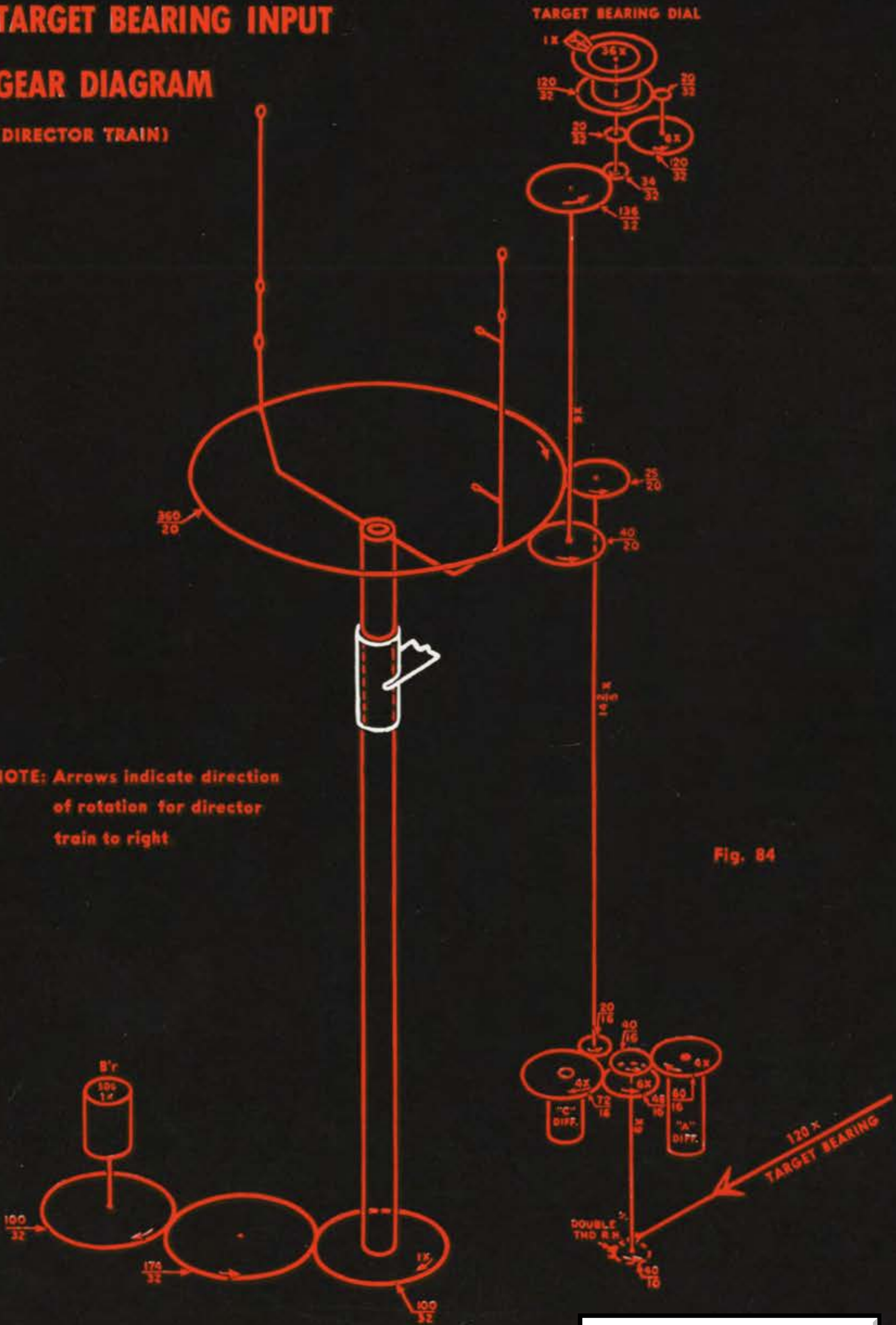
FUNCTIONAL CHECK CHART

Follow-up Switch Positions		Function	Dials		Selector Switch Position: Continuous Fire	Selector Switch Position: Level Fire	Selector Switch Position: Cross Level Fire
LEVEL	AUTOMATIC	HAND CRANK CLUTCH			DISENGAGED	ENGAGED	DISENGAGED
LEVEL	AUTOMATIC	FOLLOW-UP MOTOR			ENERGIZED	ENERGIZED	ENERGIZED
LEVEL	AUTOMATIC	ARROWS ON	DIALS	OPERATE	TOGETHER	INDEPENDENTLY	TOGETHER
LEVEL	AUTOMATIC	GENERATED	DIALS	OPERATED BY	FOLLOW-UP	FOLLOW-UP	FOLLOW-UP
LEVEL	AUTOMATIC	SELECTED	DIALS	OPERATED BY	FOLLOW-UP	HAND CRANK	FOLLOW-UP
LEVEL	AUTOMATIC	OUTPUTS OPERATED BY			FOLLOW-UP	HAND CRANK	FOLLOW-UP
LEVEL	AUTOMATIC	GALVANOMETER			DISCONNECTED	DISCONNECTED	DISCONNECTED
LEVEL		SYNCHRONIZED CLUTCH			ENGAGED	DISENGAGED	ENGAGED
LEVEL	MANUAL	HAND CRANK CLUTCH			ENGAGED	ENGAGED (DO NOT SET UP THIS COMBINATION)	ENGAGED
LEVEL	MANUAL	FOLLOW-UP MOTOR			DE-ENERGIZED	*DE-ENERGIZED* (DO NOT SET UP THIS COMBINATION)	DE-ENERGIZED
LEVEL	MANUAL	ARROWS ON	DIALS	OPERATE	TOGETHER	INDEPENDENTLY (DO NOT SET UP THIS COMBINATION)	TOGETHER
LEVEL	MANUAL	GENERATED	DIALS	OPERATED BY	HAND CRANK	WILL NOT OPERATE (DO NOT SET UP THIS COMBINATION)	HAND CRANK
LEVEL	MANUAL	SELECTED	DIALS	OPERATED BY	HAND CRANK	HAND CRANK (DO NOT SET UP THIS COMBINATION)	HAND CRANK
LEVEL	MANUAL	OUTPUTS CONTROLLED BY			HAND CRANK	HAND CRANK (DO NOT SET UP THIS COMBINATION)	HAND CRANK
LEVEL	MANUAL	GALVANOMETER			INDICATING	INDICATING (DO NOT SET UP THIS COMBINATION)	INDICATING
CROSS LEVEL	AUTOMATIC	HAND CRANK CLUTCH			DISENGAGED	DISENGAGED	ENGAGED
CROSS LEVEL	AUTOMATIC	FOLLOW-UP MOTOR			ENERGIZED	ENERGIZED	ENERGIZED
CROSS LEVEL	AUTOMATIC	ARROWS ON	DIALS	OPERATE	TOGETHER	TOGETHER	INDEPENDENTLY
CROSS LEVEL	AUTOMATIC	GENERATED	DIALS	OPERATED BY	FOLLOW-UP	FOLLOW-UP	FOLLOW-UP
CROSS LEVEL	AUTOMATIC	SELECTED	DIALS	OPERATED BY	FOLLOW-UP	FOLLOW-UP	HAND CRANK
CROSS LEVEL	AUTOMATIC	OUTPUTS CONTROLLED BY			FOLLOW-UP	FOLLOW-UP	HAND CRANK
CROSS LEVEL	AUTOMATIC	GALVANOMETER			DISCONNECTED	DISCONNECTED	DISCONNECTED
CROSS LEVEL		SYNCHRONIZED CLUTCH			ENGAGED	ENGAGED	DISENGAGED
CROSS LEVEL	MANUAL	HAND CRANK CLUTCH			ENGAGED	ENGAGED	ENGAGED (DO NOT SET UP THIS COMBINATION)
CROSS LEVEL	MANUAL	FOLLOW-UP MOTOR			DE-ENERGIZED	DE-ENERGIZED	*DE-ENERGIZED* (DO NOT SET UP THIS COMBINATION)
CROSS LEVEL	MANUAL	ARROWS ON	DIALS	OPERATE	TOGETHER	TOGETHER	INDEPENDENTLY (DO NOT SET UP THIS COMBINATION)
CROSS LEVEL	MANUAL	GENERATED	DIALS	OPERATED BY	HAND CRANK	HAND CRANK	WILL NOT OPERATE (DO NOT SET UP THIS COMBINATION)
CROSS LEVEL	MANUAL	SELECTED	DIALS	OPERATED BY	HAND CRANK	HAND CRANK	HAND CRANK (DO NOT SET UP THIS COMBINATION)
CROSS LEVEL	MANUAL	OUTPUTS CONTROLLED BY			HAND CRANK	HAND CRANK	HAND CRANK (DO NOT SET UP THIS COMBINATION)
CROSS LEVEL	MANUAL	GALVANOMETER			INDICATING	INDICATING	INDICATING (DO NOT SET UP THIS COMBINATION)

TARGET BEARING INPUT GEAR DIAGRAM

(DIRECTOR TRAIN)



NOTE: Arrows indicate direction of rotation for director train to right

Fig. 84

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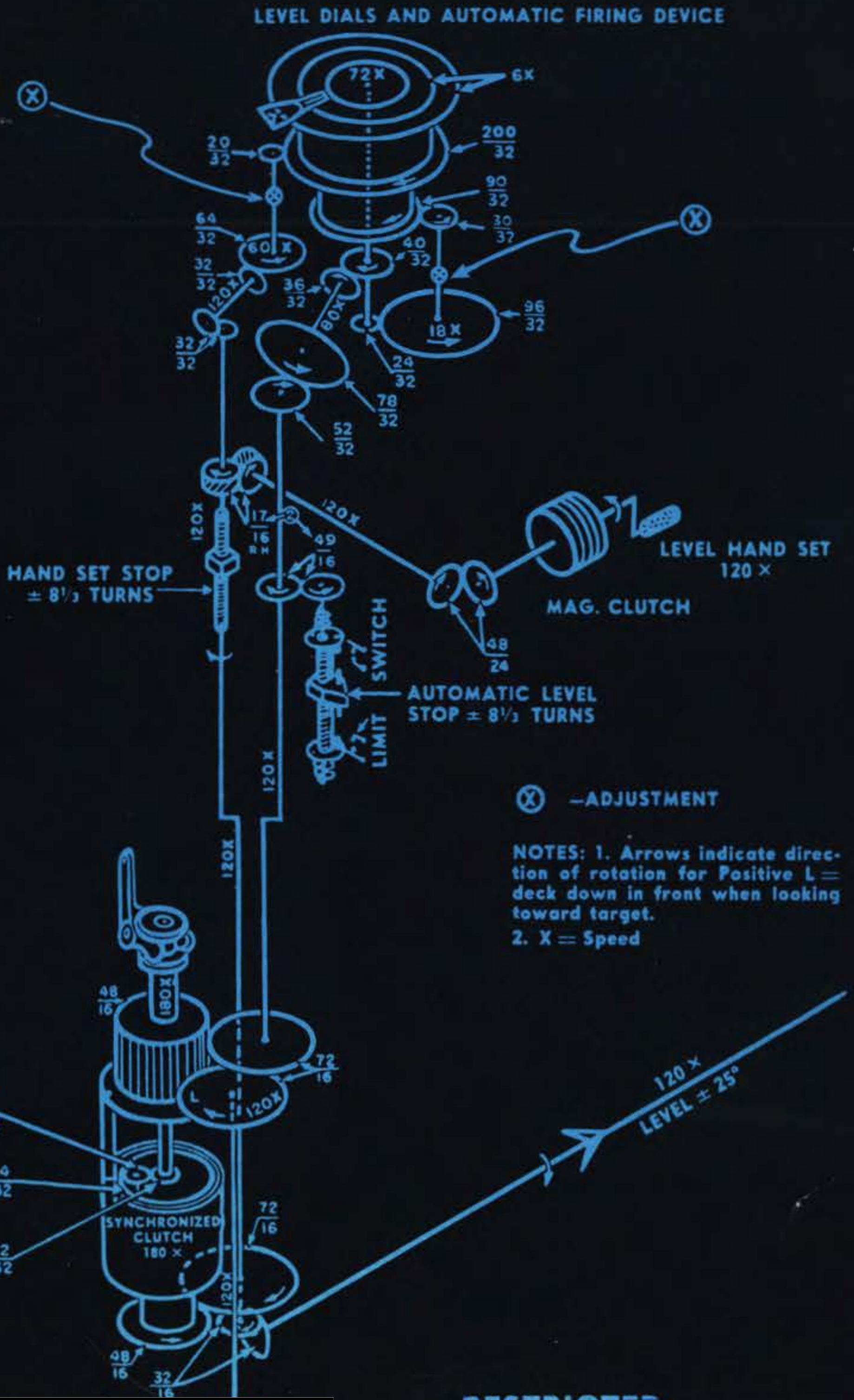
LEVEL OUTPUT GEAR DIAGRAM

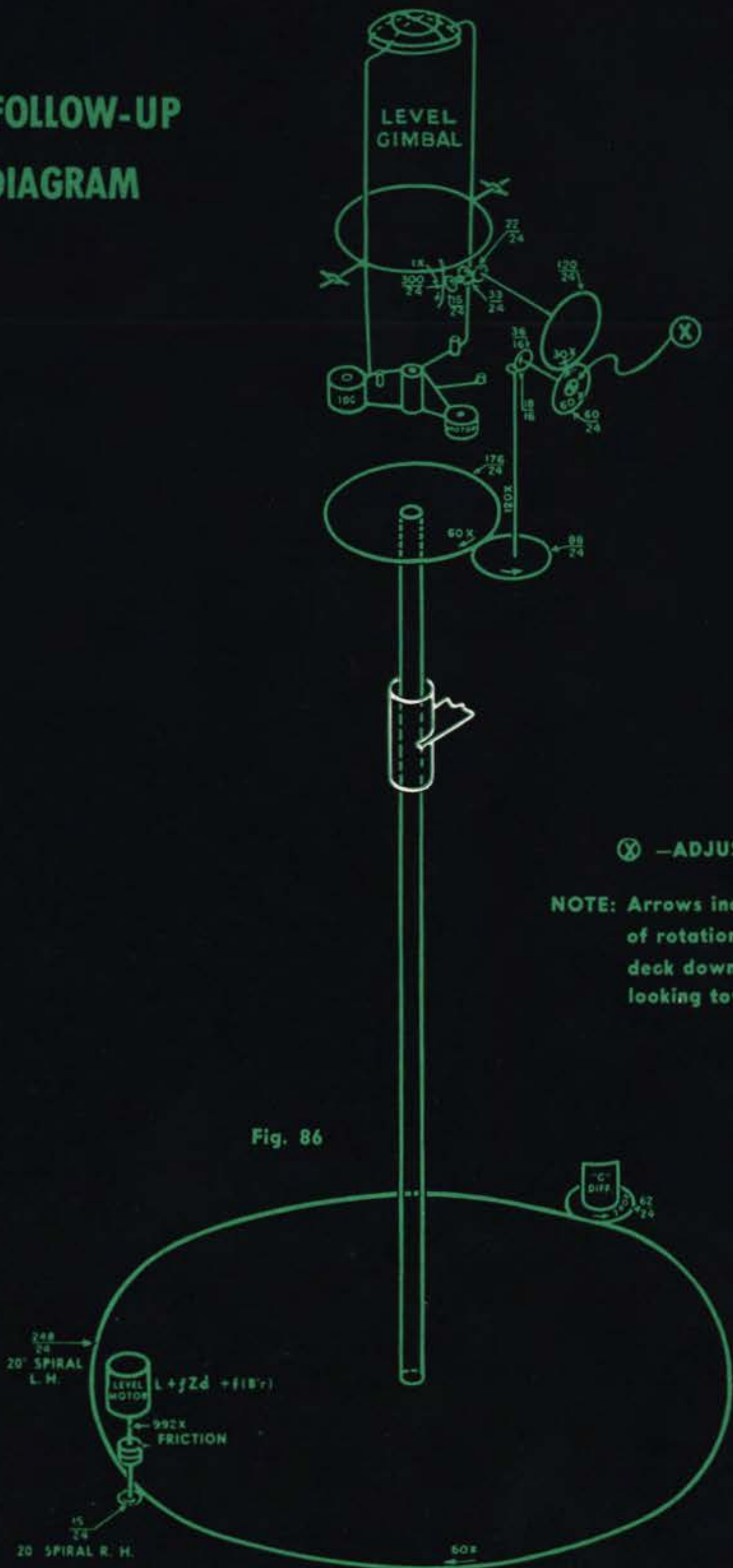


Ⓧ —ADJUSTMENT

NOTES: 1. Arrows indicate direction of rotation for Positive L = deck down in front when looking toward target.

2. X = Speed

LEVEL FOLLOW-UP GEAR DIAGRAM



Ⓧ —ADJUSTMENT

NOTE: Arrows indicate direction of rotation for Positive L = deck down in front when looking toward target.

Fig. 86

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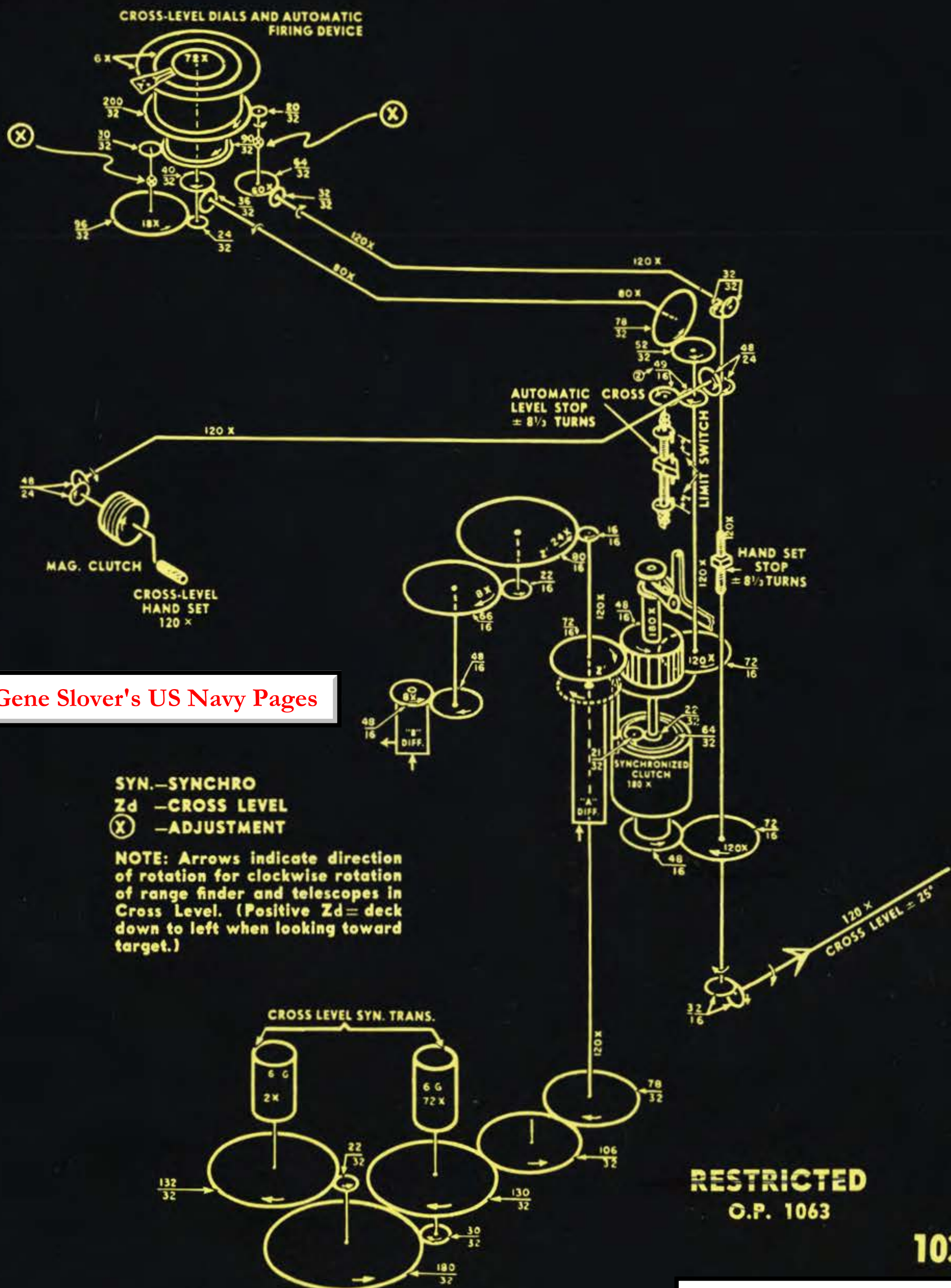
CROSS LEVEL OUTPUT GEAR DIAGRAM



SYN.—SYNCHRO
Zd —CROSS LEVEL
(X) —ADJUSTMENT

NOTE: Arrows indicate direction of rotation for clockwise rotation of range finder and telescopes in Cross Level. (Positive Zd = deck down to left when looking toward target.)

Fig. 87

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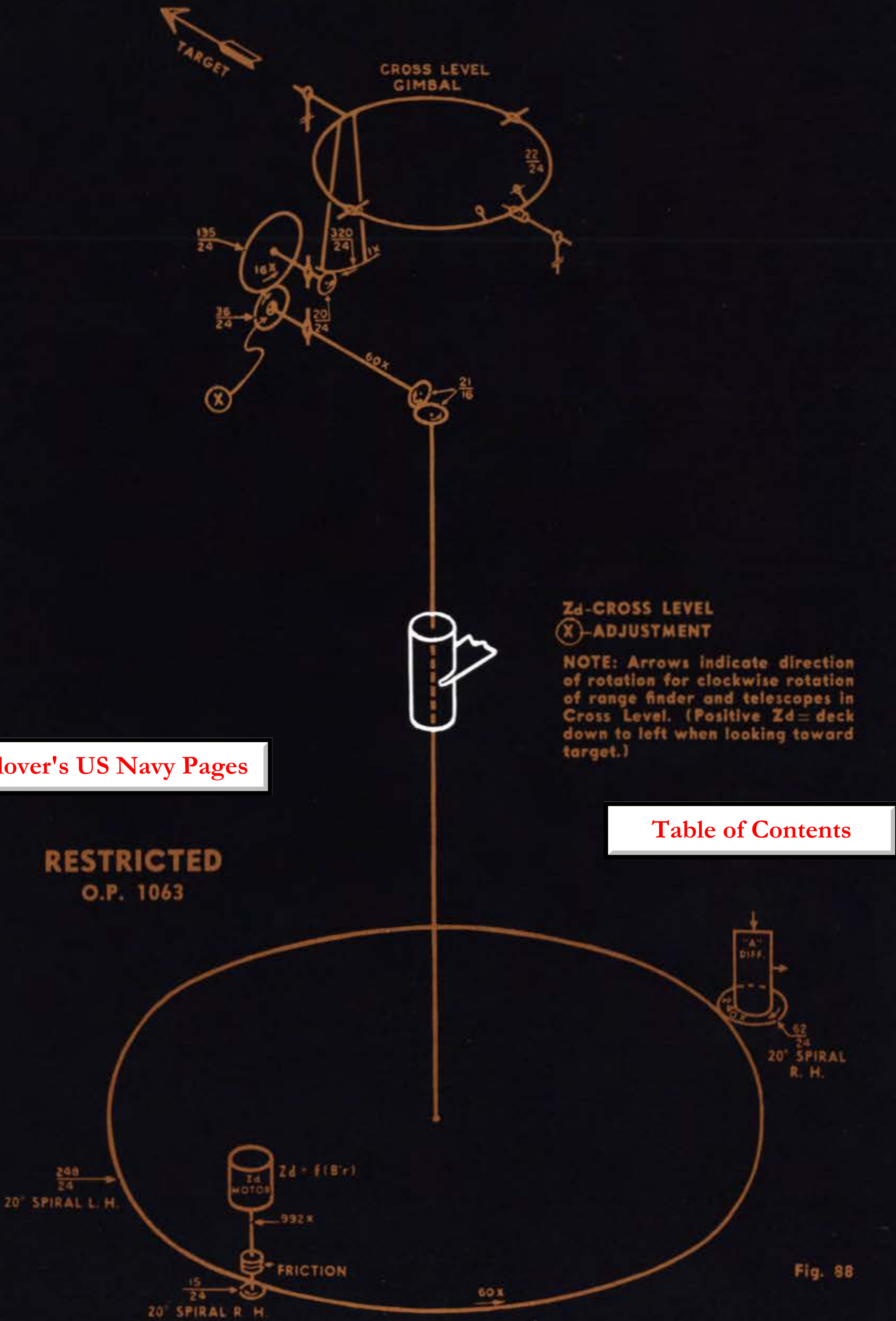
CROSS LEVEL FOLLOW-UP GEAR DIAGRAM



Zd-CROSS LEVEL
(X)-ADJUSTMENT

NOTE: Arrows indicate direction of rotation for clockwise rotation of range finder and telescopes in Cross Level. (Positive Zd = deck down to left when looking toward target.)

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Fig. 88

GIMBAL ROTATION GEARING

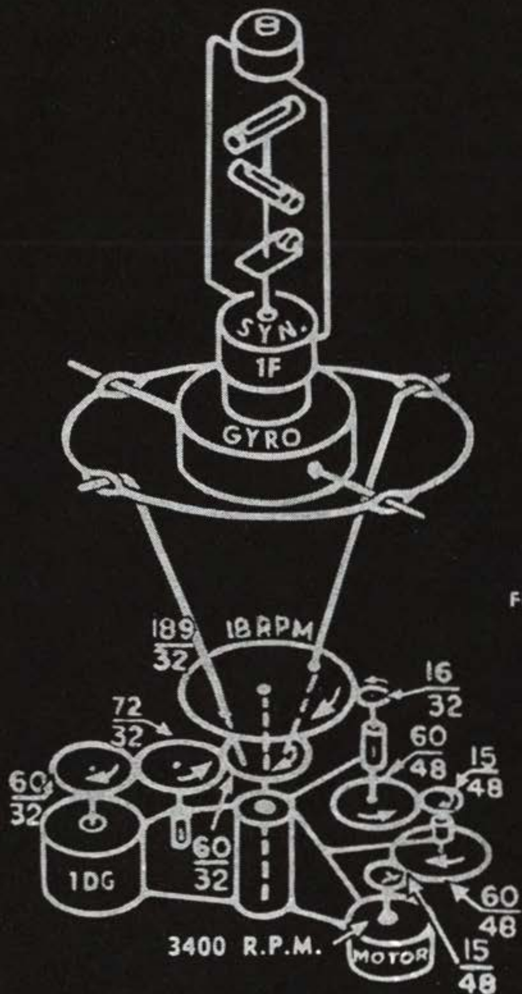

Fig. 89

LEVEL PLUS 1/30 CROSS LEVEL OUTPUT GEAR DIAGRAM

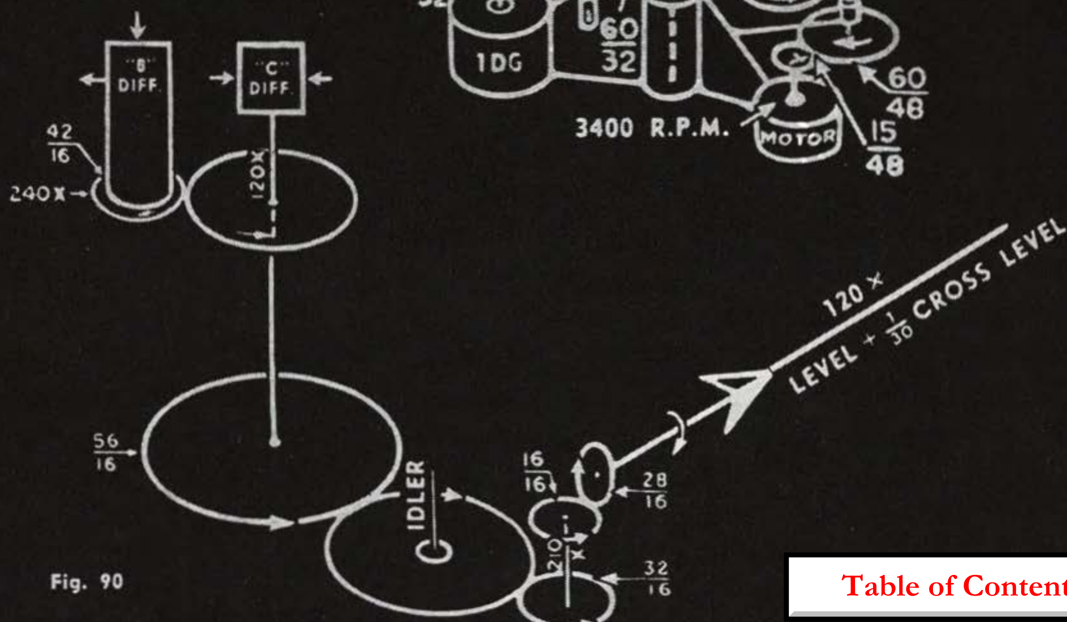

Fig. 90

CONSTRUCTION

OVERALL GEAR DIAGRAM

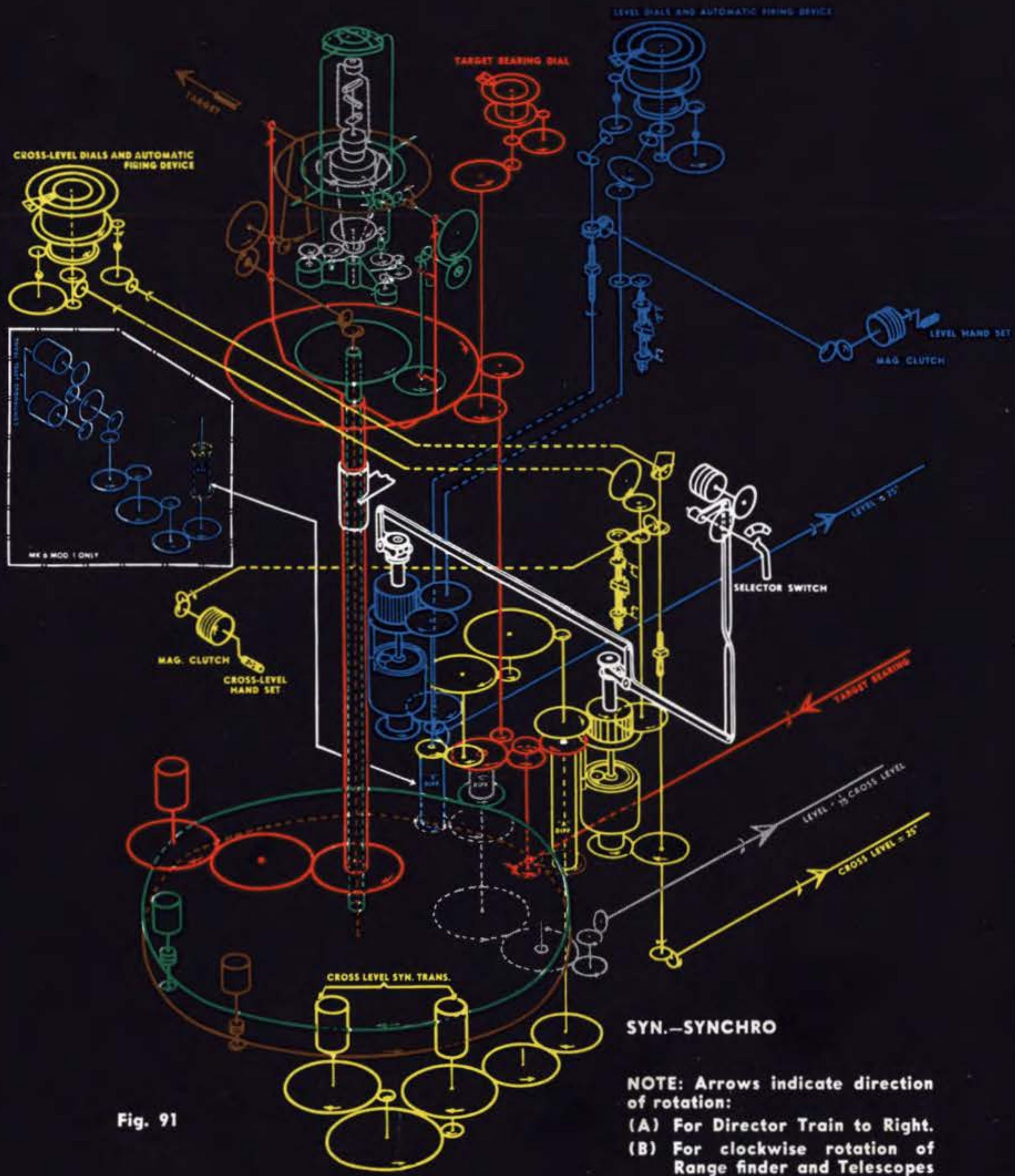

Fig. 91

SYN.—SYNCHRO

NOTE: Arrows indicate direction of rotation:

(A) For Director Train to Right.

(B) For clockwise rotation of Range finder and Telescopes in Cross Level (= Positive Zd = deck down to left when looking toward target).

(C) For positive L = deck down in front when looking toward target.

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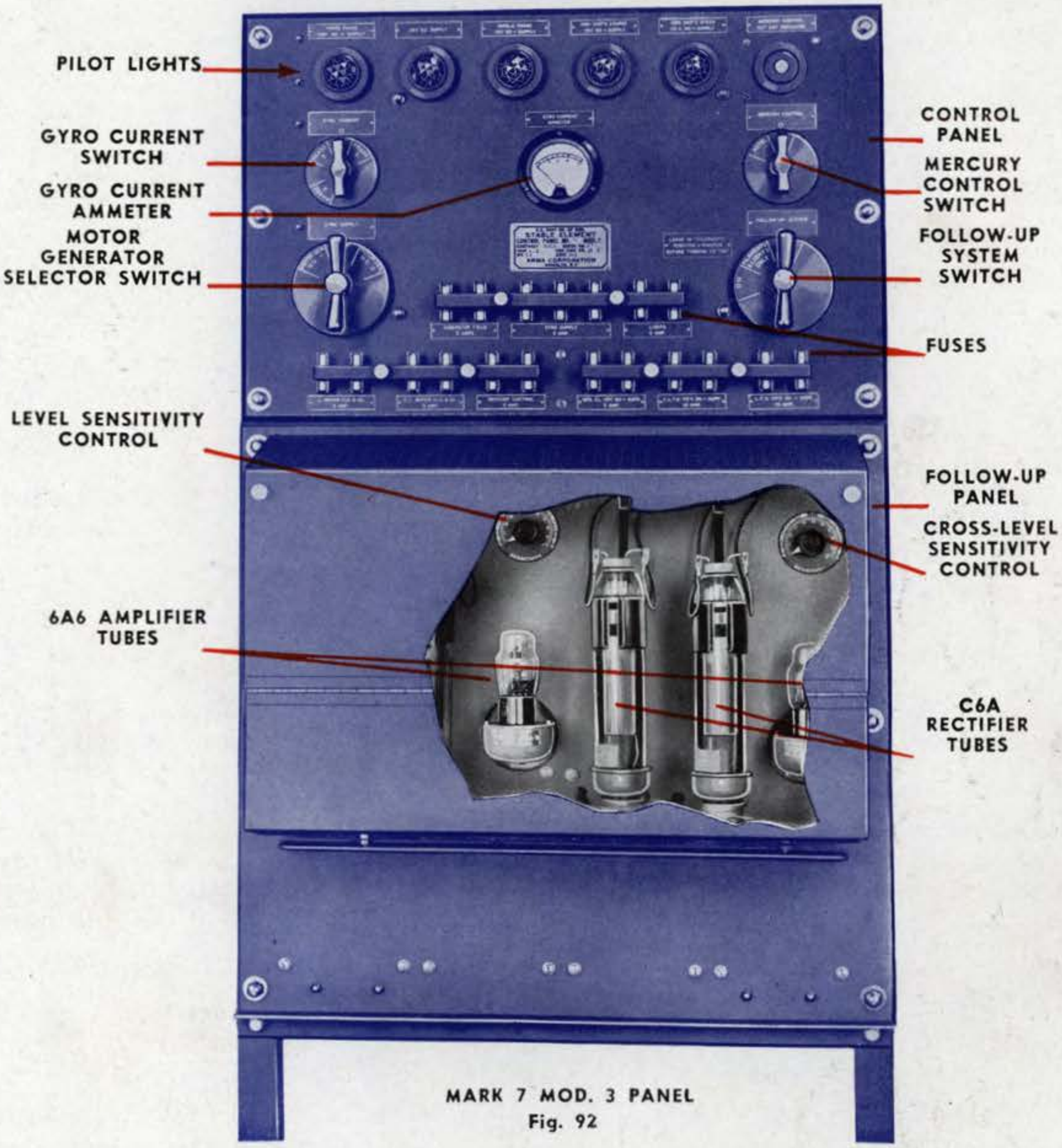
MARK 7, MOD. 3

The construction of this unit is self-evident from the illustration, Fig. 92. A section of the tube cover has been cut away to show the location of the tubes.



MARK 7 MOD. 3 PANEL
Fig. 92

This is a simplex panel, designed to control one Stable Element. The other Mods. of the Mark 7 series are similar in appearance and operation.

NOTE: On certain Mods. there is only one Cutout Valve Control, as shown in the insert, Fig. 94, which unit is operated by change of Own Ship's Course (Co). See section on Information, Chart C for differences in Mods.

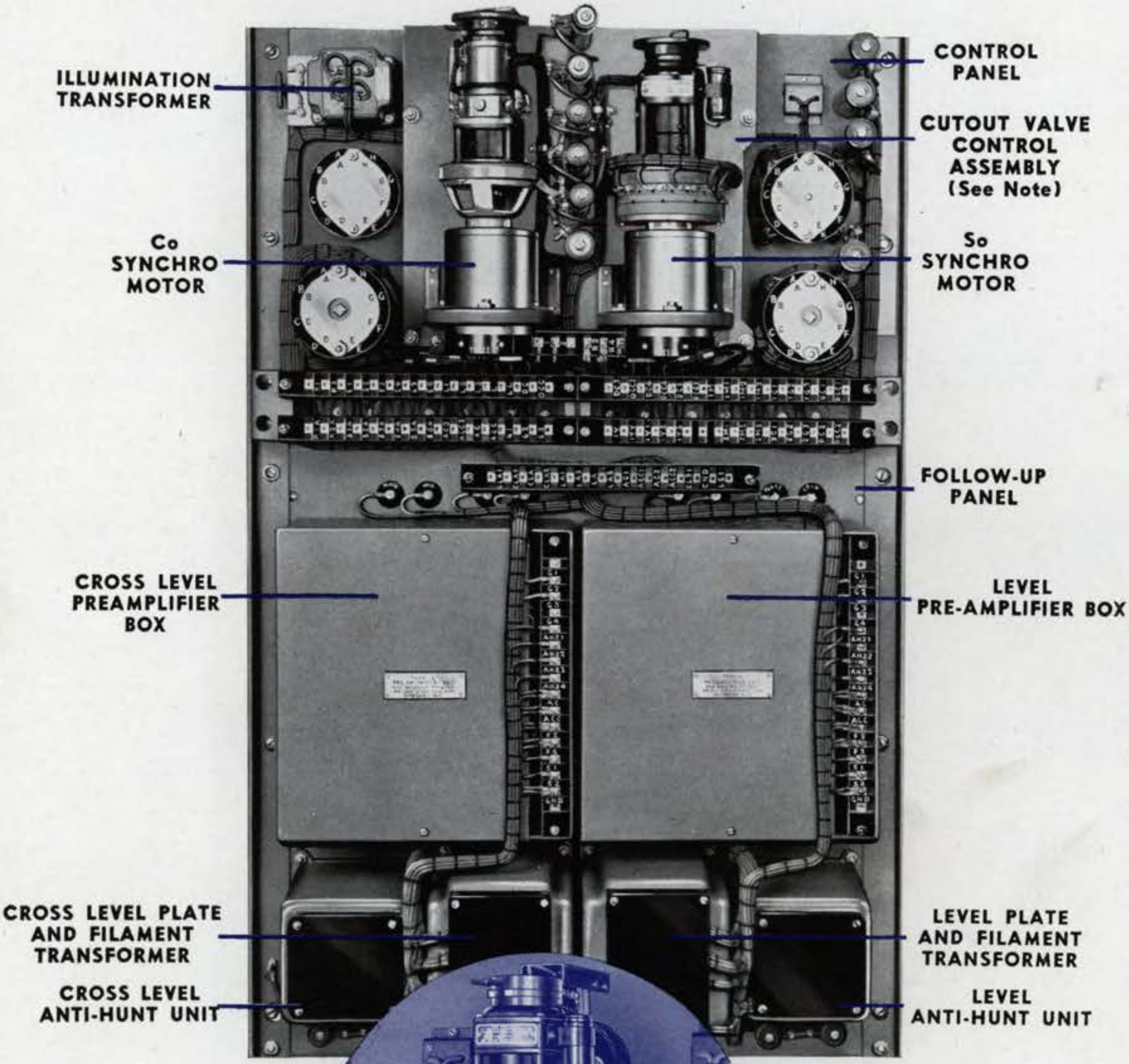


Fig. 93

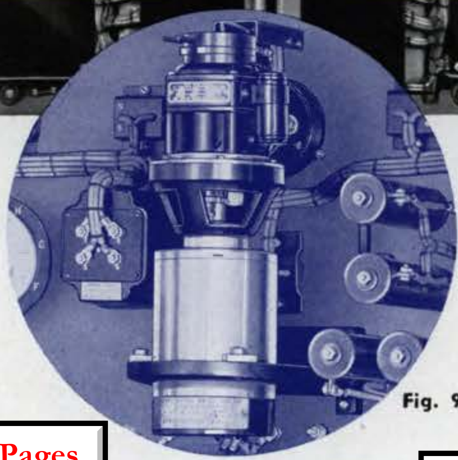


Fig. 94

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MARK 8, MOD. 6

The Mark 8 Panels are duplex panels, designed to operate two Stable Elements Each pair of follow-up systems is identical to that of the Mark 7 panel.

Fig. 95

FRONT VIEW

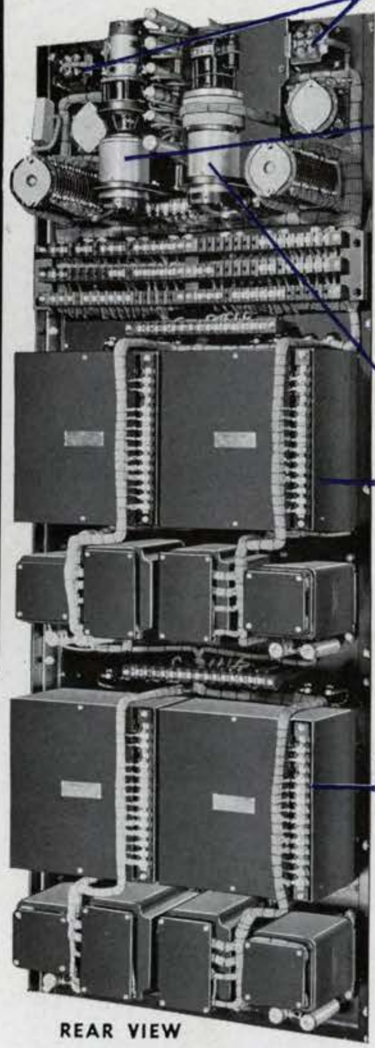

Fig. 96

REAR VIEW

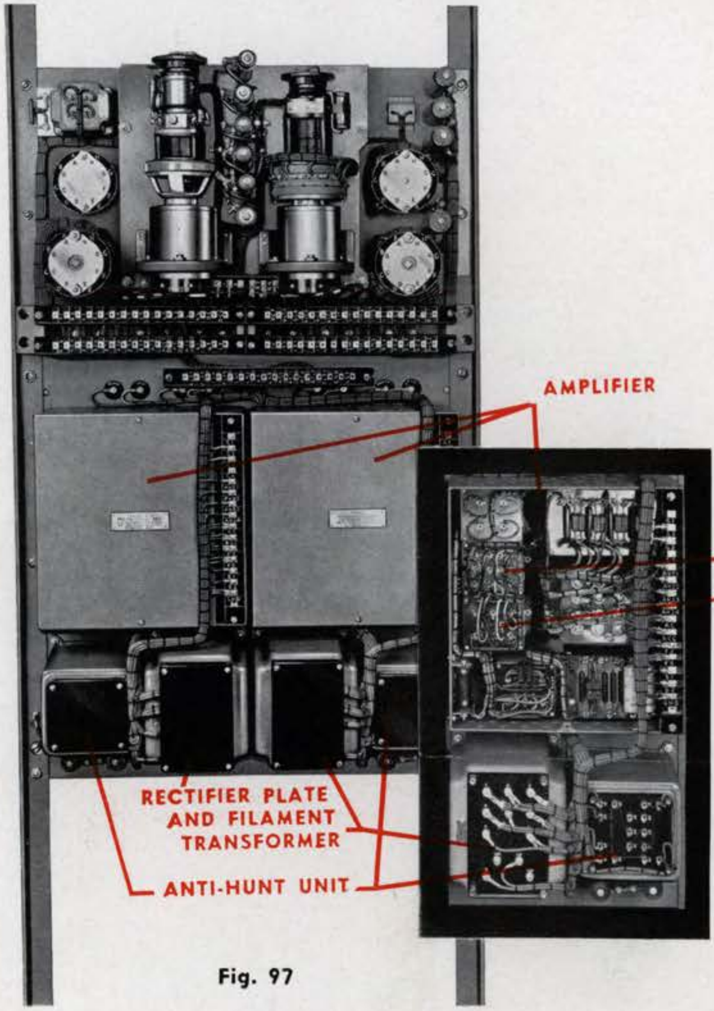

Fig. 97

The location of the follow-up amplifiers is indicated in Fig. 97. Each amplifier is made up of several cased units, sectionalizing the circuit according to function and thus aiding in testing or replacing faulty units. The insert shows these units with the covers removed, revealing the location of the various sub-units described in previous sections.

The tube socket for the 6A6 dual-triode amplifier tube is an integral part of the amplifier chassis, projecting through a hole in the front panel to make the tube accessible from the front.

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POTENTIOMETER CONTROL OF D. C. BIAS

Variable control of the D. C. grid bias in the Follow-up Amplifiers is effected by replacing resistors R-27 and R-28 with 25,000 ohm potentiometers as directed in Ordalt 2520. (See figs. 38 and 97B.) The potentiometers are mounted on a bracket (fig. 97A) installed on top of the D. C. Grid Bias Unit. (See fig. 97.)

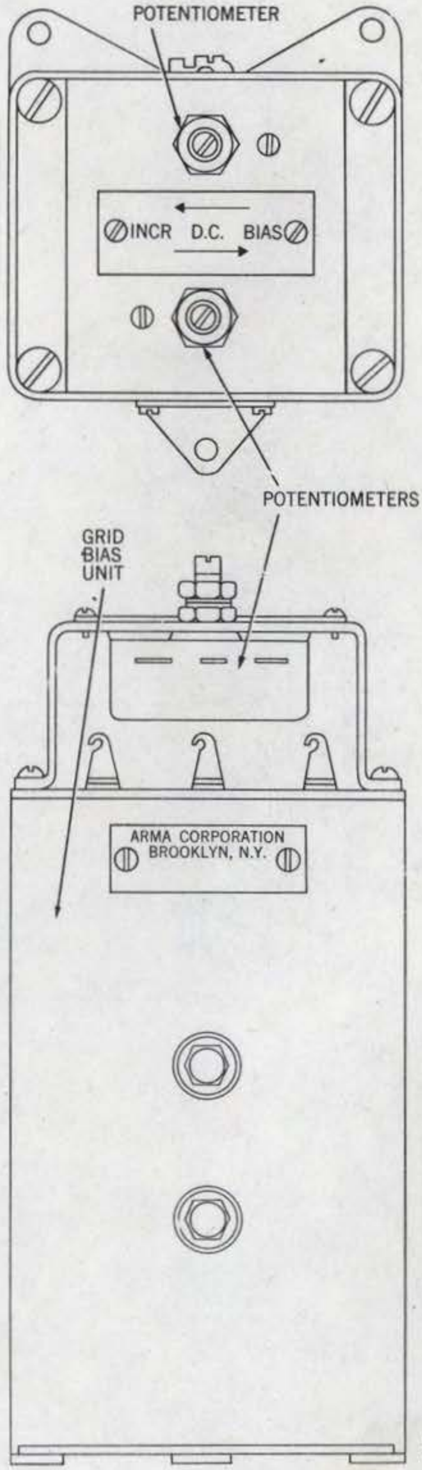


Fig. 97A

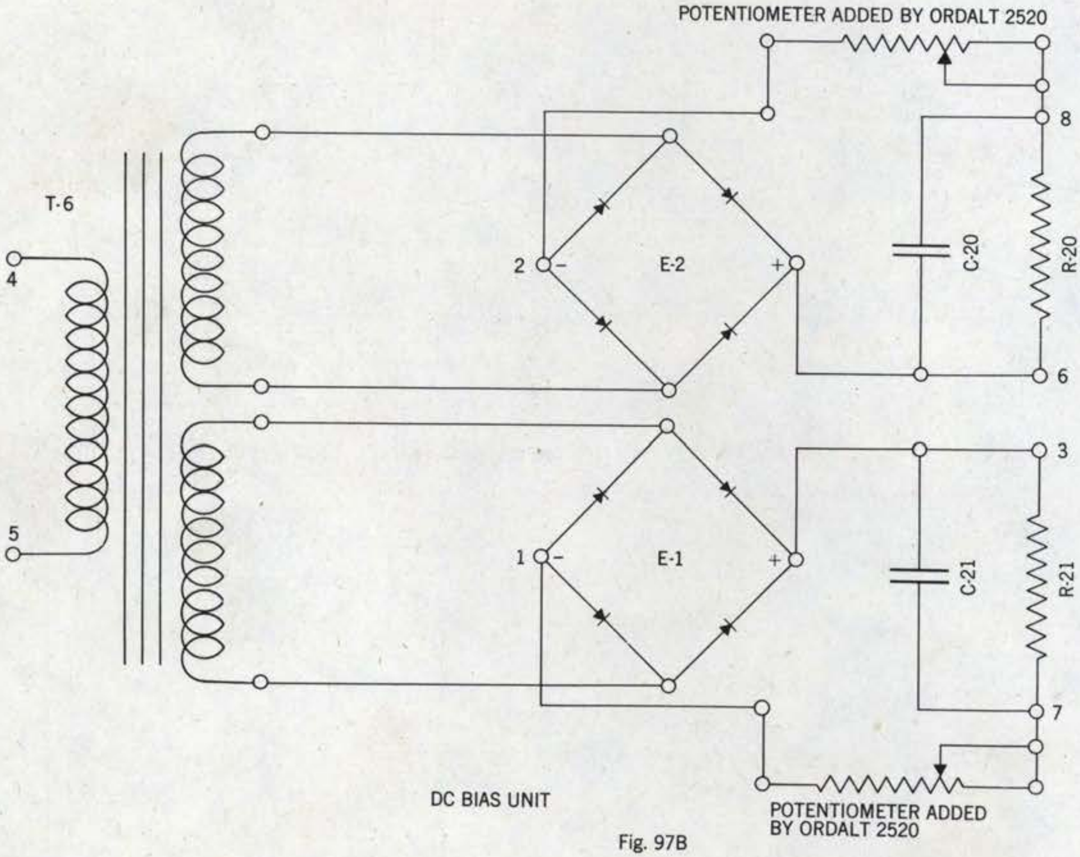
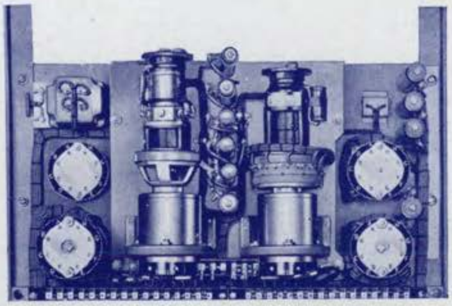

POTENTIOMETER ADDED BY ORDALT 2520
T-6
4
5
2
E-2
C-20
R-20
8
6
1
E-1
C-21
R-21
3
7
DC BIAS UNIT
POTENTIOMETER ADDED BY ORDALT 2520

Fig. 97B

CUTOUT VALVE CONTROL



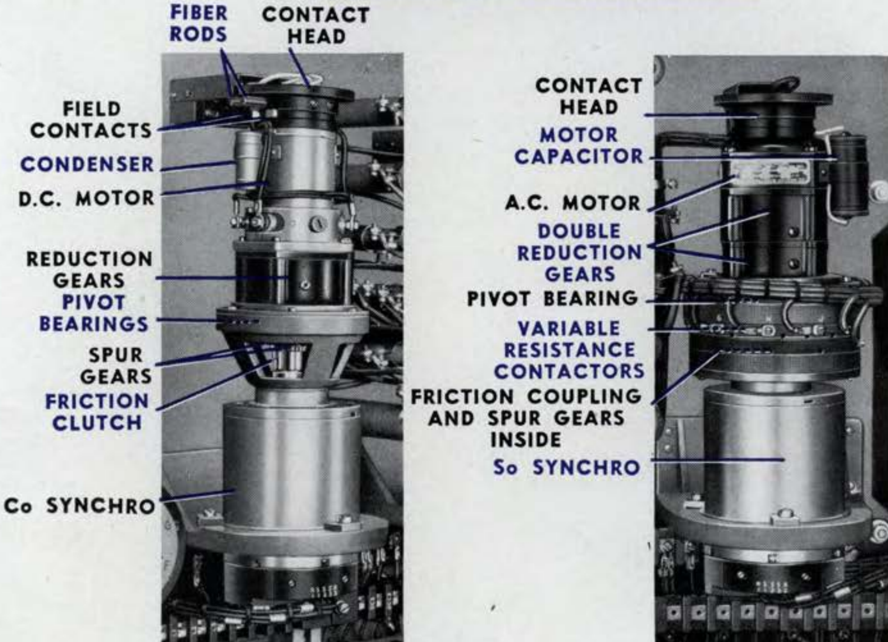


Fig. 98

The construction of this unit is self-evident from the photograph, Fig. 98. The A.C. auxiliary motor has a double set of reduction gears whereas the D.C. auxiliary motor has only one set. All units of the cutout are mounted on a panel approximately 13″x14″, the auxiliary motors being pivoted on the frames of the So and Co 5N Synchro motors as explained in Application, page 45.

All resistors and other associated components are mounted on this panel, which is secured to the back of the Control Panel, as shown, by means of 4 bolts. Electrical connections are made by means of a terminal block mounted near the bottom edge of the unit panel.

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Fig. 99

The various types of motor generators are all of similar construction, differing only in that they are designed to carry different loads (one, four or six gyro wheels).*

Basically the unit consists of a squirrel cage rotor and an inductor rotor mounted on the same shaft, a motor stator excited by 115 volt 3-phase 60 cycle A.C. from the I.C. Switchboard (through the Control Panel), a 115 volt D.C. generator field and a three-phase stator winding which produces a 70 volt 3-phase 146-cycle output for operation of the gyro wheel(s).

*Some ships are equipped with two motor generators, both permanently wired to the Control Panel, but only one of which may be used at any given time. On other ships, with two Plotting Rooms, there are four motor generators, two for each room, each pair being wired and used as stated above. Further data on the motor generator units used with the Stable Element(s) may be found in the specifications on Charts A and E under Information.

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INSTALLATION

While the Stable Element is normally installed by regular installation engineers, occasion may arise when the unit must be re-installed, moved, or replaced. The following pages should enable competent naval personnel to perform this job satisfactorily.

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INSTALLATION

MOUNTING

The first step in installing the Stable Element is to align the case exactly with the forward and aft line of the ship. Reference should be made to the "FWD" and "AFT" nameplates on the base of the instrument, and the adjacent engraved lines should correspond to the aforementioned line of the ship.

LEVELING

Since the deck of the ship will seldom be, or remain, in a perfectly horizontal position, a gunner's quadrant must be used to assure correct leveling of the instrument with respect to the deck. (The left side access cover should be removed, and the gunner's quadrant placed along the upper edge of one of the Cross Level Gimbal mounting blocks as shown in Fig. 100. The terminal strip must be removed temporarily for this operation. Readings should be taken at several positions of the training gear to assure alignment in all directions.) By shimming if necessary, under the mounting lugs of the Stable Element, the horizontal planes of the instrument may be brought into exact parallelism with the reference plane as indicated by the gunner's quadrant. After the instrument is adjusted it may be secured to the deck, whereupon it should be checked again with the gunner's quadrant. After the proper corrections have been made (if any) the quadrant should be removed and the terminal strip replaced.

PRECAUTIONS

The following precautions should be observed when installing the unit:

1. Be sure the lock on the Sensitive Element is secured in place to prevent damage when the instrument is being moved about.

2. Keep all covers on the instrument as much of the time as possible to keep dirt and other foreign matter from entering the mechanism.

3. Make sure that the three bolts holding the Stable Element to the deck are secured solidly.

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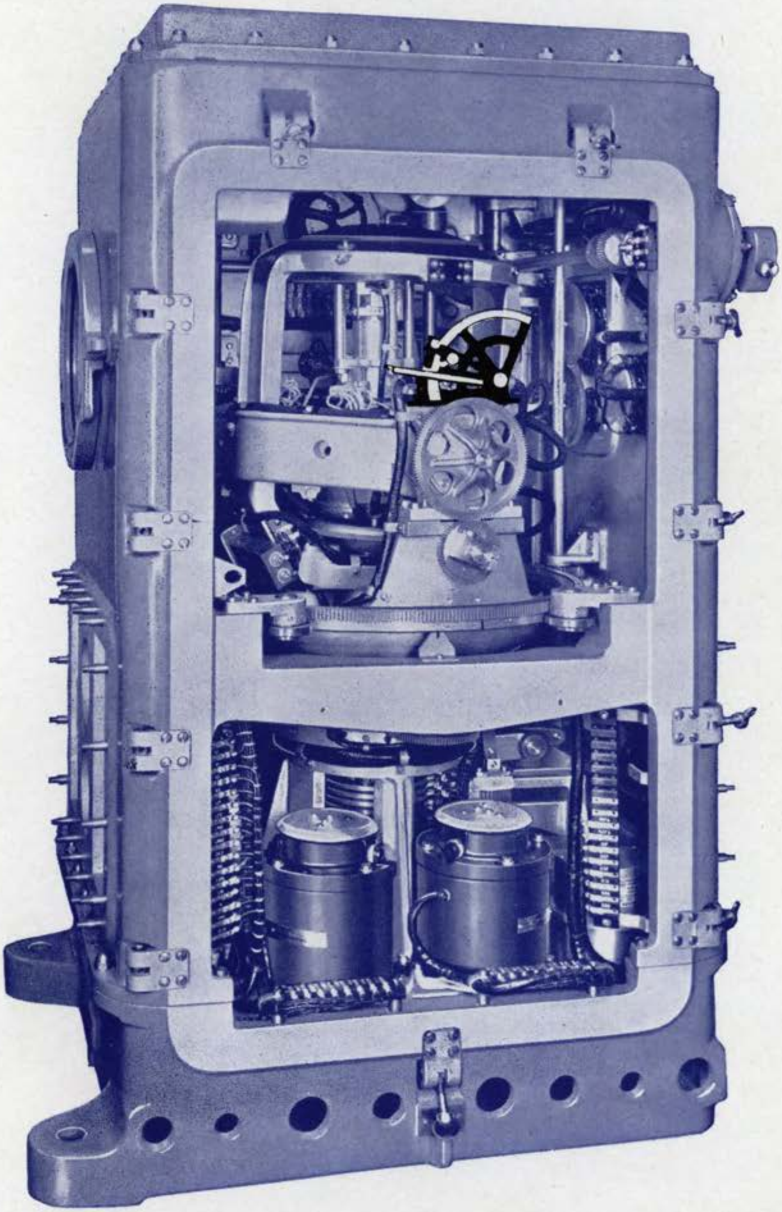

Fig. 100

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MERCURY SYSTEM

If there is no mercury in the mercury control system, which will be the case at the initial installation of the instrument, add the required amount. The amount required is exactly 11 ounces, and in refilling the tanks, reference should be made to Adjustment No. 3 on page 172 under Adjustments. If re-installing the instrument, or if it is suspected that mercury has been lost at any time, remove either drain plug shown in Fig. 101 and drain the remaining mercury, being careful not to drop any of it into the lower part of the instrument. Then replace the drain plug, check to see that it as well as the drain plug on the other tank (in some cases there is on y the one) are tight, and refill the tanks with the required amount of clean mercury.

Fig. 101

ELECTRICAL CONNECTIONS

The Stable Element is now ready to be electrically connected to the Control and Follow-up Panels and the Fire Control and I.C. Switchboards. Secure all cables by means of the clips and terminals provided. Check the line voltages and where different taps are provided at the Control Panel, connect the leads to the marked terminals which correspond to the indicated line voltage.

After all connections have been made and *checked*, the gyroscope should be started up according to the instructions outlined on page 120. Any troubles encountered here should be traced and remedied by referring to the section on Operation and the section on Casualties, pages 119 and 185 respectively.

ALIGNING

Once the gyroscope has been started, the initial positioning of the North-South level on the latitude correction motor must be made. First position the adjustable latitude weight mounted on the platform of this motor until it indicates the latitude of own ship at the time. Then disconnect temporarily the gimbal rotation motor from its terminal block on the Sensitive Element, and proceed according to the instructions outlined under Adjustment No. 6, page 175.

After these adjustments have been performed, and the gimbal rotation motor has been re-connected, the Sensitive Element should be allowed to settle completely with

Fig. 102

the Mercury Control Switch in the "ON" position and the follow-up systems energized. The Target Bearing (Director Train) input shaft should be turned by hand until the Target Bearing dials on the instrument read 0 degrees. When the Sensitive Element is completely settled, reference should be made to the Level and Cross Level dials of the instrument. These dials should give readings which agree with the readings obtained on the gunner's quadrant when measuring the angle between the reference plane and the true horizontal.

If such is not the case, the instrument should be rechecked with the gunner's quadrant, as outlined in the preceding paragraphs.* If the gunner's quadrant still gives its former results then the Stable Element must be examined.

*In no event should the dials be adjusted at this time to obtain correct readings, as they have been set at the place of manufacture if this is a new installation, and other checks should be made first if this is a re-in

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The Gimbal bearings should be examined for excessive tightness or lack of freedom, and if found at fault, should be corrected, as this condition could cause the Sensitive Element to fail to settle in the vertical. There should be from .003″ to .004″ play per bearing when cold.

The Restrictor Set Screw (Fig. 101) should be removed and the instrument then allowed to settle. The removal of this screw will allow the Sensitive Element to settle properly despite certain conditions which would otherwise tend to prevent normal settling in the vertical. The Level and Cross Level dials should now be referred to, and if there is now no discrepancy between the readings on the dials and the gunner s quadrant, the former discrepancy was due to the failure of the Sensitive Element to settle properly, in which case reference should be made to the section on Casualties, pages 187 and 188.

DIAL SETTING—If, after the above checks, the same discrepancy still exists, the trouble lies in the setting of the dials, in which case they must be reset. This procedure is outlined in Adjustment No. 11, page 179. Once this adjustment has been made, it will be necessary to re-adjust the case of the Stable Element so that the plane of the Cross Level Gimbal mountings is parallel to the reference plane. This procedure has been outlined previously on page 114 of this section.

MECHANICAL COUPLINGS

The instrument should next be connected to the adjacent Computer. Turn the Level and Cross Level follow-up switches on the instrument to "Manual," and the Selector Switch to "Continuous Fire" if not already in this position. Turn the hand input cranks until their respective dials agree with the respective input values of the Computer. Turn the Target Bearing input shaft by hand until the Target Bearing dial agrees with the Director Train output value of the Computer.

The input and output shafts of the Stable Element may now be coupled to the respective shafts of the Computer.

SYNCHRO GENERATOR ADJUSTMENT

The electrical transmitting system should now be checked for electrical zero. The Synchro receivers which are excited by the Synchro generators in the Stable Element should be checked to ascertain whether or not they agree with the transmitted values from the Stable Element, referring to the dials of the instrument. The Synchro generators are set so that electrical zero is obtained when the corresponding dials read 2000 minutes. If the transmitted values are not the same as the dial readings on the Stable Element, the Synchro generators must be turned in their mounting brackets as outlined in Adjustment No. 12 on page 183.

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INSTRUCTIONS FOR OPERATING

Starting and securing the instrument, methods of follow-up, methods of firing, and general information pertaining to its operation.

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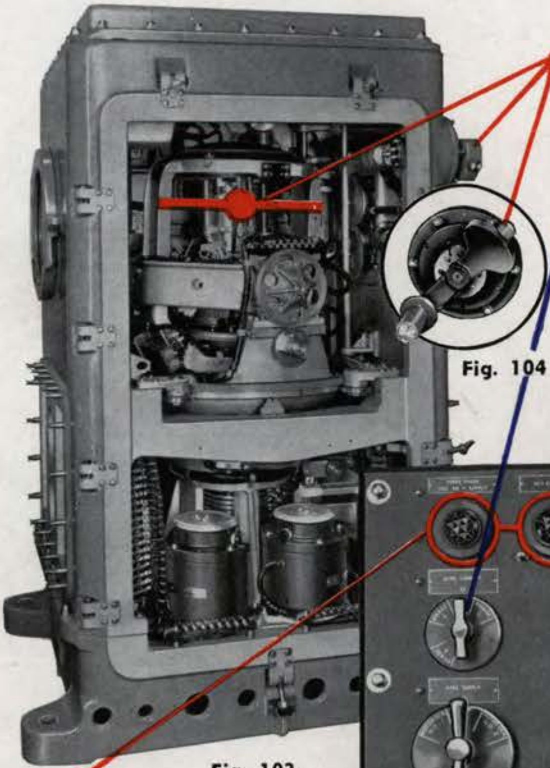
STARTING

The Stable Element may be started when the ship is at anchor or under way, and the following procedure should be followed in either case:



1 Remove the locking clamp from the Sensitive Element and loosen the locking screws on the Level and Cross Level hand input cranks.

Fig. 104

2. On the Control Panel, turn the mercury control switch to "ON." The remaining switches, with the exception of the gyro current switch, should be in their "OFF" positions.

Fig. 103

4. Check that all of the pilot lights on the Control Panel are lighted.

Fig. 105

5. On the Stable Element turn the Selector Switch to "Continuous Fire" and the Level and Cross Level follow-up switches to "Automatic" if they are not already in those positions.

3. Check that no fuses are blown on the Control Panel. (If any red fuse is blown, a red flag appears in the window near one end of one type, while in another type a spring-loaded stud projects from one end of the fuse body.)

Fig. 107

Fig. 106

Fig. 109

6 Set the latitude weight on the Sensitive Element in its proper position if it is not already so set.

7 On the Simplex Control Panels (except Mark 7 Mod. 4) turn the gyro supply switch to the motor generator it is desired to use.

8 On all Control Panels turn the follow-up system switch or switches to the position which lights the filaments of the amplifier and rectifier tubes. (On the Mark 7 Mod. 4 and all Mark 8 (duplex) panels this operation also completes the gyro supply circuit.)

9 Check that the latitude motor is energized and that the latitude platform heads north.

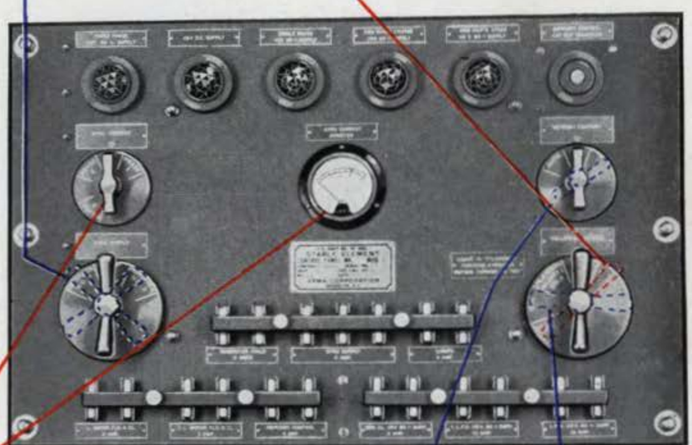


Fig. 108

10 By means of the gyro current switch on the Control Panel, check from time to time all three phases of the gyro current until the gyro wheel has reached normal operating speed (approximately 10 minutes). While coming up to speed, the readings will be off scale; therefore, do not leave the switch in any of the three checking positions any longer than is necessary to obtain a quick reading, as otherwise the meter may be injured due to continuous overloading. The normal operating current for each phase when the gyro is up to speed is approximately 1.1 amperes.

11 After the gyro has settled, turn the follow-up system switch or switches to "ON."

12 Turn the Mercury Control Switch to "Automatic."

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METHODS OF FOLLOW-UP

Two methods of follow-up are provided for both Level and Cross Level—Automatic and Manual. Automatic follow-up is normally used for both systems. When the follow-up switches are in "Automatic" position, follow-up is automatic, and the position of the

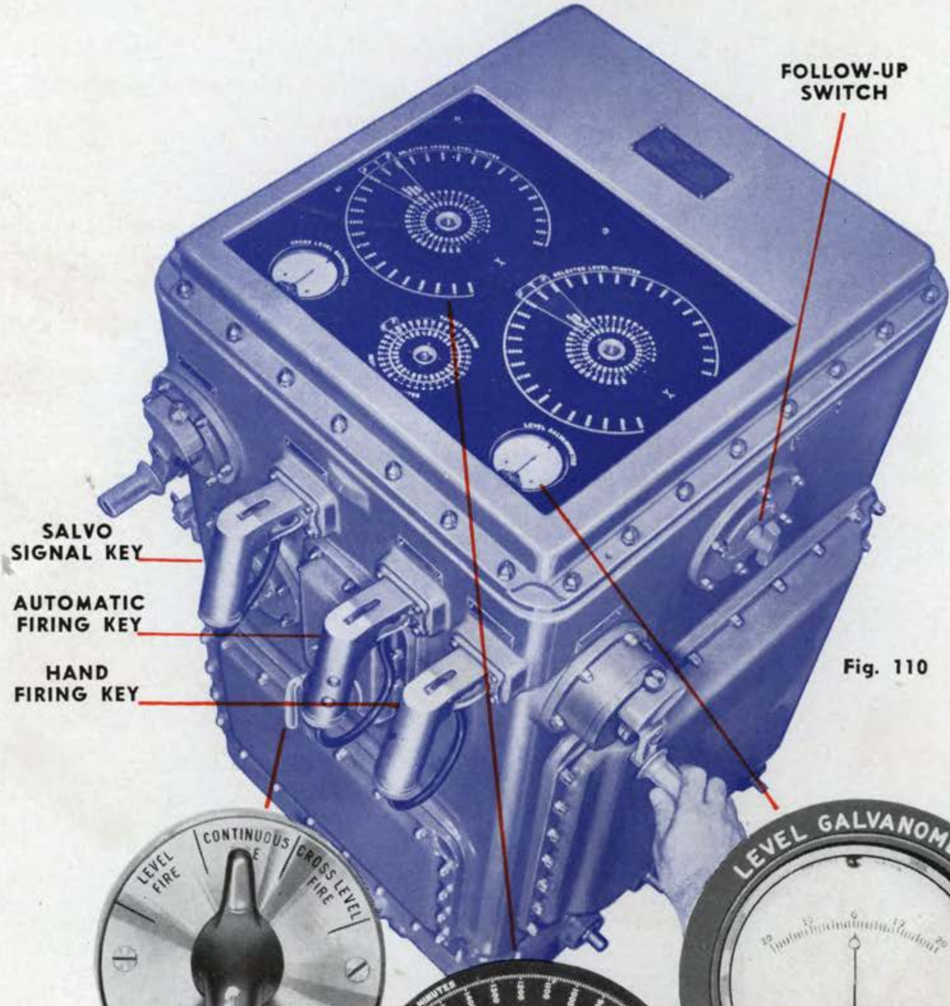

Fig. 110

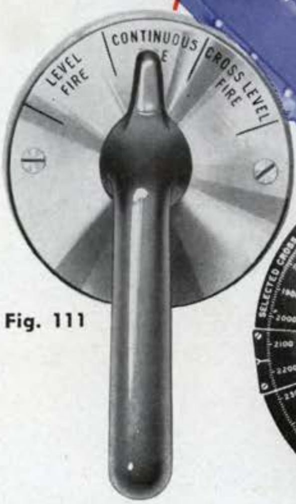

Fig. 111

Fig. 112

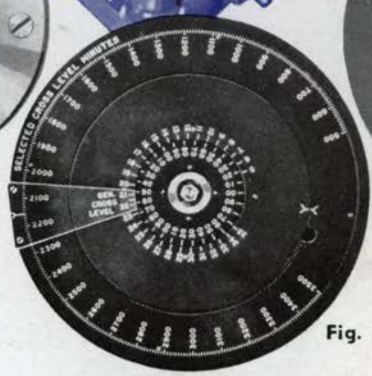

Fig. 113

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Selector Switch determines the method of firing the guns, as explained in a subsequent paragraph. When, for any reason, it is necessary or desirable to use Manual follow-up, the Selector Switch should be placed in the "Continuous Fire" position. The follow-up switch for whichever system (Level or Cross Level) is to be controlled manually is turned to the "Manual" position, which de-energizes and engages the magnetic clutch between that hand input crank and its associated gearing. This also breaks the armature and field circuits of that particular follow-up motor and transfers the signals generated by the follow-up coil from the amplifier unit to the galvanometer. (See also the Functional Check Chart on page 99.)

Once the follow-up switch has been turned to the "Manual" position, the operator should turn the hand input crank in such a manner that the respective galvanometer needle is maintained as nearly as possible in its zero position. This zeroing of the galvanometer needle indicates that the respective gimbal (Level or Cross Level) is being maintained in the correct position with its follow-up coil centralized over the follow-up magnet.

If the galvanometers do not function, owing to trouble in the follow-up magnet, follow-up coils or in the galvanometers themselves, the manual follow-up system can not be used because of the lack of a reference point. In this case the Stable Element can no longer serve the fire control system until it is again operating properly.

METHODS OF FIRING

The three general methods of firing are "Continuous," "Automatic" and "Hand."

CONTINUOUS FIRE— When continuous fire is desired, the Selector Switch is placed in the "Continuous Fire" position. In this position the firing contacts are closed at all times due to continuous stabilization in both Level and Cross Level, and the guns may be fired at any instant by actuating the Automatic Firing Key on the front of the Stable Element, provided, of course, that the firing circuit is otherwise completed through the Fire Control Switchboard.

When turning the Selector Switch to the "Continuous Fire" position from, say, "Level Fire," this may only be accomplished when the generated and selected dials of the Level system are set on the same reading. They may be made to agree with each other by turning the Level hand input crank until the arrow head on the selected dial has aligned itself with the arrow head on its associated outer generated dial. (See Fig. 113). If an attempt is made to turn the Selector Switch when the arrows are separated and moving with respect to each other, the switch will not rotate until the notches in the disengaged synchronized clutch have been aligned with the pin. By maintaining pressure on the switch, engagement will take place as the selected dial and its associated generated dials reach agreement.

The same holds for the Cross Level system when changing to "Continuous Fire" from "Cross Level Fire." Once the switch is in the "Continuous Fire" position, the Level generated and selected dials will agree with each other, the Cross Level generated and selected dials will agree with each other, and both selected dials will continuously follow their respective generated dials as follow-up takes place.

AUTOMATIC FIRING—For "Automatic" selected firing, the Selector Switch is placed in "Level Fire" or "Cross Level Fire," as desired. For whichever position is selected, the corresponding synchronized clutch is disengaged and the corresponding manual input magnetic clutch is de-energized, engaging the hand crank with the gearing which turns the selected dial and the output shaft of that system. (This de-energizing of the magnetic clutch allows it to become engaged due to the pressure of a coil spring which brings the friction surfaces of two discs together.) As the synchronized clutch is disengaged, as stated above, the turning of the hand input crank has no effect upon the automatic follow-up of the respective gimbal on the Sensitive Element, but does, however, turn the respective output shafting to a position corresponding to the value indicated on the selected dial.

As the high and low speed generated dials turn due to automatic follow-up, they move with respect to the selected dial, and the firing contacts will close at the predetermined setting which is adjusted and read by means of the selected dial.

The automatic firing key should be held shut, and since it is in series with the firing contacts of the Stable Element, the circuit will be completed upon the closing of the firing contacts at the pre-selected position of the dials.

HAND FIRING—The hand firing key may be depressed at any time by the operator and will complete the firing circuit, regardless of whether the automatic firing key is depressed or not, provided the hand firing switch on the Fire Control Switchboard is closed.

The salvo signal key is used for the transmission of a salvo signal, and is operated by depressing its trigger when this signal is to be transmitted.

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FIRING CONTACTS—These contacts are located under the dials as shown in Fig. 114. Their spacing and timing are explained under Adjustments on page 179.

LEVEL CROSS-LEVEL SENSITIVITY CONTROL

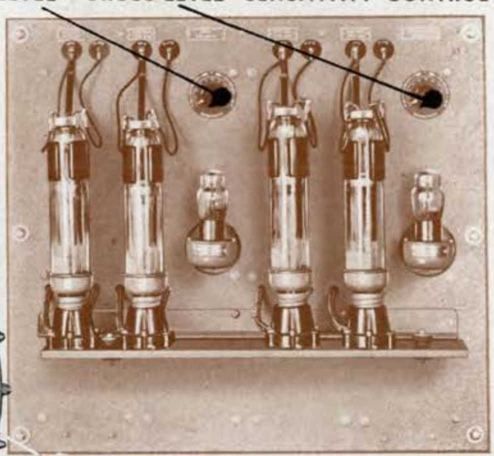
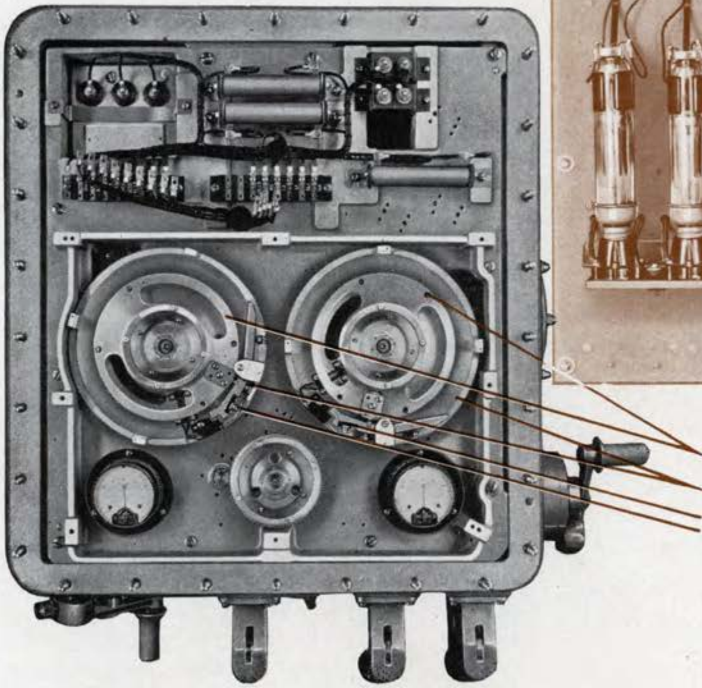


Fig. 115

Fig. 114



GENERATED DIAL MOUNTING
SELECTED DIAL MOUNTING
FIRING CONTACTS

SENSITIVITY ADJUSTMENT

As explained on page 66, the Sensitivity adjustment for each follow-up system is set so that the maximum deviation from normal is approximately 3 minutes of arc. It is possible that the dead space of the follow-up systems will have to be increased on board ship for critical speeds or as a result of certain causes that tend to vibrate the deck. To accomplish this, the "Sensitivity Control" of both follow-ups should be reduced first to a point well below roughness. Then each control in turn should be increased until roughness of the follow-up begins and then backed off very slowly until the roughness just disappears. These adjustments are to be made while under way and while simulating actual firing conditions. As the "Sensitivity Control" may be quite critical at certain settings, the above procedure is necessary to obtain the best possible results.

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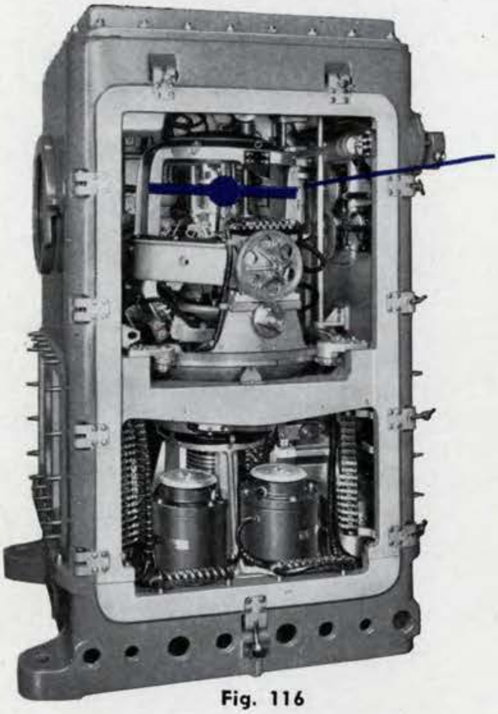
Fig. 116

SECURING

The instrument is secured by reversing the procedure outlined under "Starting." De-energize all circuits at the Control Panel first, after which the lock should be replaced on the Sensitive Element. Also tighten the locking screw on each of the two hand input cranks.

Fig. 117

GENERAL PRECAUTIONS

The Stable Element, while quite rugged, is a precision instrument and certain precautions are necessary to obtain proper operation. Careful observance of the following will aid in preventing damage to the equipment:

1. In securing, do not break A.C. or D.C. circuits at the I.C. Switchboard until all switches on the Stable Element and Control Panel have been secured.

2. All fixed and adjustable weights on the Sensitive Element have been properly set at the installation of the equipment. With the exception of the adjustable latitude weight on the latitude correction motor, these weights should under no circumstances be disturbed.

3. See that the flexible leads on the Sensitive Element do not foul when the gimbal rotation motor is operating.

4. Lash the Sensitive Element in extremely rough weather.

5. Follow a *regular* routine of inspection, lubrication and maintenance, as outlined in the section on Maintenance, page 127.

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MAINTENANCE

The following section deals with general maintenance and lubrication of the instrument.

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1. SYNCHRO BEARINGS

While it is desirable to lubricate Synchro bearings every 24 months, it is not absolutely necessary. However, if a Synchro is removed for any reason, the opportunity should be taken to lubricate its bearings if they have not been lubricated in the previous 18 months. Use sufficient oil in each bearing to produce a complete oil film on races. Do not use an excess of oil. Shell Aircraft Hydraulic Gear Oil No. V-226 is recommended.

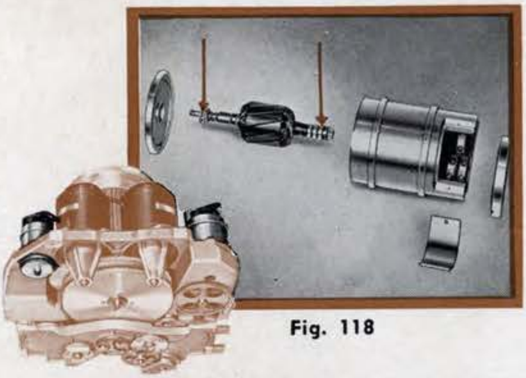

Fig. 118

2. GIMBAL ROTATION MOTOR BEARINGS (G. E. TYPE K S P)

Both bearings of this motor should be lubricated with Navy Lubricant No. 2075, and two "Gits Oilers," one for each bearing, will be found leading to the bearings in question. The oil should be used sparingly, several drops sufficing for every three months of operation.

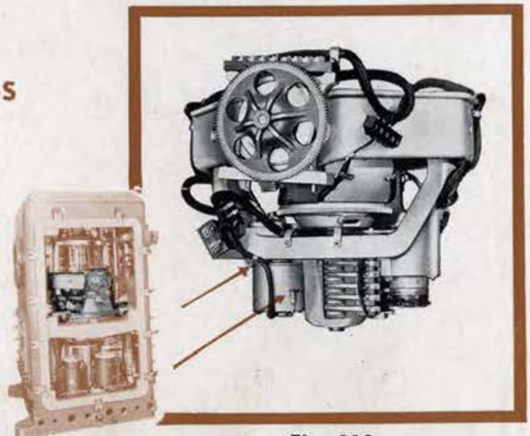

Fig. 119

3. LEVEL AND CROSS LEVEL FOLLOW-UP MOTOR BEARINGS

The bearings in these two motors should be packed with a grade B grease (Navy Spec. 14L3b). When the instrument leaves the factory, these bearings are packed with Gulf Precision Grease No. 2 and this grease is recommended for subsequent lubrication if available.

Fig. 120

4. MOTOR GENERATOR BEARINGS

Lubricate these bearings in exactly the same way as the Level and Cross Level follow-up motor bearings are lubricated, as mentioned in the preceding paragraph.

Fig. 121

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5. GYRO WHEEL BEARINGS

Oil may be introduced through knurled screw protected holes on the top and bottom of the gyro case. After every 60 hours of operation, Gyro Oil No. WS602, made by the Standard Oil Co. of N. J., should be added to each bearing. When the instrument leaves the factory these bearings are lubricated with this oil which is recommended for subsequent lubrication if available. As an alternative use Navy Lubricant No. 3065, only however, in the event that the WS602 cannot be obtained. For proper oiling procedure see Lubrication Log on page 131.

Fig. 122

Fig. 123

6. GIMBAL BEARINGS

The gimbal bearings should be packed with Gulf Precision Grease No. 1 only during the period of routine overhaul, or in case the instrumentisd is assembled for any other reason. When the instrument leaves the factory these bearings are lubricated with this lubricant which is recommended for subsequent lubrication if available. As an alternative use a grade B grease (Navy Specification 14L3b), only however, in the event that the Precision No. 1 cannot be obtained.

Fig. 124

Fig. 125

7. MISCELLANEOUS BEARINGS

All bearings, other than those mentioned in the preceding paragraphs, should be packed with a grade B grease (Navy Specification 14L3b) during the period of routine overhaul

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or in case the instrument is disassembled for any other reason. When the instrument leaves the factory these bearings are lubricated with Gulf Precision Grease No. 1 and this lubricant is recommended for subsequent lubrication if available.

GEARS AND STOP SCREWS

All of the gears and stop screws with traveling nuts should be lubricated with Gulf Precision Grease No. 1 every 18 months.

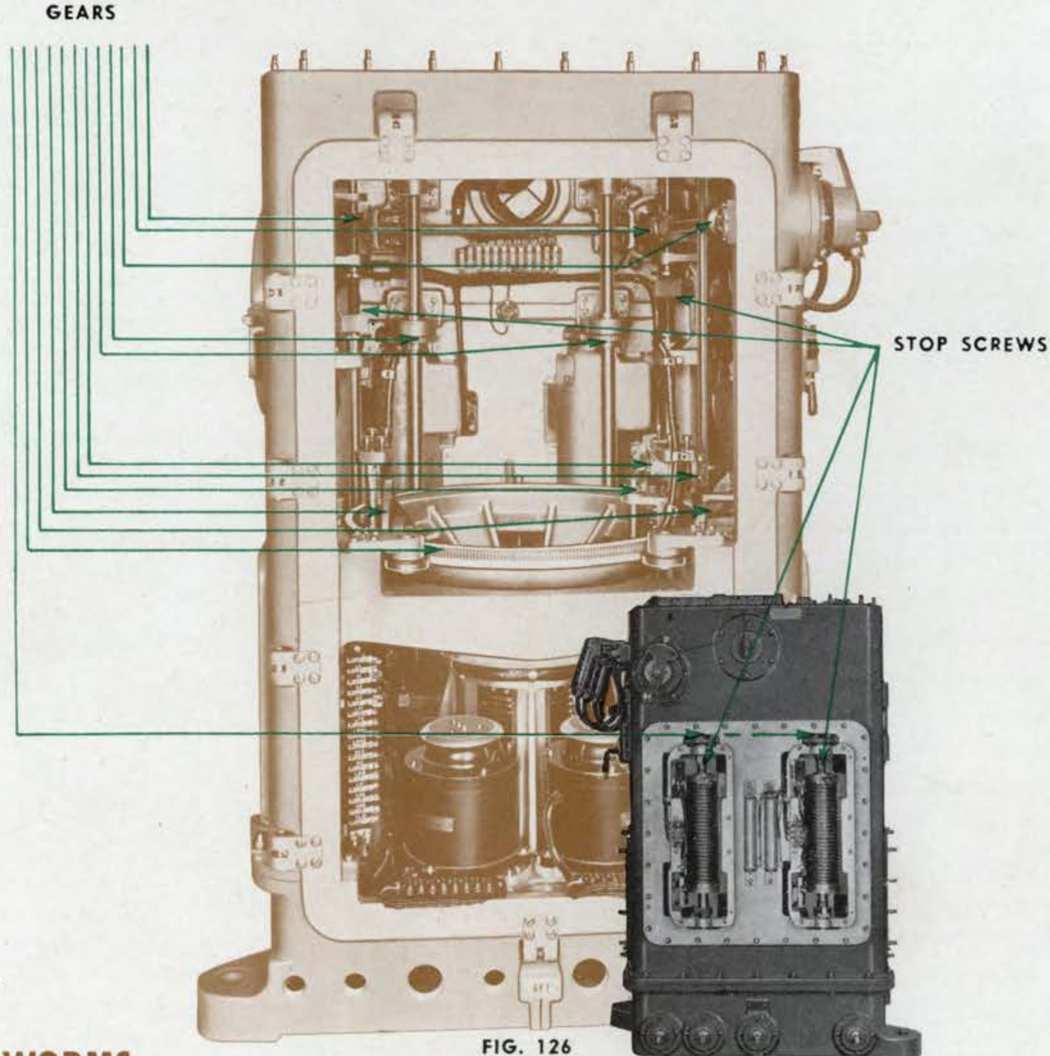

FIG. 126

Fig. 127

WORMS

On more recent instruments the worm and worm wheel on the director train input is lubricated by Navy Lubricant No. 2075 introduced through a "Gits" oiler on the adapter. Add several drops every six months. On older Mods. this worm is to be lubricated with Gulf Precison Grease No. 1 every 18 months.

POINT	LUBRICATE	LUBRICANT		AMOUNT	NOTES
		RECOMMENDED	SUBSTITUTE		
Synchro Bearings	Every 24 months	Shell Aircraft Hydraulic Gear Oil No. V-226		Sufficient to cover races	★
Gimbal Rotation Motor Bearings	Every 3 months	Navy No. 2075		3 to 5 drops in each "Gits" oiler	
Level & Cross Level F.U. Motor Bearings	Every 24 months	Gulf Precision Grease No. 2	Grade B Grease Navy Spec. 14L3b	Pack sparingly	
Motor Generator Bearings	Every 24 months	Gulf Precision Grease No. 2	Grade B Grease Navy Spec. 14L3b	Pack sparingly	
Gyro Wheel Bearings	Every 60 hours	Gyro Oil No. WS602	Navy Lub. No. 3065	6 drops in top bearing. For bottom bearing see note.	☐
Gimbal Bearings	Only during period of routine overhaul or when otherwise dis-assembled	Gulf Precision Grease No. 1	Grade B Grease Navy Spec. 14L3b	Pack sparingly	
Bottom Chassis Bearings	Only during period of routine overhaul or when otherwise dis-assembled	Gulf Precision Grease No. 1	Grade B Grease Navy Spec. 14L3b	Pack sparingly	
All other ball bearings	Only during period of routine overhaul or when otherwise dis-assembled	Gulf Precision Grease No. 1	Grade B Grease Navy Spec. 14L3b	Pack sparingly	
All gears in instrument	Every 18 months	Gulf Precision Grease No. 1	Grade B Grease Navy Spec. 14L3b	Thin film on teeth	
Worm and Worm wheel	Every 18 months	Gulf Precision Grease No. 1	Grade B Grease Navy Spec. 14L3b	Thin film on teeth	
Worm and Worm wheel (Late Mods.)	Every 6 months	Navy No. 2075	Navy No. 2075	6 drops in "Gits" oiler	
Generated stop screws	Every 18 months	Gulf Precision Grease No. 1	Grade B Grease Navy Spec. 14L3b	Thin film on threads	
Selected stop screws	Every 18 months	Gulf Precision Grease No. 1	Grade B Grease Navy Spec. 14L3b	Thin film on threads	
O.S.S. D.C. motor (On Control Panel)	Every 6 months	Navy No. 2075		2 drops in each bearing	
O.S.C. A.C. motor (On Control Panel)	Every 6 months	Navy No. 2075		2 drops in each bearing	
Rotary Switches Shafts	When necessary	Navy No. 2075		1 drop back of control knob on handle	

★ While it is desirable to lubricate these bearings every 24 months, it is not absolutely necessary. However, if a Synchro is removed for any reason, the opportunity should be taken to lubricate its bearings if they have not been lubricated in the previous 18 months. Do not over-lubricate.

☐ Oil is introduced through knurled screw protected holes on the top and bottom of the gyro case. Note: Remove knurled screw on bottom of gyro case, tilt the gyro in the direction to make the oil flow out, and with the gyro still in this tilted position, add as much oil as the oil well can take. Replace knurled screw.

NOTE: Proper lubrication is dependent upon the amount of operation to which the instrument is subjected. Excessive oiling or greasing is of no use and only serves to collect foreign matter on the various parts of the equipment on which it drops. The above procedure is recommended, and a log should be kept showing the date of lubrication of the various parts.

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MAINTENANCE

MECHANICAL

It is essential that all of the parts of the Stable Element be kept free from foreign matter. Covers should be removed only when absolutely necessary and then replaced as soon as possible.

Adjustments should be made only if absolutely necessary and then only by competent personnel. (A thorough check should be made to ascertain just which adjustments are necessary to correct any trouble, thus decreasing the chances of disarranging the entire system.)

The following checks should be made periodically:

1. See that the drain plugs on the mercury system are tight and that no mercury has leaked onto any of the parts in the lower section of the instrument.

2. Check the bolts holding all covers in place on the instrument to insure against entrance of dirt and other foreign matter.

3. Check the gimbal bearings for excessive tightness or looseness.

4. Follow the recommended lubrication schedule. Wipe off surplus lubricants and AVOID OVER-LUBRICATION.

ELECTRICAL

The following electrical equipment checks should be made regularly:

1. Check pilot lamps for burned out bulbs. *

2. See that all fuses are of the correct values as indicated on the respective receptacles, and make good contact in their clips.

3. See that armature of mercury control cutout magnet operates freely and returns to its proper position when de-energized.

4. See that collector rings and brushes at the base of the Sensitive Element and in the pedestal of the bottom chassis are clean and make good contact. **

5. Check A.C. line voltage occasionally, and make sure that tapped leads on Control Panel transformers are on the taps corresponding to the voltage of the line.

6. With all circuits de-energized, check terminal screws in all terminal strips to make sure none of them are working loose.

7. Wipe off collection of grease or dirt on exposed contacts of mercury control cutout motors in rear of Control Panel.

*This should be done at every start.

**Contacts and collector rings should need no cleaning. This holds true also for the collector rings of Synchro units. Collector rings should NEVER be cleaned with crocus cloth, emery cloth or sandpaper as this only causes needless wear and scratching of the burnished surfaces. However, any oil film that may collect on them can be removed by wiping with a clean rag dampened with alcohol.

ROUTINE ADJUSTMENTS

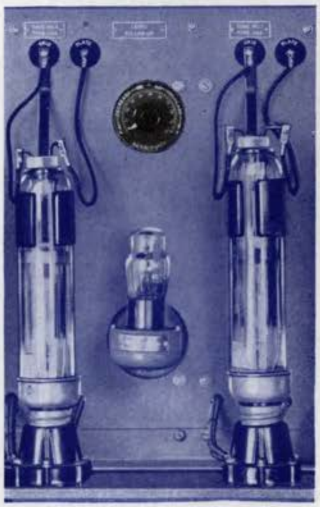
Ordinarily no adjustments on the equipment are necessary with the exception of the following:

Fig. 128

1. Latitude correction weight. This should be adjusted every time the instrument is to be used, positioning it to within plus or minus $\frac{1}{32}$ of an inch of the mark on the scale corresponding to the correct latitude of the ship.

Fig. 129

2. Mercury level in mercury control system. Loss of mercury can be discovered during routine maintenance checks and if loss is suspected, the system can be drained and exactly 11 ounces of clean mercury added.



3. Sensitivity of Amplifiers. This adjustment is described on page 125 under Instructions.

Unless the instrument is disassembled for repairs or overhaul, no other adjustments should be necessary. If any adjustment is thought necessary, refer to the various adjustments on pages 167 to 183, and allow only competent personnel to perform the required work.

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DISASSEMBLY AND REASSEMBLY

This section covers the necessary steps in disassembling and reassembling the Stable Element or parts thereof during routine overhaul or in case of damage or breakdown. Adjustments necessary in recalibrating the instrument during reassembly are indicated in this section.

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To disassemble the Stable Element, the following sequence of operations should be followed implicitly. Disassembly should only be performed when absolutely necessary and then only by competent personnel. It should be done in a clean room and all parts should be laid on clean cloths or otherwise kept as free from dirt as possible.

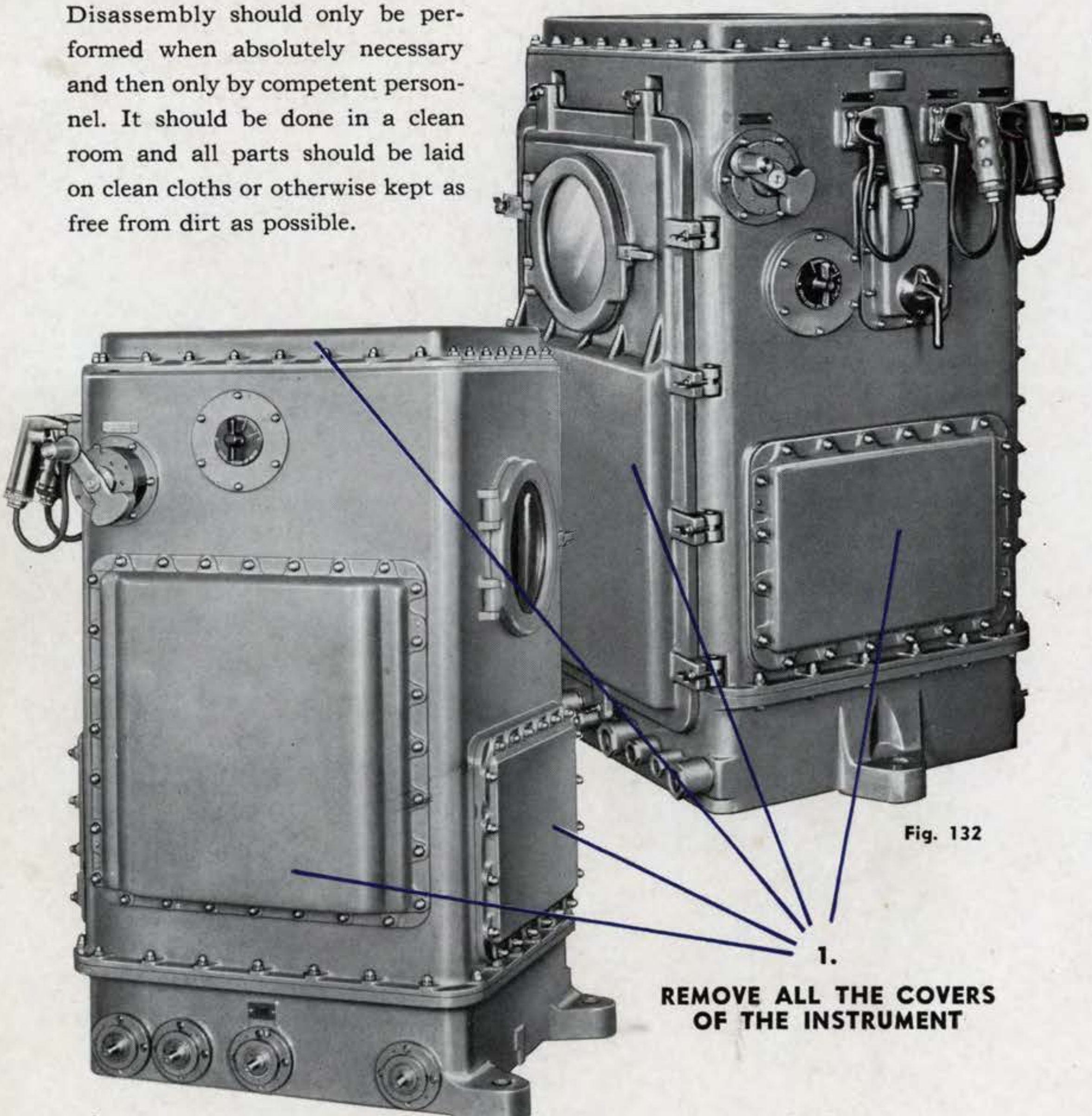

Fig. 132

Fig. 131

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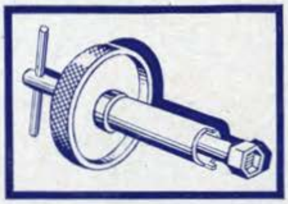
2. REMOVE THE INDEX PLATE
(eight screws)

3. REMOVE ALL THE DIALS

Use Synchro wrench for center dials. The remaining ring dials are removed with a screwdriver (four small screws in each).



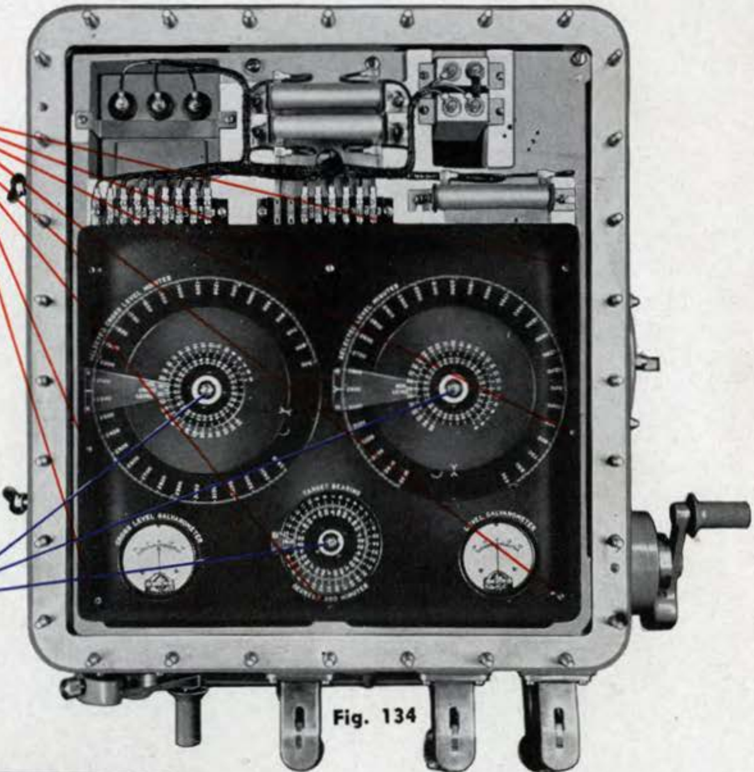


Fig. 134

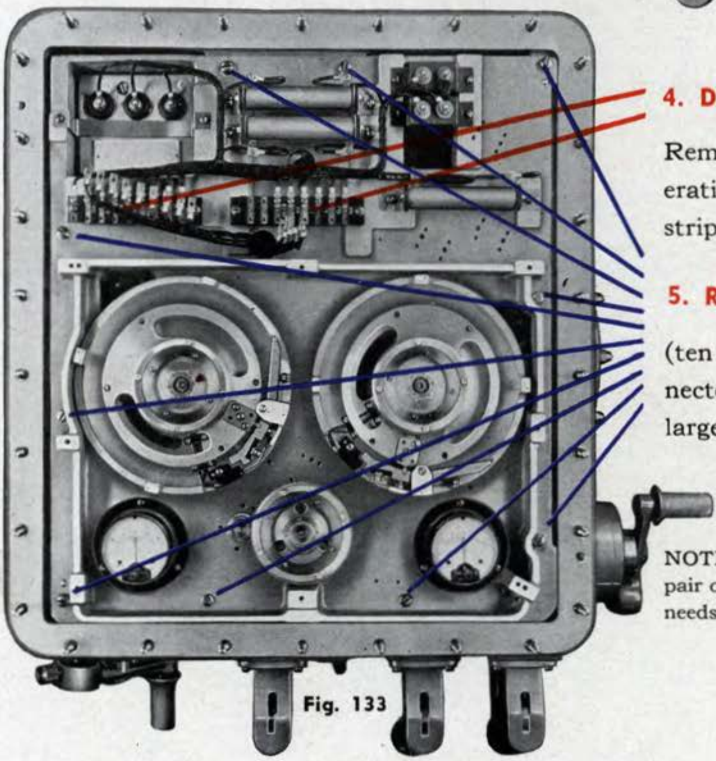


Fig. 133

4. DISCONNECT WIRING

Remove terminal lugs from operating side of the two terminal strips only. (15 terminals)

5. REMOVE TOP PLATE

(ten screws). Allow the disconnected cable to pull through its large hole in the top plate.

NOTE: Further disassembly or repair of top plate units is obvious and needs no detailed description.

6. DISCONNECT WIRING

Remove all terminals on these two terminal blocks. Also remove adjacent clips.

(Top plate must be removed before this operation can be performed)

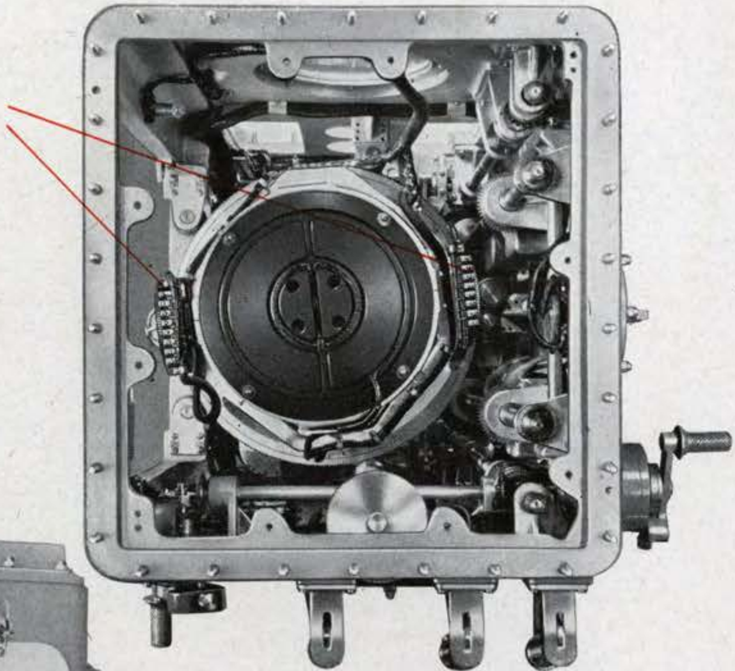


Fig. 135

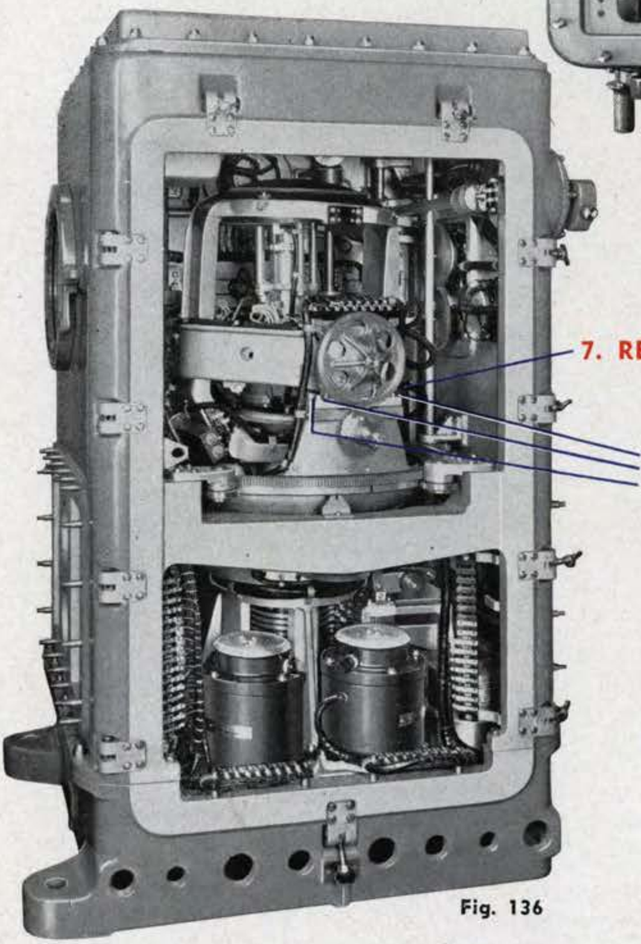


Fig. 136

7. REMOVE MOUNTING BRACKET SCREWS

Four screws secure each mounting bracket. (One bracket visible here; other bracket is opposite)

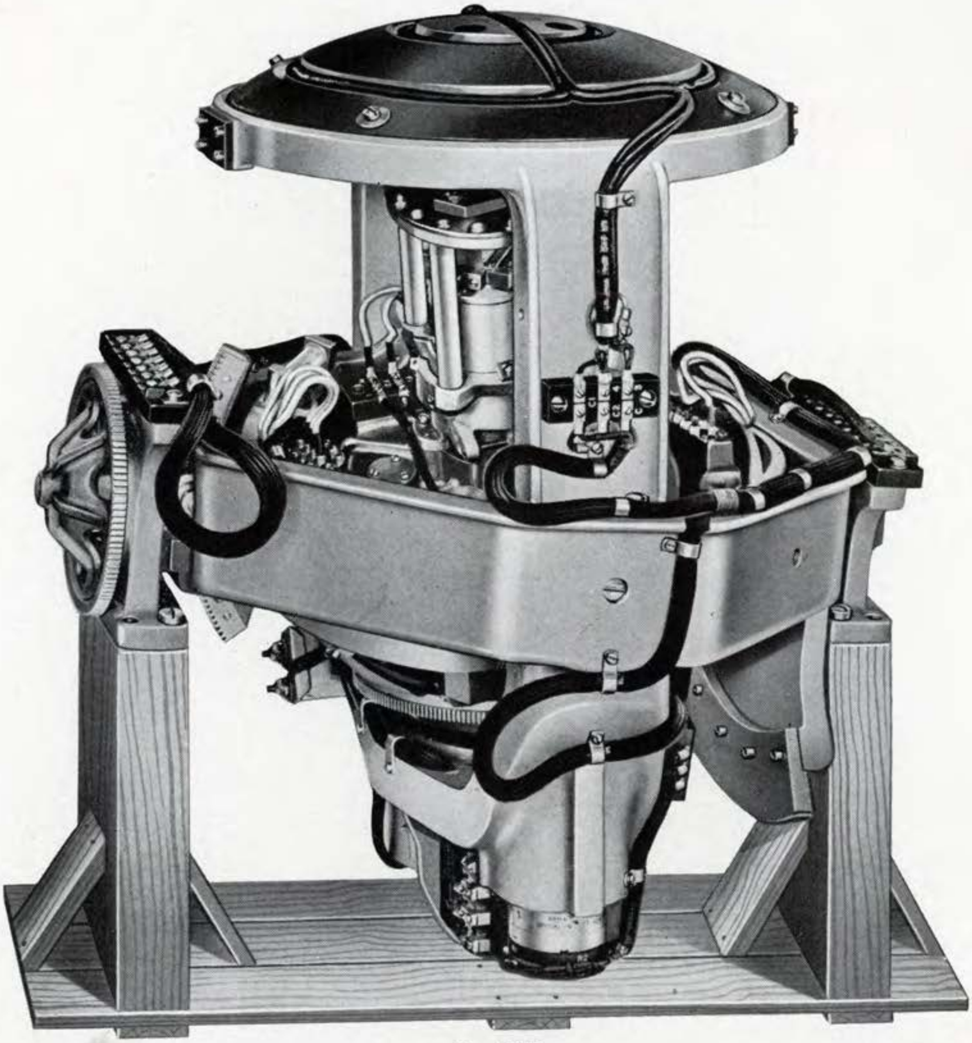


Fig. 137

8. LIFT THE SENSITIVE ELEMENT

Through the open top of the housing grasp the Cross Level Gimbal and lift the unit straight upwards until the dowel pins in the two mounting brackets are free of the mounting pads, then maneuver the assembly out through the left side access opening.

NOTE: The Sensitive Element is more easily worked upon and is less likely to be damaged if it is placed so that its two mounting brackets rest on blocks of wood or the like which are (or can be) fastened securely to a work bench.

9. DISCONNECT WIRING
and remove clips from each of the terminal blocks mounted on the automatic stops.

(Preceding steps must be performed before attempting this procedure)

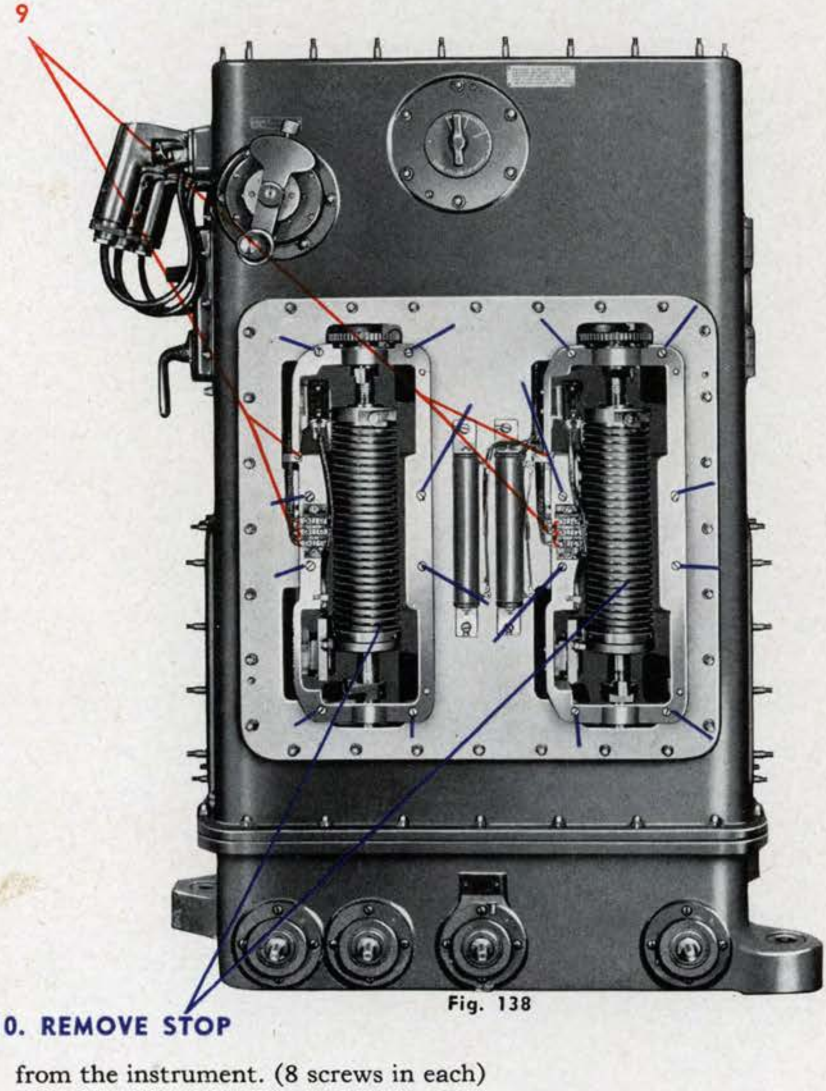


Fig. 138

10. REMOVE STOP

from the instrument. (8 screws in each)

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11. REMOVE CLIPS securing cables to gimbal support pads.

11a. REMOVE TRAIN TRANSMITTING UNIT AND CONNECTING WIRES (see Fig 78B)

11B. Remove CONTINIOUS LEVEL TRANSMITTING UNIT AND CONNECTING WIRES (see Fig 78E)

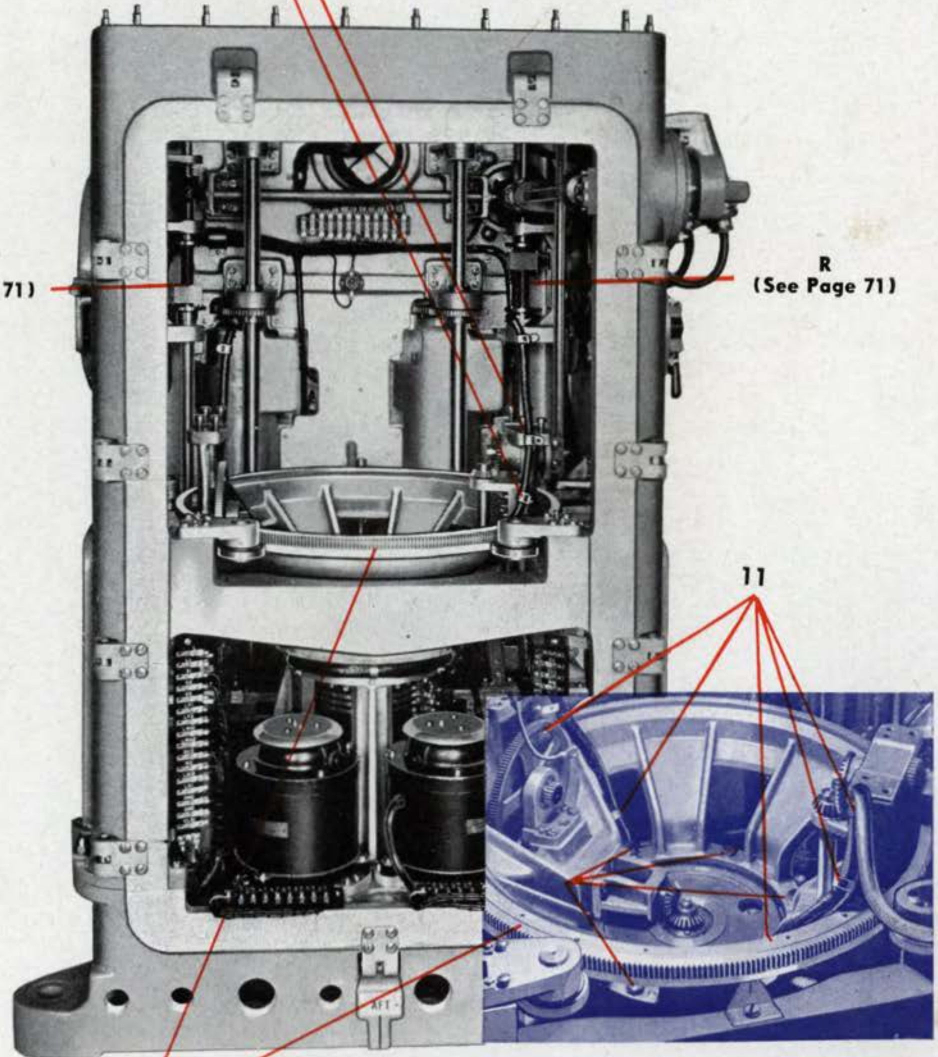

Fig. 139

Fig. 140

12. REMOVE THE SUPPORT AND TRAINING GEAR

(Six hex head bolts).

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13. REMOVE CONNECTING COUPLINGS between bottom chassis stub shafts and the vertically mounted hand set stop mechanism shafts. (Remove four screws in each coupling, separate halves and remove.)

Fig. 141

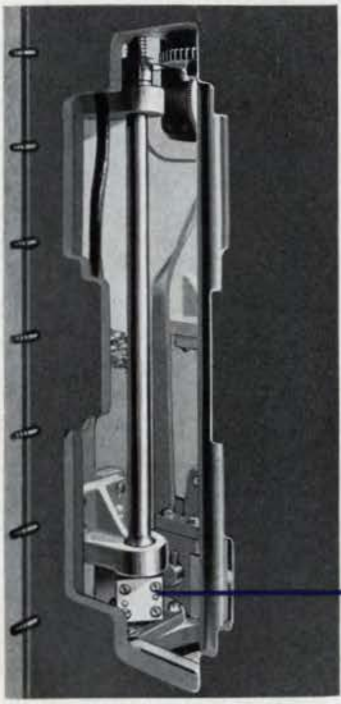

Fig. 142

Fig. 143

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14. REMOVE SMALL VERTICAL SHAFT Remove four screws and two slip dowels from top bracket and swing bracket to one side. Remove four screws from bottom bracket. Pull shaft and brackets upward and out of mesh with its keyed-type sleeve coupling on the bottom chassis.

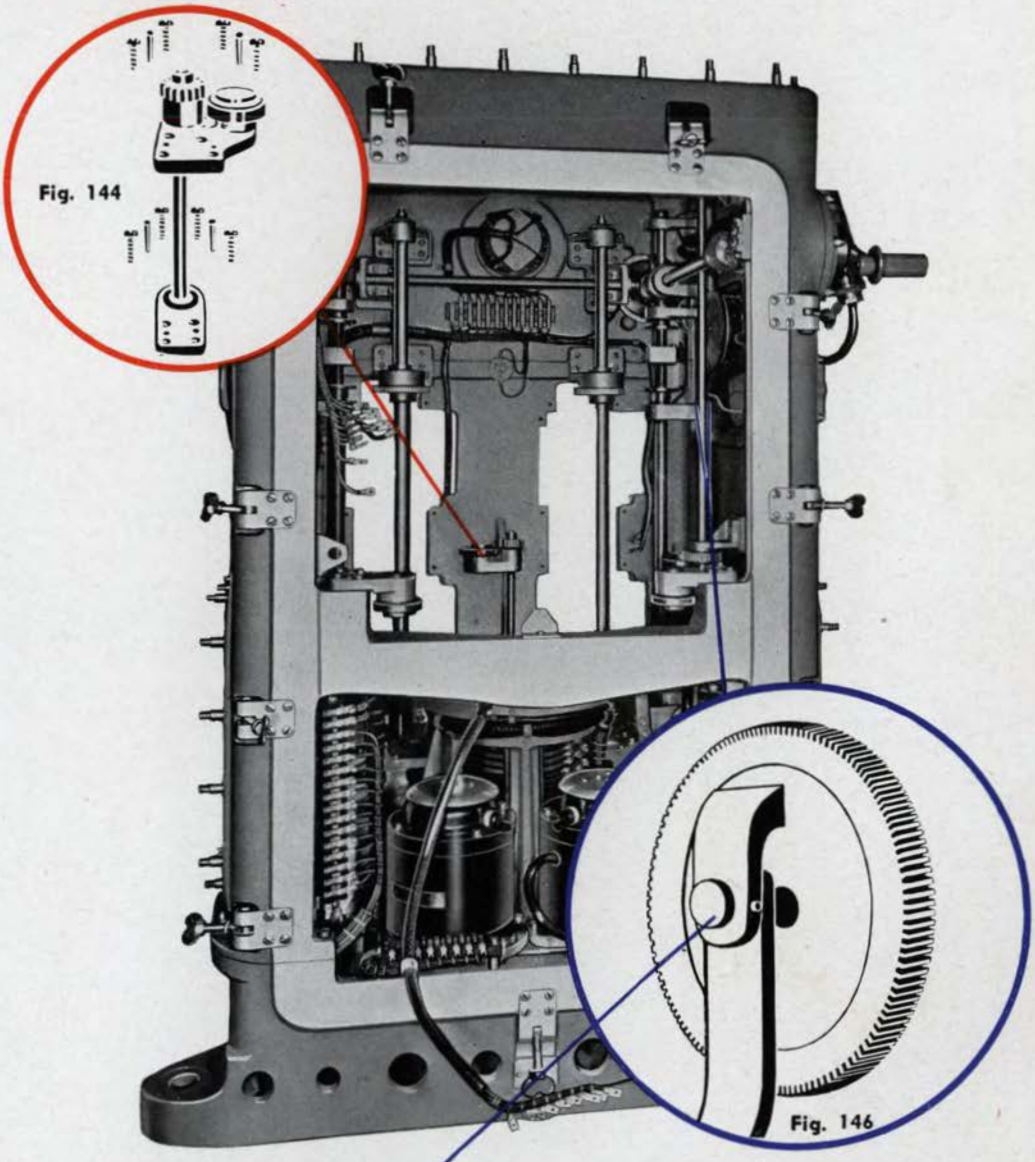

Fig. 144

Fig. 146

Fig. 145

15. REMOVE THE LARGE PIN securing clutch lever to Selector Switch gear. (First remove small taper pin, then pull large pin toward rear of instrument.)

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16. SWING BRACKET TO ONE SIDE (MARK 6 MOD. 1 ONLY)

(Upper bracket only—3 screws and two slip dowels of Continuous Level Synchro drive-shaft)

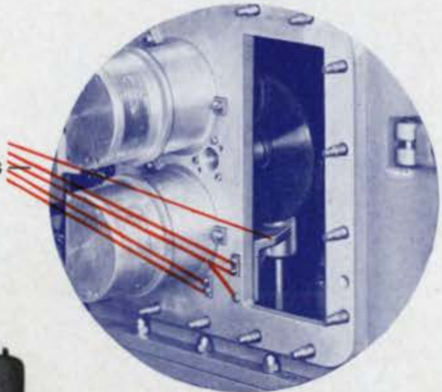

Fig. 147

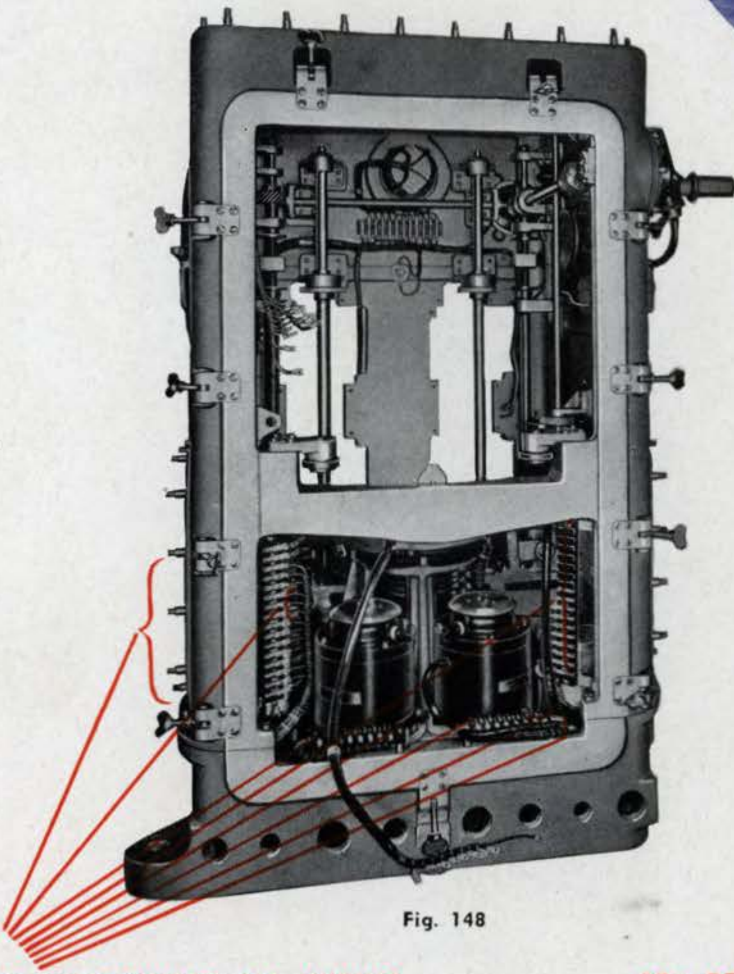

Fig. 148

17. DISCONNECT ALL WIRING

between top section and bottom section which would prevent separation of the two sections.

17a. REMOVE CABLE CLAMPS

on all cables which would also hinder this separation.

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18. REMOVE SECURING BOLTS holding top section to bottom section (19 around three sides, 2 in lower edge of left side access opening).

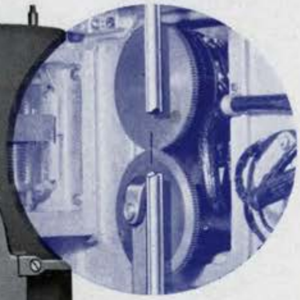

Fig. 150

NOTE:
If it is necessary to remove the Selector Switch or (for any other reason) to disengage the gears which operate the electrical switch adjacent thereto, mark the gear mesh in order to facilitate correct remeshing of these gears during reassembly.

Fig. 149

19. LIFT TOP SECTION FROM BOTTOM SECTION

Pay special attention to all wiring cables to prevent snagging on projections or fouling in any other way.

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20. REMOVE INPUT AND OUTPUT SHAFTS

. . . and adapters by removing four securing screws in each adapter and pulling out shaft and adapter as a unit.

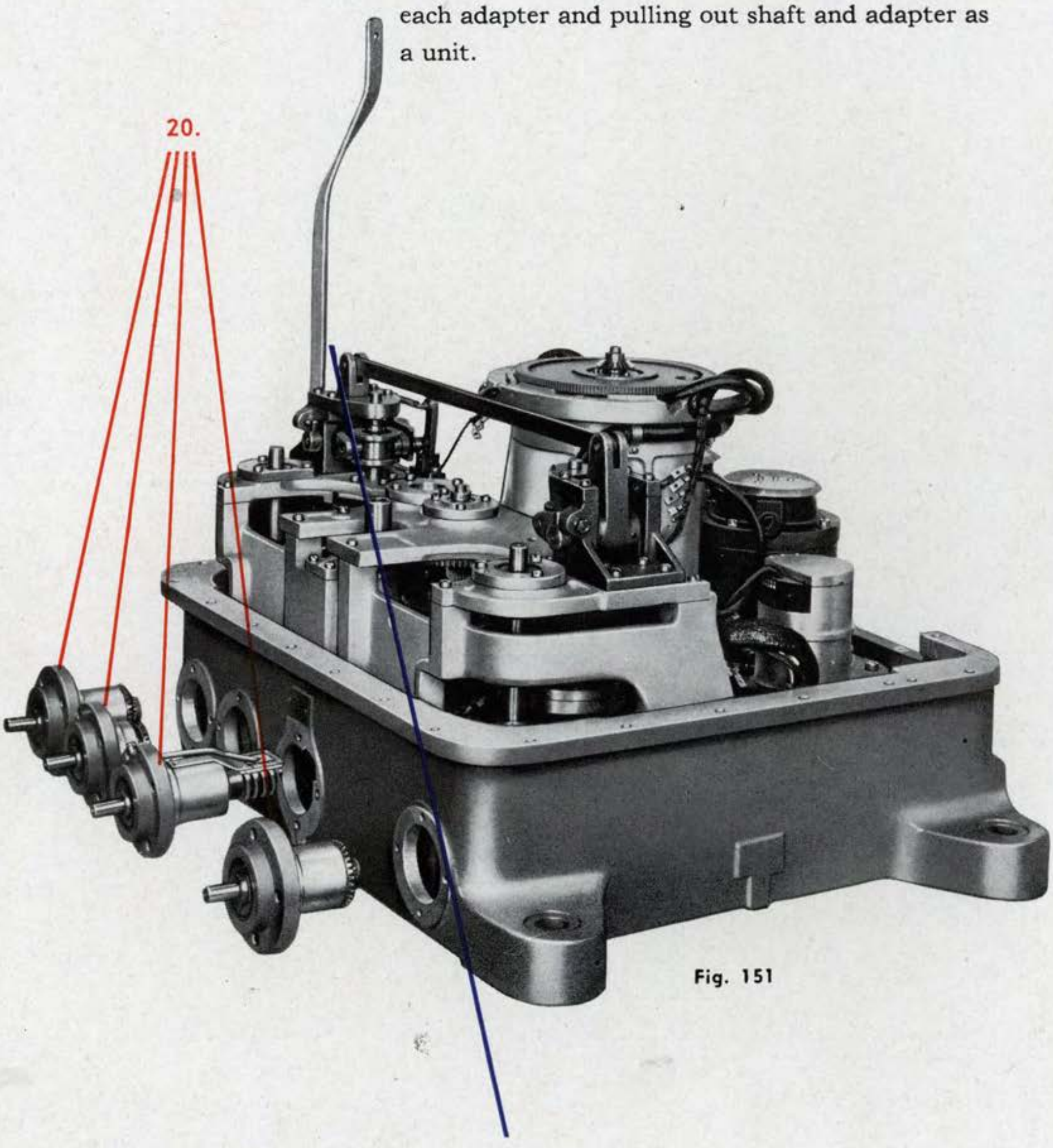

Fig. 151

21. REMOVE CLUTCH OPERATING LEVER

by removing the pin by which it is pivoted in the clutch operating bell crank.

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22. DISCONNECT WIRING and cable clips and remove terminal blocks from left side of bottom chassis case.

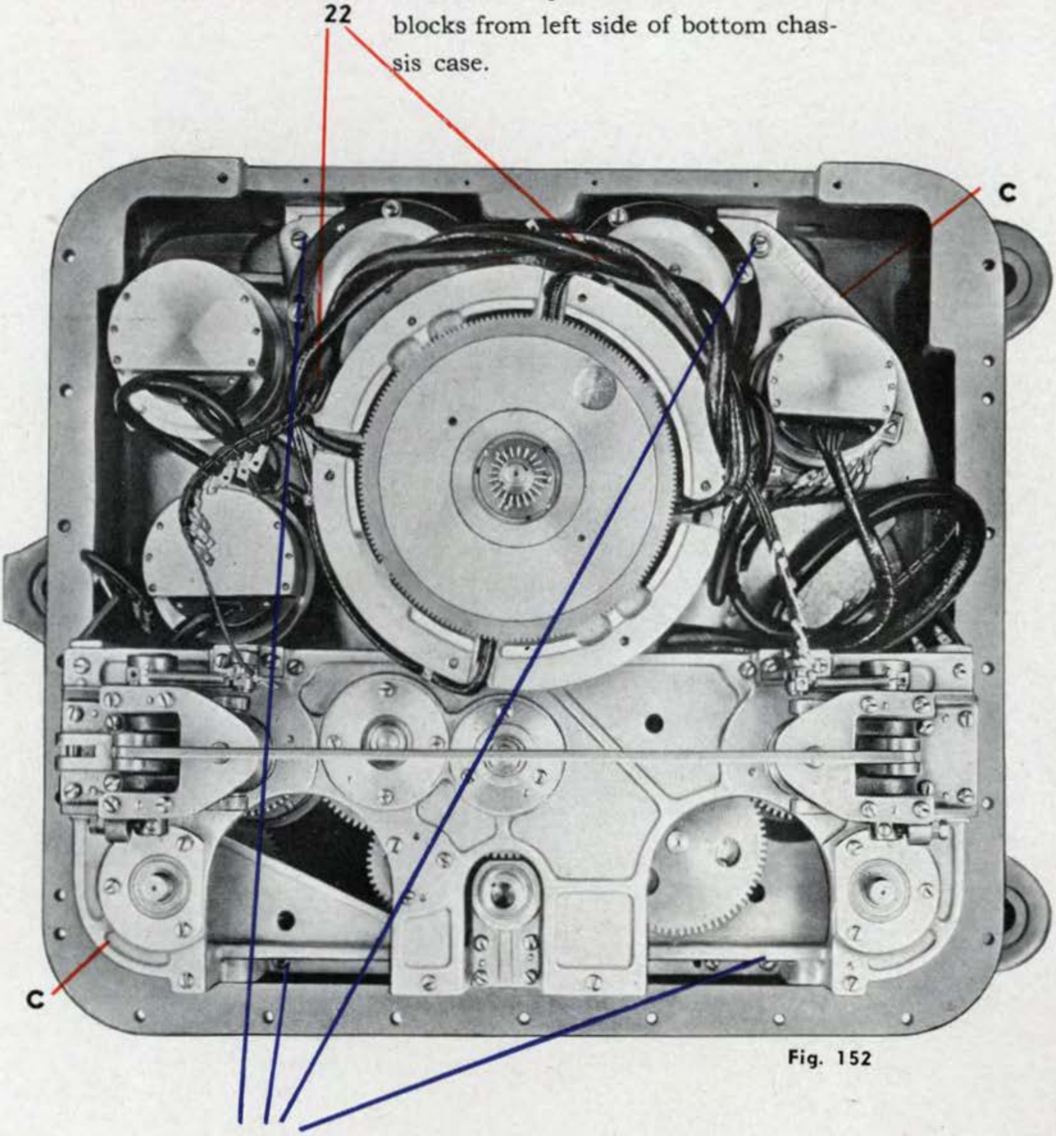

Fig. 152

23. REMOVE 4 SCREWS
which secure bottom chassis in bottom section.

24. REMOVE BOTTOM CHASSIS
grasping at C-C and lifting it from the bottom section case.

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25. DISCONNECT CLUTCH CONNECTING BAR

from rear clutch (one taper pin).

26. REMOVE U-SHAPED TOP PLATES

from both clutches (four securing screws and one spring on each plate)

27. REMOVE BOTH CLUTCH OPERATING MECHANISMS

(four screws in each) Clutch connecting bar may be left connected to front clutch.

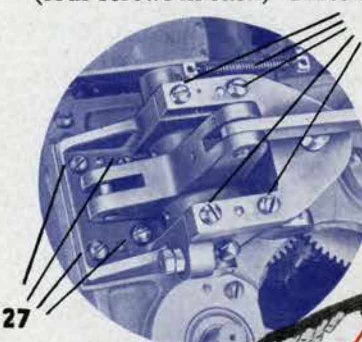


Fig. 154

Fig. 155

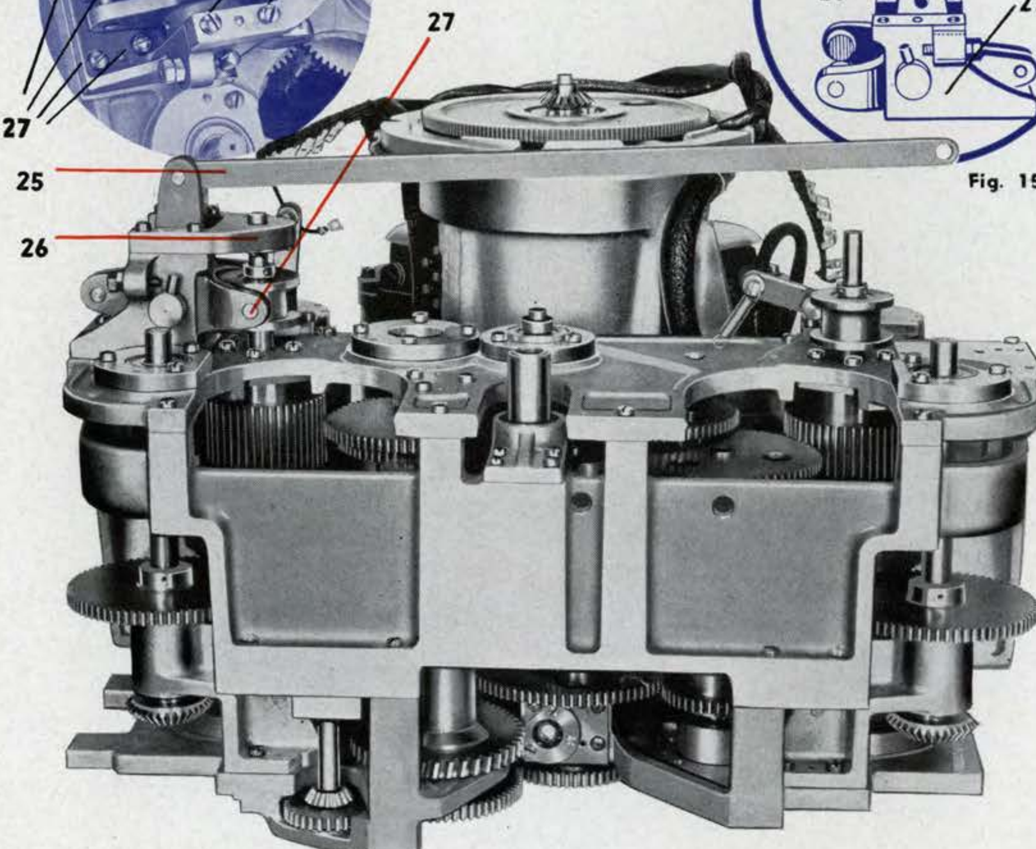
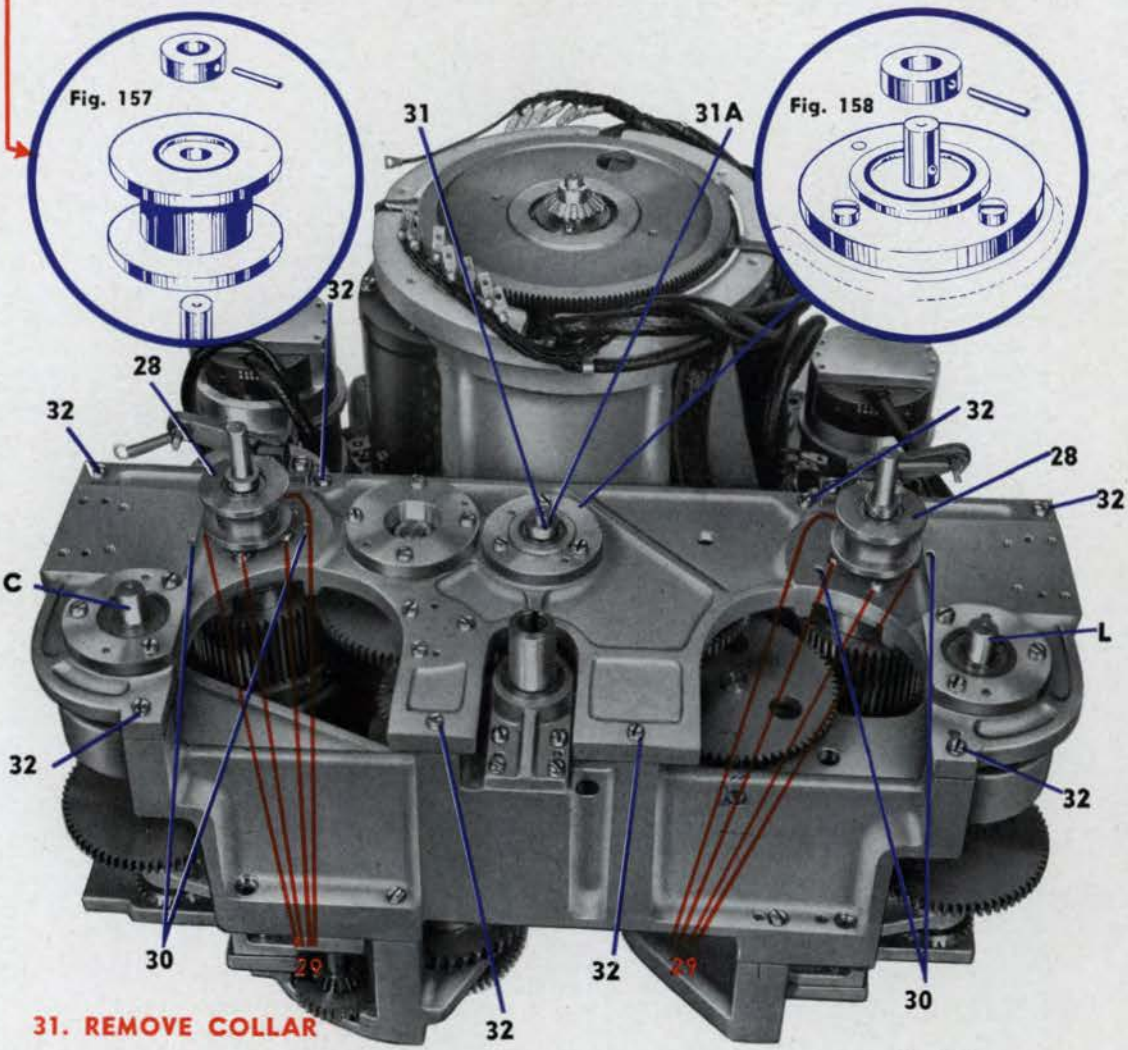


Fig. 153

28. REMOVE LIFTING SPOOLS
from each clutch by removing taper pin and collar above each spool.

29. REMOVE 4 SCREWS
from each clutch adapter plate.

30. LOOSEN CLUTCH ADAPTER PLATES
by tapping or pushing downwards on their respective dowel pins until plates drop free.



31. REMOVE COLLAR

from this shaft (remove 1 taper pin)

Fig. 156

32. REMOVE TOP MECHANISM PLATE

(8 screws) As plate is lifted, push downwards on shafts L and C and the shaft 31A.

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DISASSEMBLY OF THE BOTTOM SECTION

33. REMOVE BRACKET

with its shaft and gear (4 screws, 2 dowels)

34. REMOVE BRASS GEAR

(Keyed and secured by taper pin in hub)

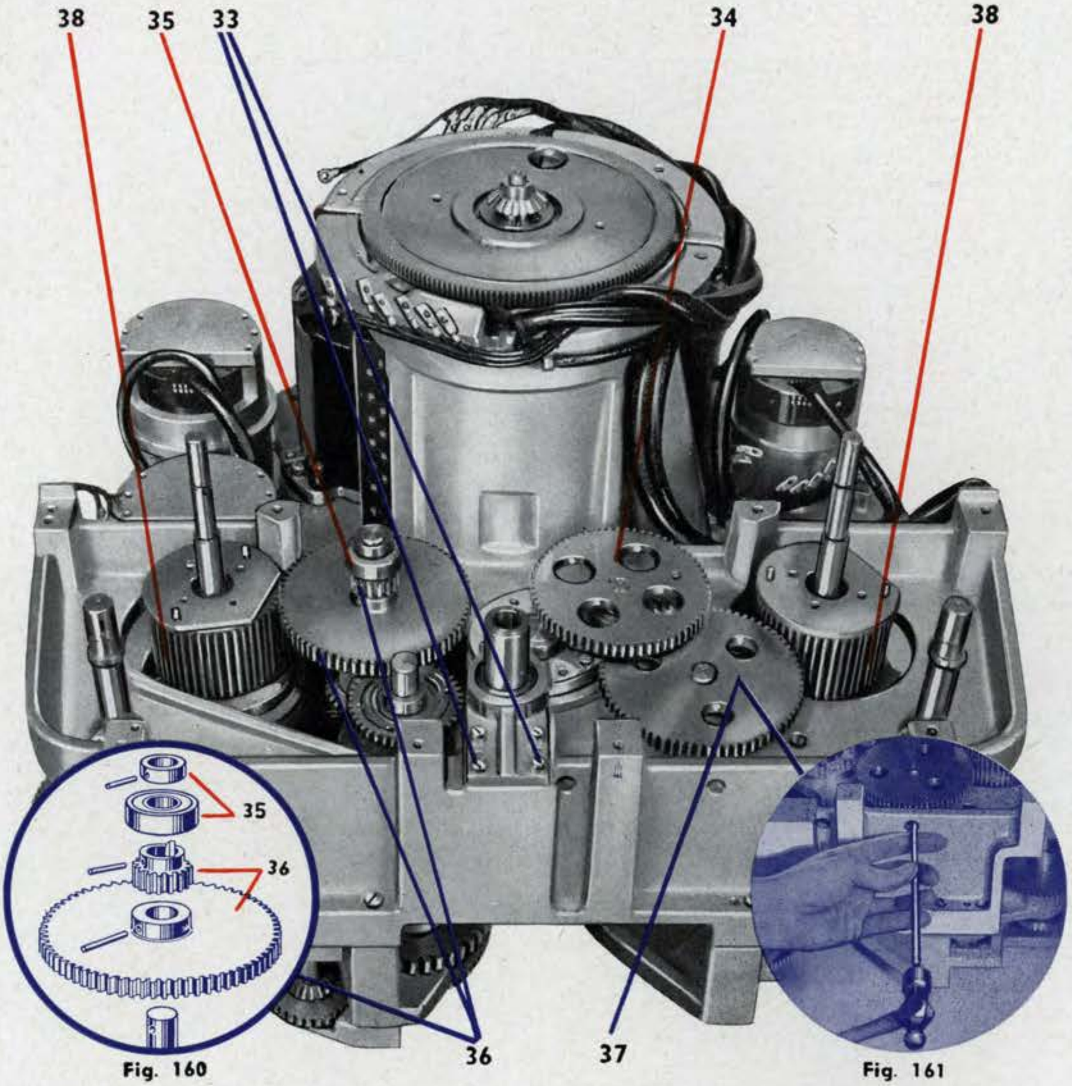

Fig. 160

Fig. 161

Fig. 159

35. REMOVE COLLAR AND BEARING

(taper pin in collar).

36. REMOVE 2 GEARS

(Taper pin in hub of each, top gear also keyed).

37. REMOVE BRASS GEAR

(Use drift punch on taper pin in hub) See Fig. 161. Also keyed.

38. REMOVE BOTH CLUTCH MECHANISMS

by lifting upwards.

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39. REMOVE COLLAR

(one taper pin) from top of center differential.

40. REMOVE ADAPTER

(three screws, two dowels) which surrounds collar just removed.

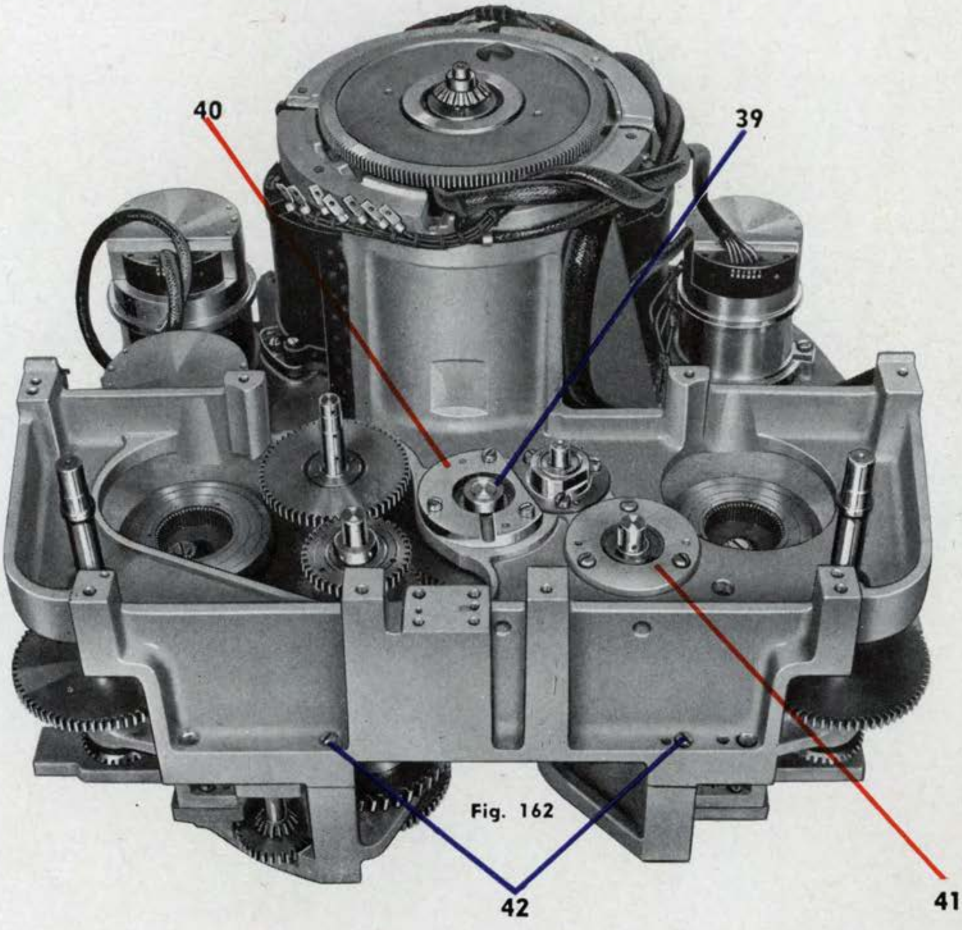

Fig. 162

41. REMOVE ADAPTER

(three screws, two dowels) (Remove Woodruff key from this shaft as well as from other shafts where such a key interferes with removal of adapters, etc.)

42. REMOVE 2 SCREWS

securing bottom mechanism plate to main casting.

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43. TURN CHASSIS UP and rest it as shown on its flat edge (right side).

44. REMOVE FOLLOW-UP MOTORS
with their mounting bases and gearing. (3 screws and 2 slip dowels in each base).

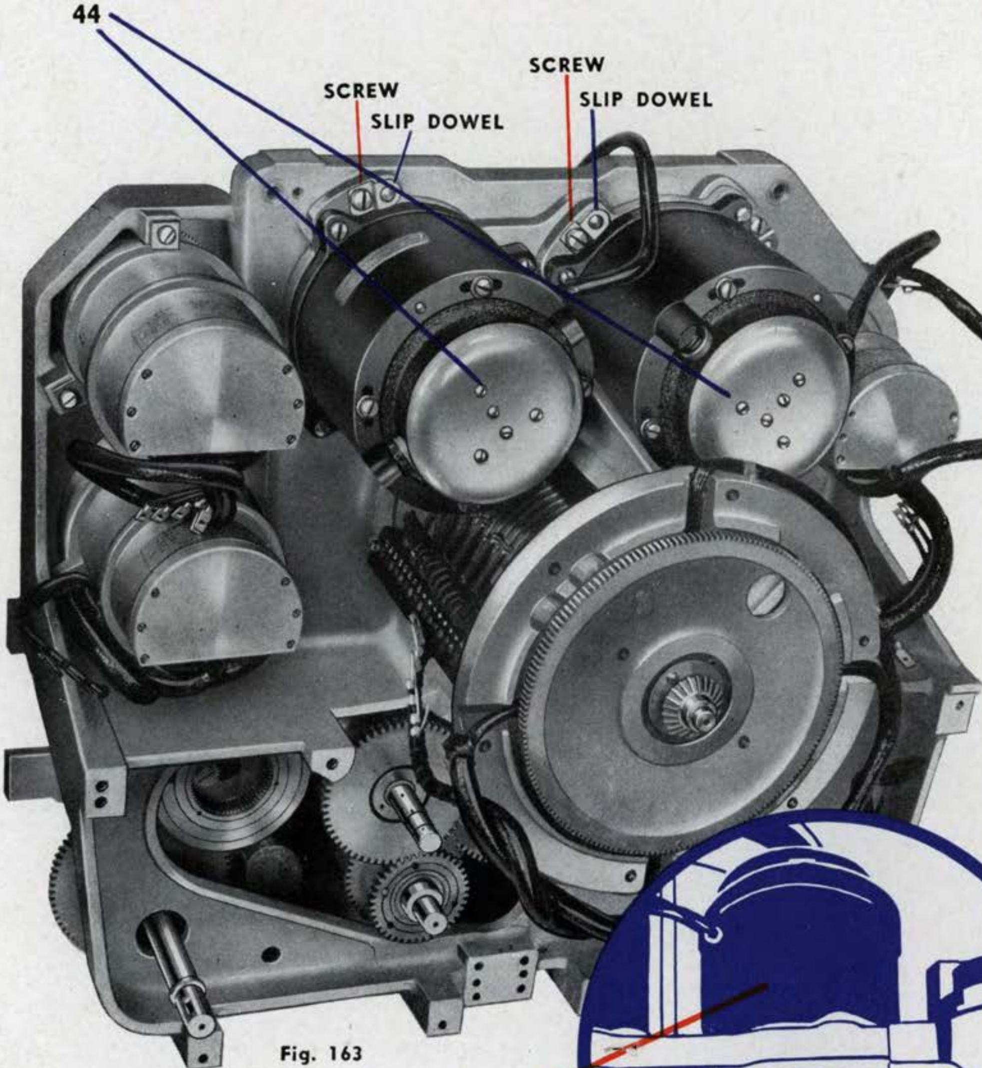

Fig. 163

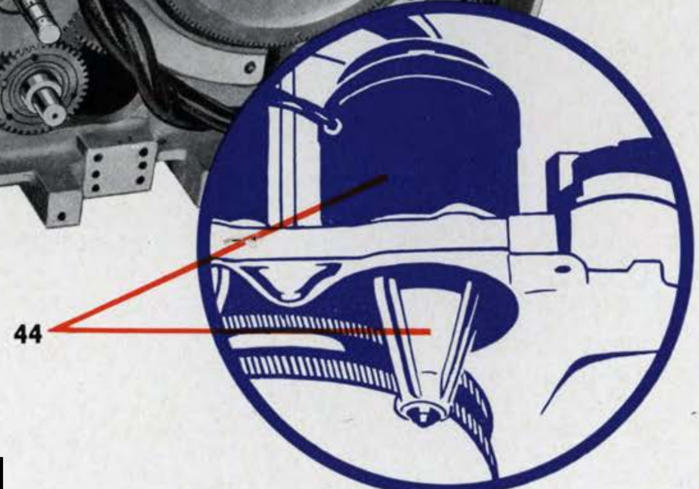

Fig. 164

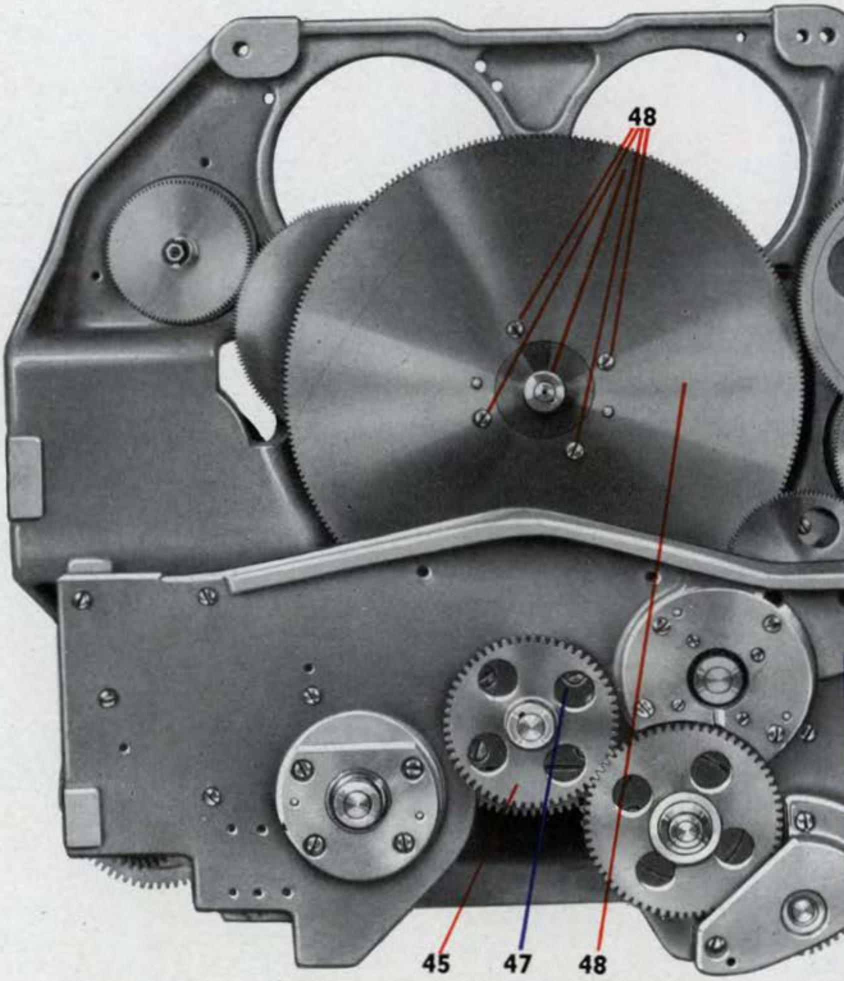

Fig. 165

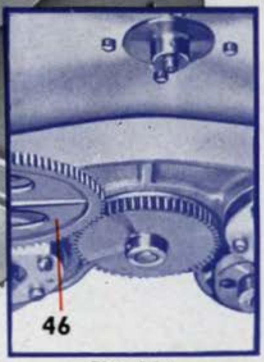

Fig. 166
(Mark 5 Only)

45. REMOVE GEAR

(Taper pin and key in hub)

47. REMOVE ADAPTER

(4 screws). Tap on shaft of center differential from top side to push adapter out.

46. REMOVE IDLER GEAR

and adapter as a unit (3 screws in adapter). Mark 5 only.

48. REMOVE LARGE GEAR

and hub separately. (Remove 4 screws in gear and tap gear off its dowel pins. Then remove taper pin in hub and remove hub and key.)

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49. REMOVE 3 SCREWS
in adapter. (Line up holes in gear with holes in bottom mechanism plate in order to reach these screws.)

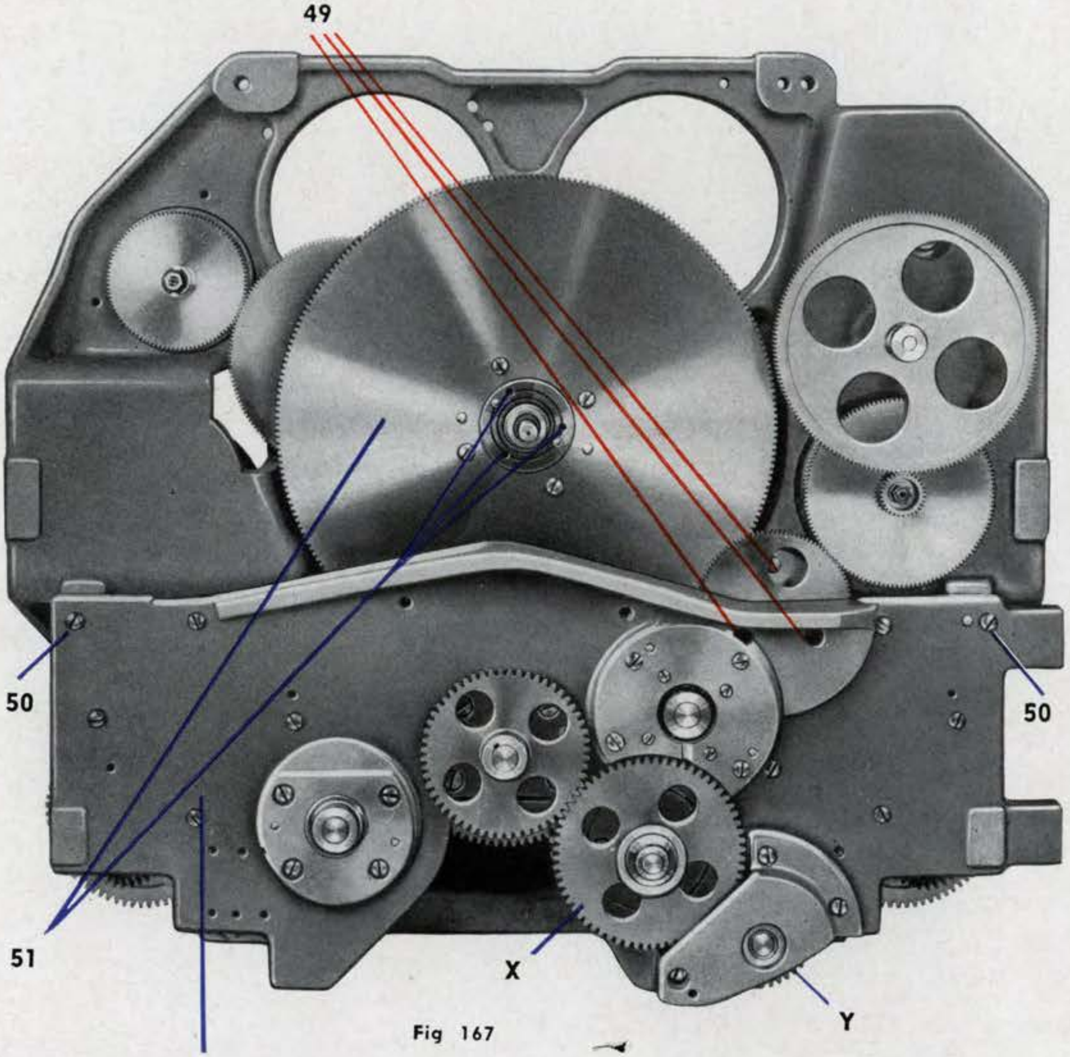

Fig 167

50. REMOVE BOTTOM PLATE
(2 remaining screws. Others were removed in step 42.) Remove plate carefully. The gears X and Y and all three differentials will come with the plate. Hold all component parts to prevent dropping.

51. REMOVE OTHER LARGE GEAR
together with its hub. (3 screws each secured half in hub and half in tubular shaft.)

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52. REMOVE BEVEL GEAR

and key (taper pin in hub).

53. REMOVE CENTER SHAFT

(solid) by pushing it out through the bottom.

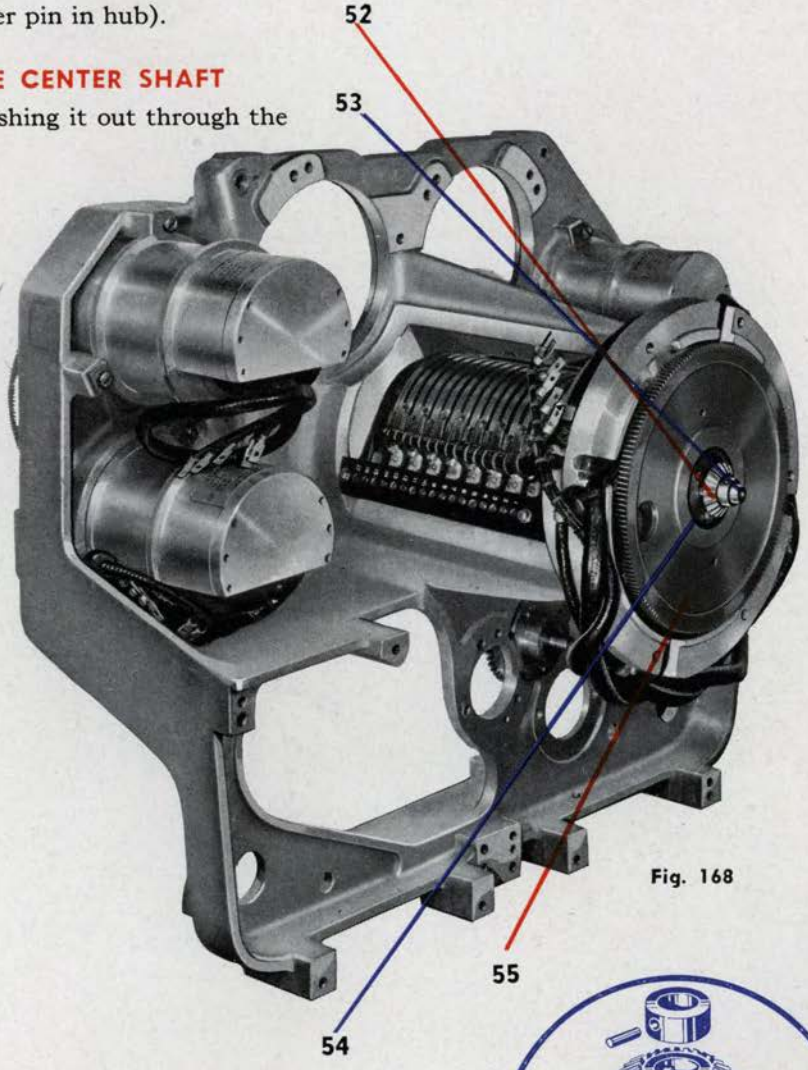

Fig. 168

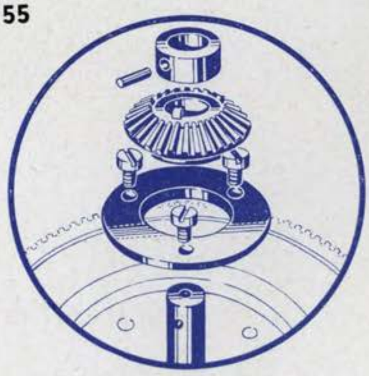

Fig. 169

54. REMOVE BEARING RETAINER

below the bevel gear (three screws).

55. REMOVE SPUR GEAR

(three screws half in its hub and half in its tubular shaft).

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56. REMOVE TUBULAR SHAFT

by pulling out through the bottom.

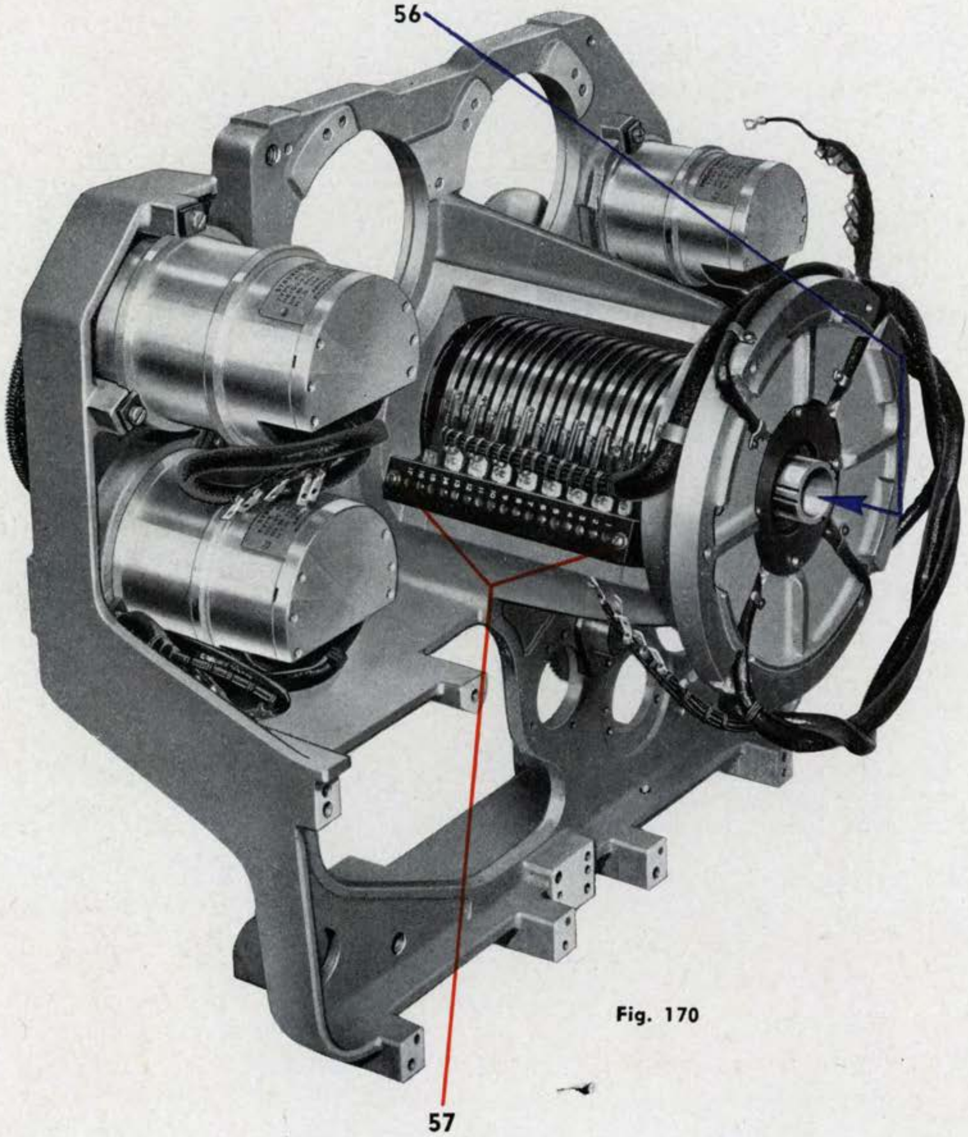

Fig. 170

57. REMOVE BRUSH BLOCK (2 screws)

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58. REMOVE SPUR GEAR
(taper pin in hub).

59. REMOVE 3 SCREWS AND COLLAR
on lower end of pedestal assembly.

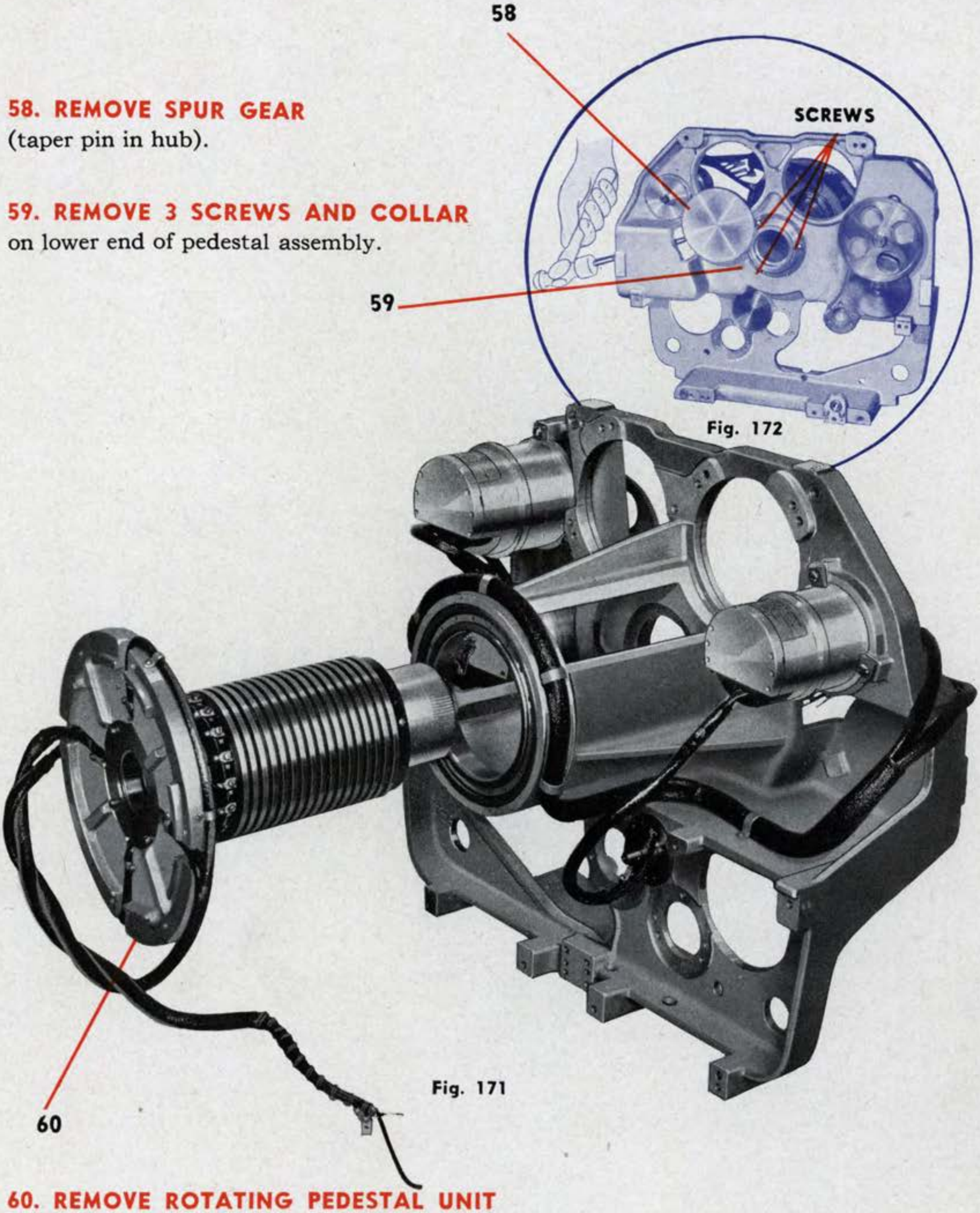

Fig. 172

Fig. 171

60. REMOVE ROTATING PEDESTAL UNIT
from the chassis by pulling it out through the top of its mount.

NOTE: Further disassembly of the bottom section or of its component parts is obvious and requires no detailed description.

NOTE: In the following procedure all wiring and cable clips not specifically mentioned should be removed where their presence prevents the removal of one piece from another. These steps will be readily apparent as they are reached.

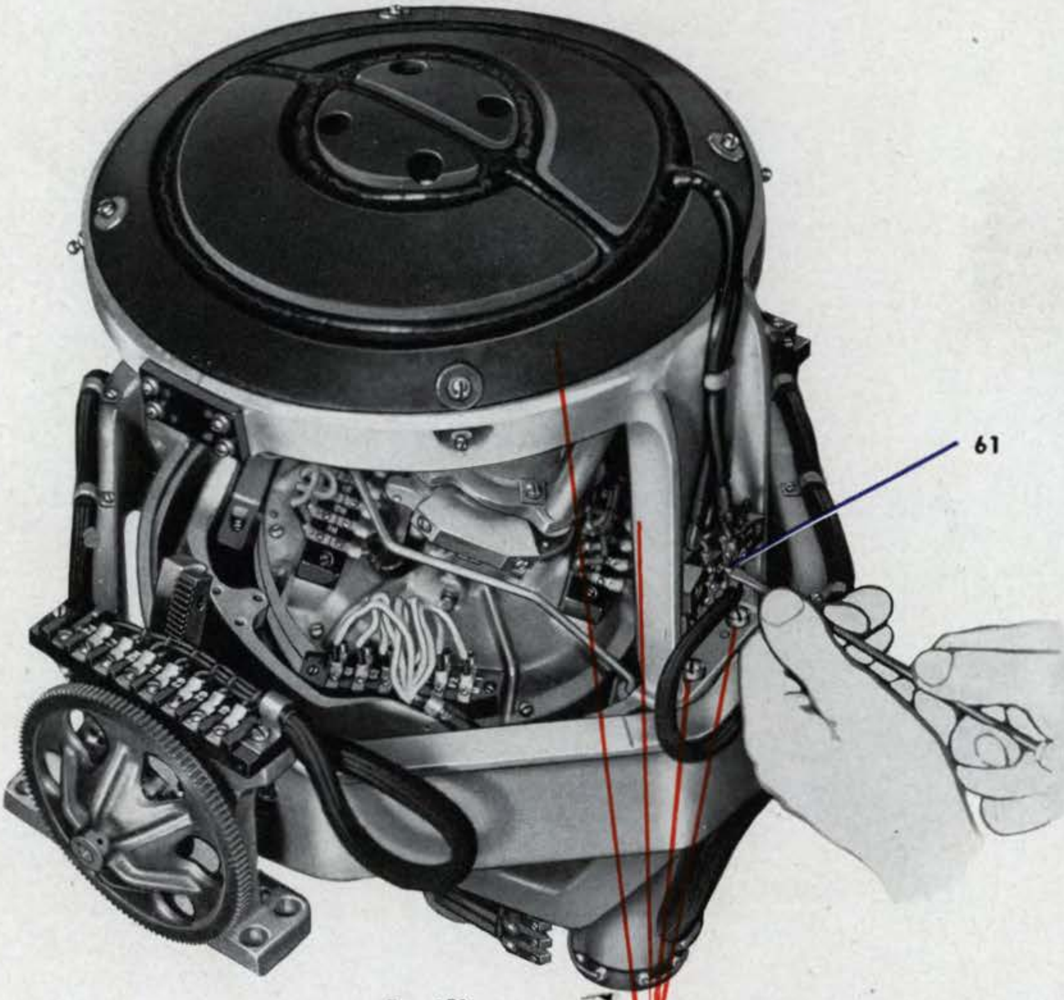

Fig. 173

61. DISCONNECT WIRING of follow-up coils (3 terminals, 1 clip and 1 ground).

62. REMOVE FOLLOW-UP COIL AND SUPPORT (2 screws in each leg.)

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63. REMOVE THE MAGNET

and its base as a unit.
(2 wires, 4 screws)

CAUTION:
Do not loosen the lower ends of the four supporting studs, as this will alter the position of the dowels on their upper ends.

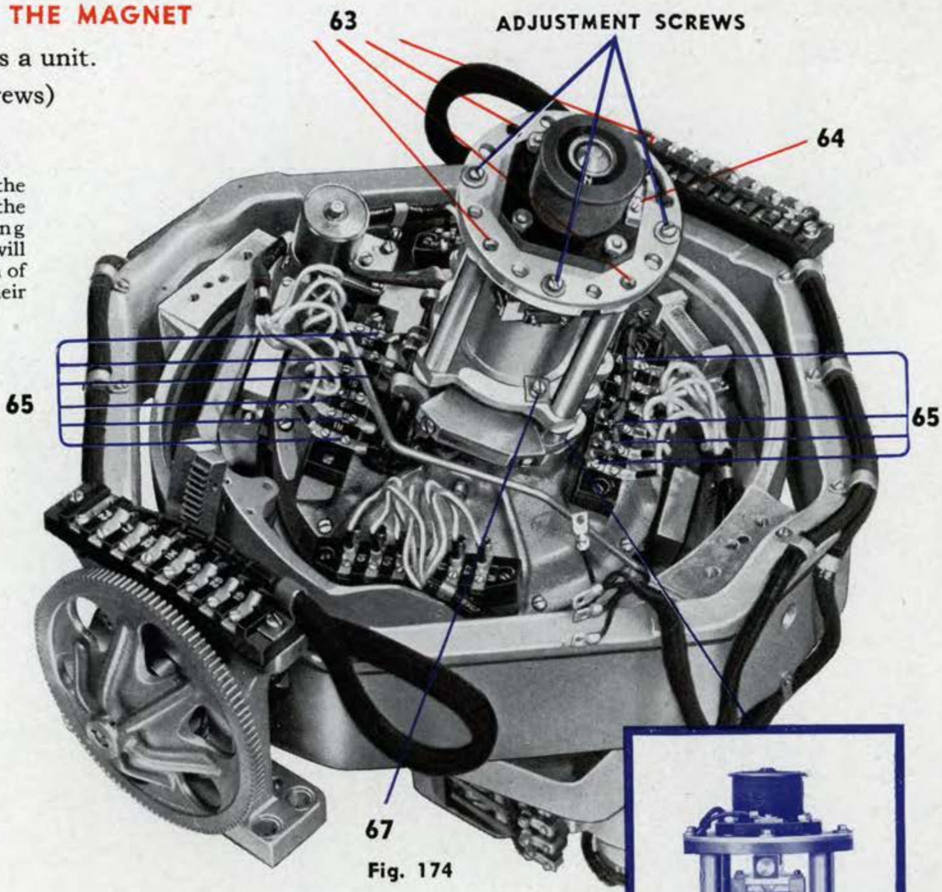

Fig. 174

Fig. 175

64. REMOVE CABLE

supplying follow-up magnet (3 clips and terminals F-1 and F-2).

65. REMOVE WIRING

of latitude motor cable from terminal block (terminals R-1, R-2, S-1, S-2, S-3). Also remove wiring of gyro motor and mercury valve magnet, M-1, M-2, G-1, G-2, G-3, at this time)

66. REMOVE LATITUDE MOTOR AND BASE

as a unit (4 screws). Offset screwdriver required.

67. REMOVE LATITUDE MOTOR FROM BASE

(Disconnect wiring from bottom of motor, remove three clamps [one shown in Fig. 174] and remove motor.)

68. REMOVE TERMINAL BLOCKS from gyro case. (2 screws in each)

69. LOOSEN 2 PIVOT LOCKING SCREWS (and locknuts), one on each side of gyro case.

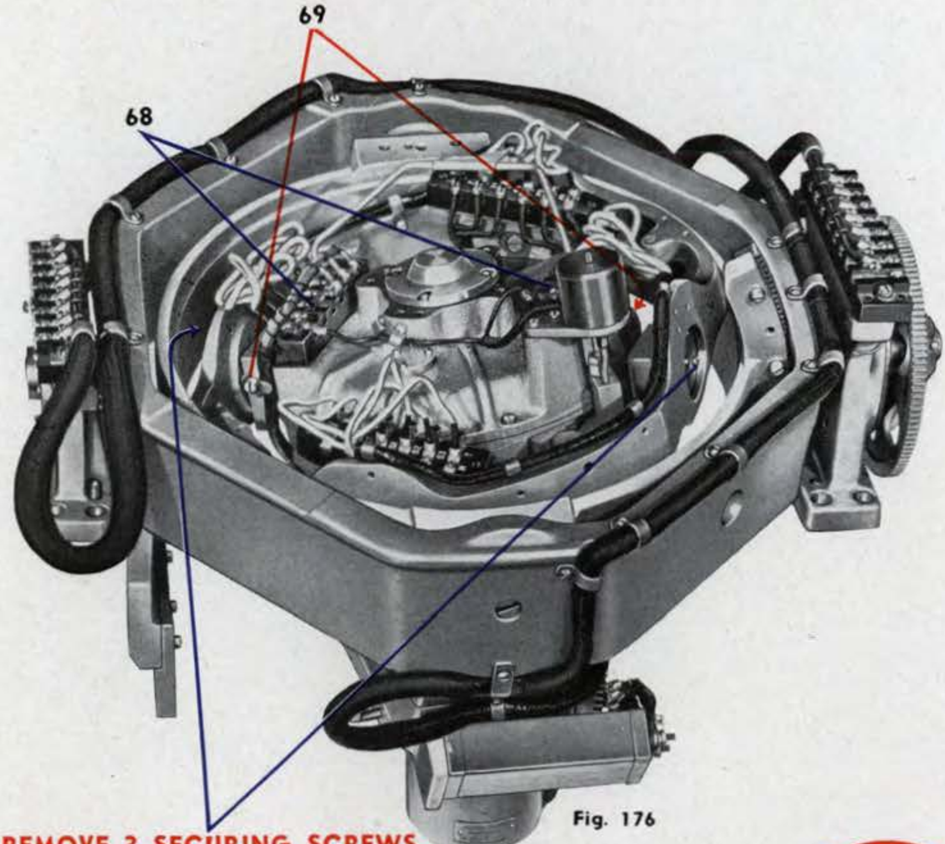

Fig. 176

70. REMOVE 3 SECURING SCREWS in each bearing retainer (one retainer on each side of gyro case).

Fig. 177

71. UNSCREW THE 2 PIVOT STUDS (toward the outside) until the gyro case is free and can be removed from the inner gimbal ring (gyro gimbal).

CAUTION: Do not allow the case to cant or drop while performing this operation, as serious damage could result to the assembly. A good precaution is to support the gyro by means of clamps as shown in Fig. 178, such clamps replacing the terminal blocks on the gyro case for this step. These clamps also serve the purpose of taking the weight from the pivot studs and bearings, thus greatly facilitating their removal.

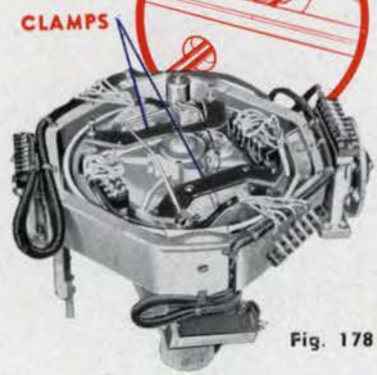

Fig. 178

72. REMOVE WIRING

(flexible leads) from the terminal blocks on rotating fork.

73. LOOSEN 2 PIVOT LOCKING SCREWS

(and locknuts), one on each arm of rotating fork.

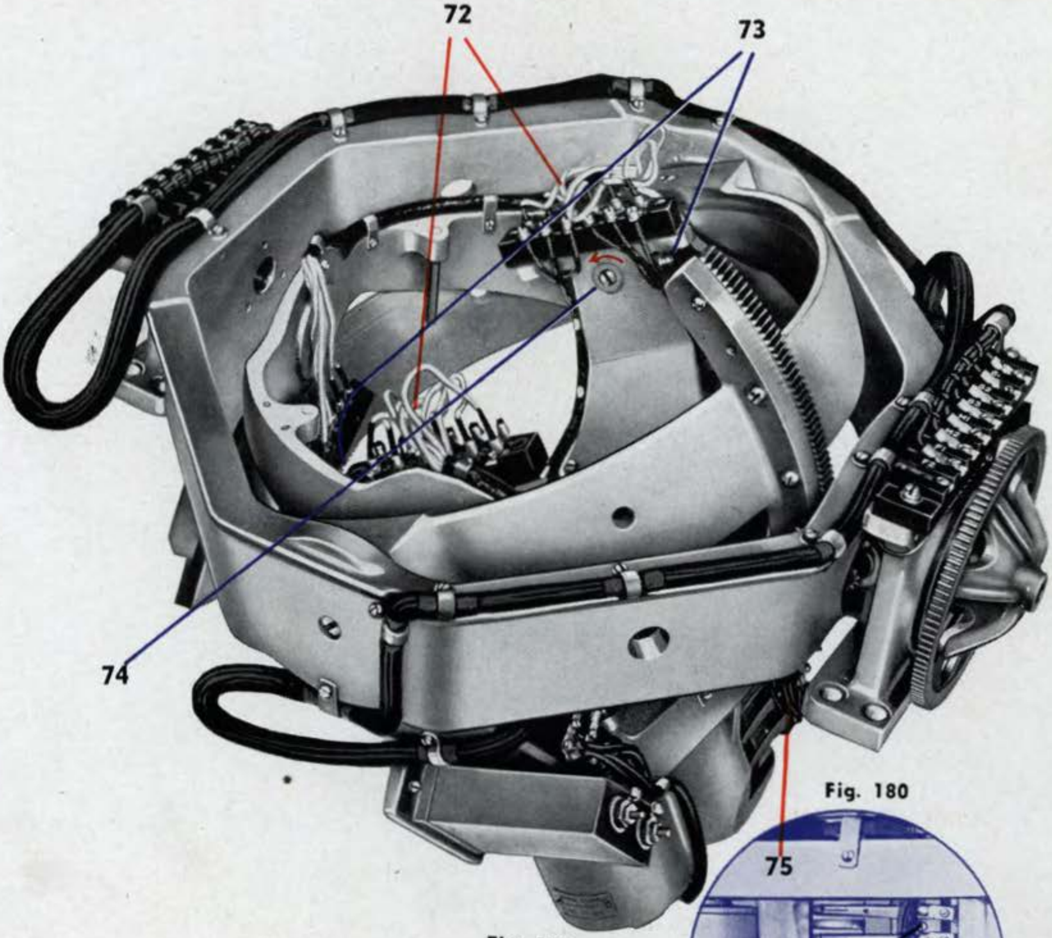

Fig. 179

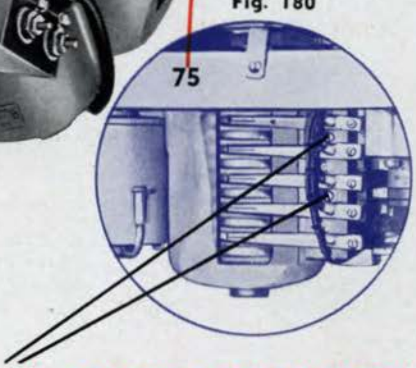

Fig. 180

74. UNSCREW THE 2 PIVOT STUDS

(toward the inside) until the gyro gimbal is free and can be lifted out.

75. REMOVE 2 BRUSH BLOCKS

from bottom frame of Level Gimbal (2 screws in each). Let hang by wires.

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76. REMOVE TAPER PIN AND COLLAR
from bottom of rotating fork shaft.

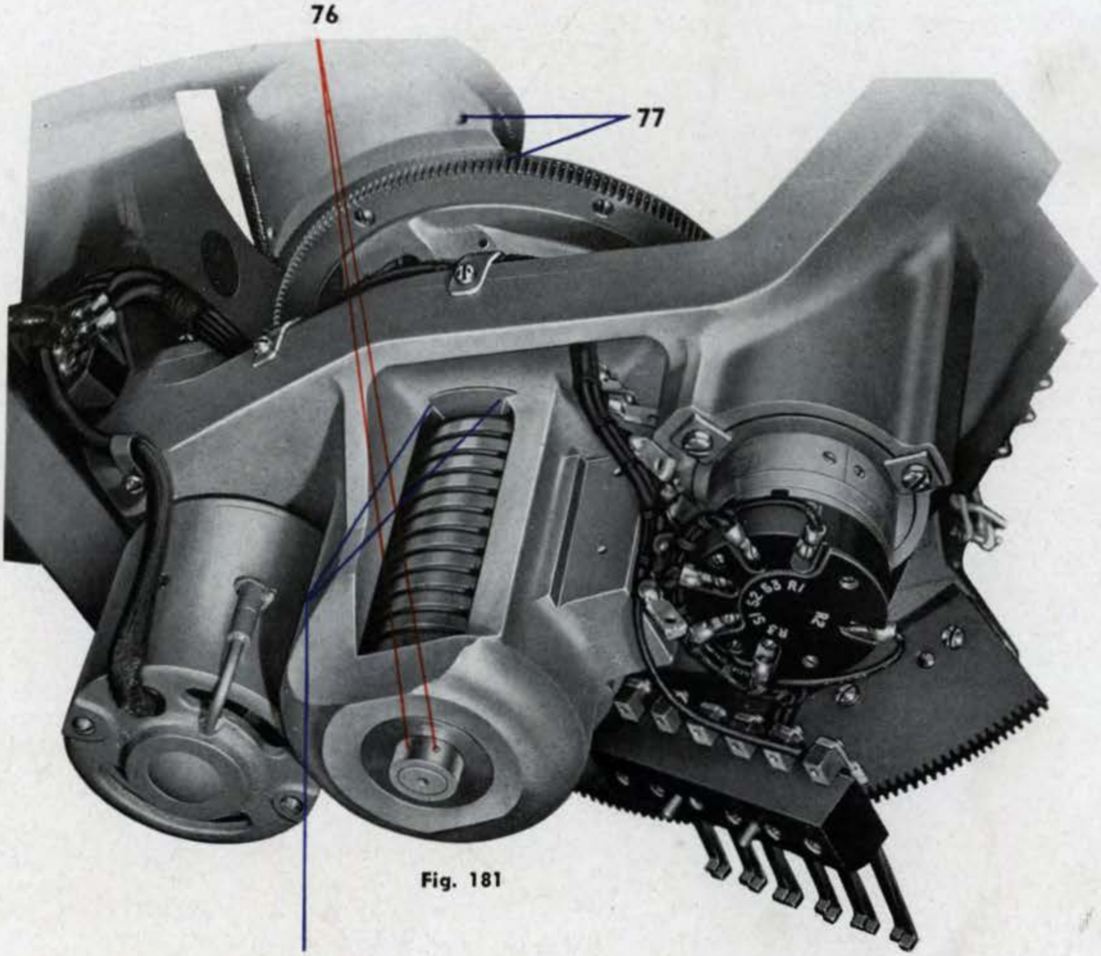

Fig. 181

76A. MARK SPACER at two points as shown in order to facilitate correct reassembly.

77. LIFT THE ROTATING FORK
up and out of the Level Gimbal.

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78. REMOVE SYNCHRO IDLER GEAR

(taper pin and collar).

On older Mods. it may be necessary to remove this taper pin and collar before performing step 77, allowing this idler gear to pull out with the rotating fork.

79. REMOVE PLATE AND IDLER GEARING

of Gimbal Rotation Motor (4 screws, 2 slip dowels).

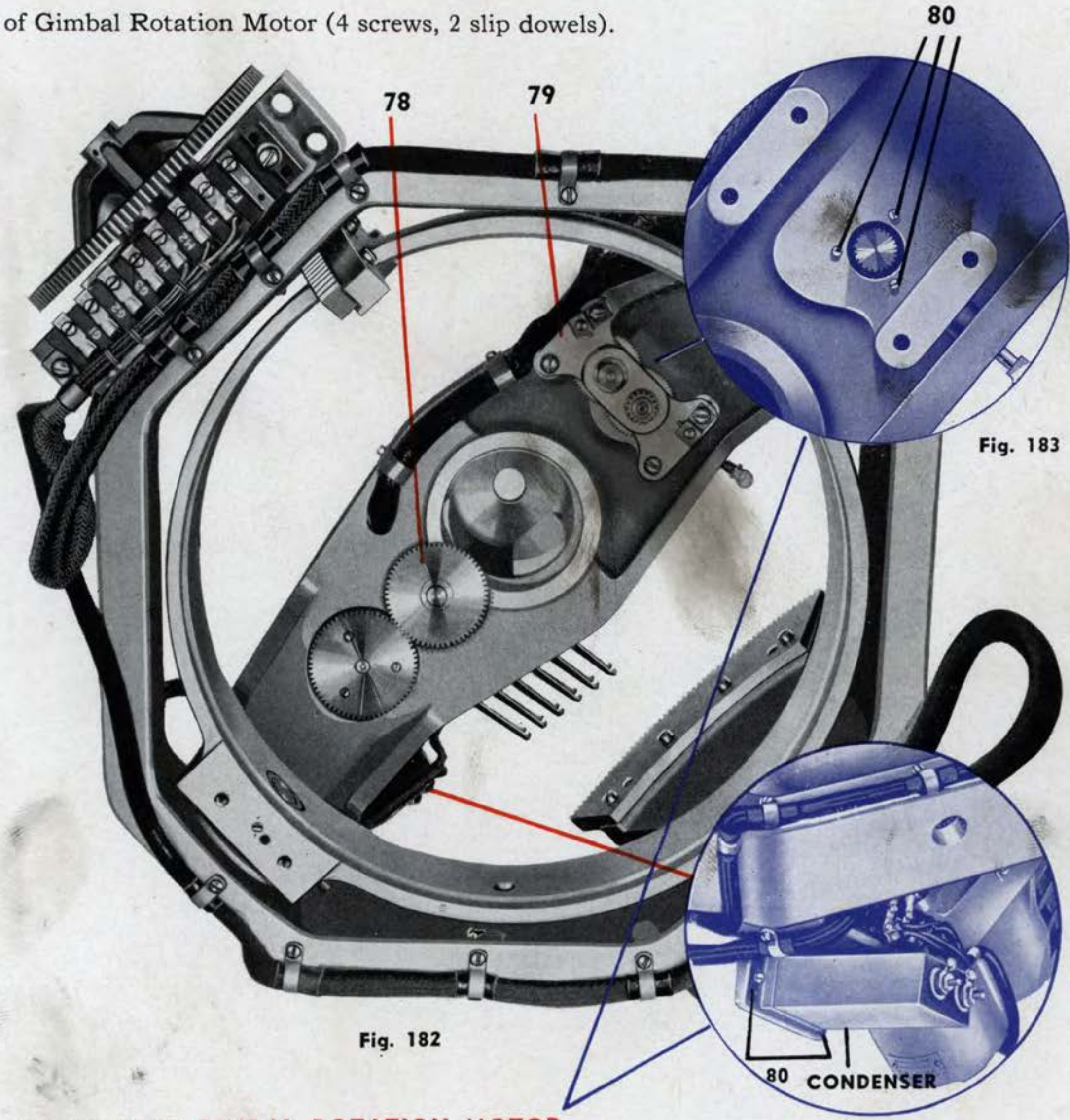

Fig. 183

Fig. 182

Fig. 184

80. REMOVE GIMBAL ROTATION MOTOR

(3 screws) and condenser (2 screws) and associated terminal blocks and wiring.

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81. LOOSEN PIVOT LOCKING SCREWS

in Level Gimbal (one on each bearing.)

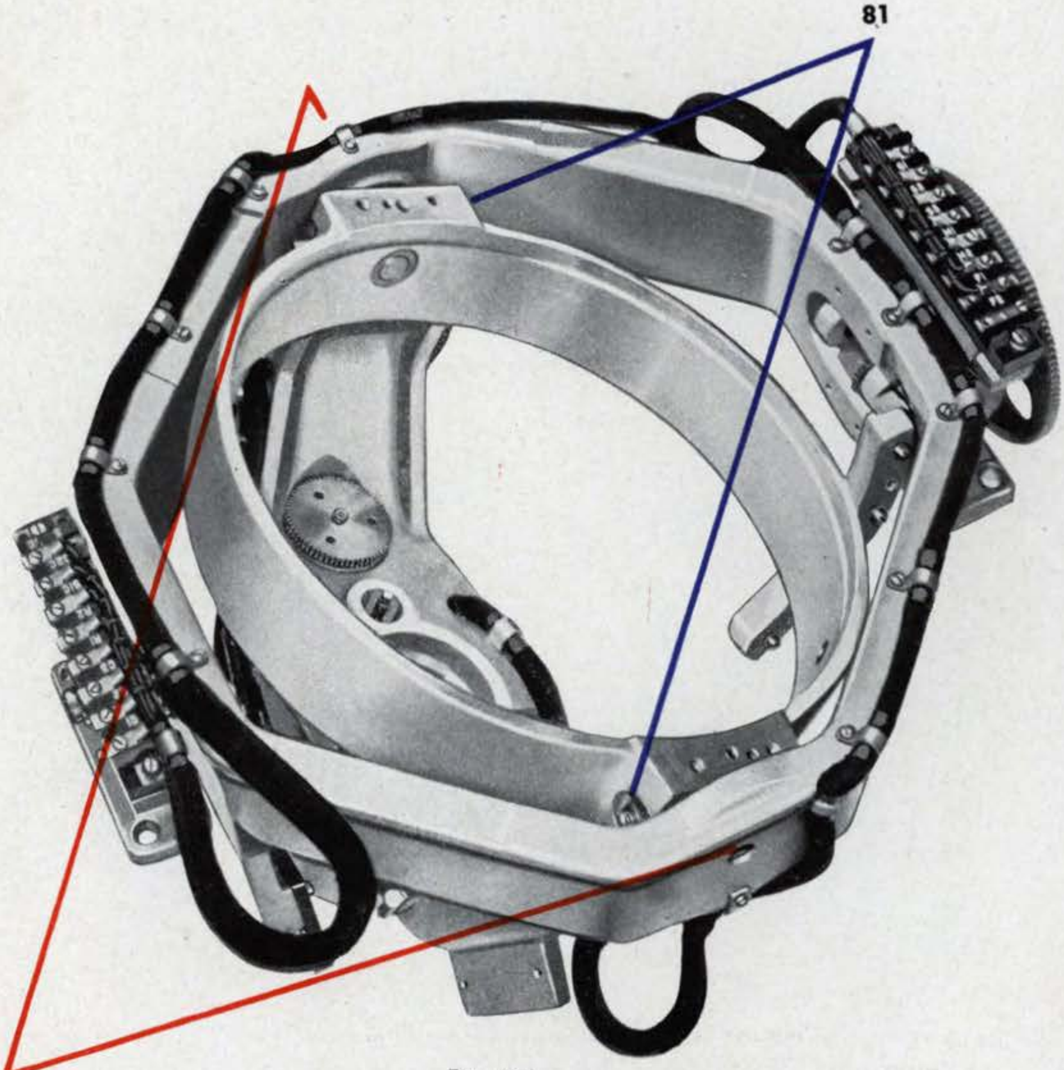

Fig. 185

82. SCREW THE 2 PIVOT STUDS

inward (from the outside) until the Level Gimbal is free and can be removed. (It will be necessary to remove wiring and clips before the gimbal can be freed.)

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Fig. 186

83. REMOVE LEVEL GEAR

(taper pin and key).

84. REMOVE TAPER PIN AND COLLAR

from behind Level Gear.

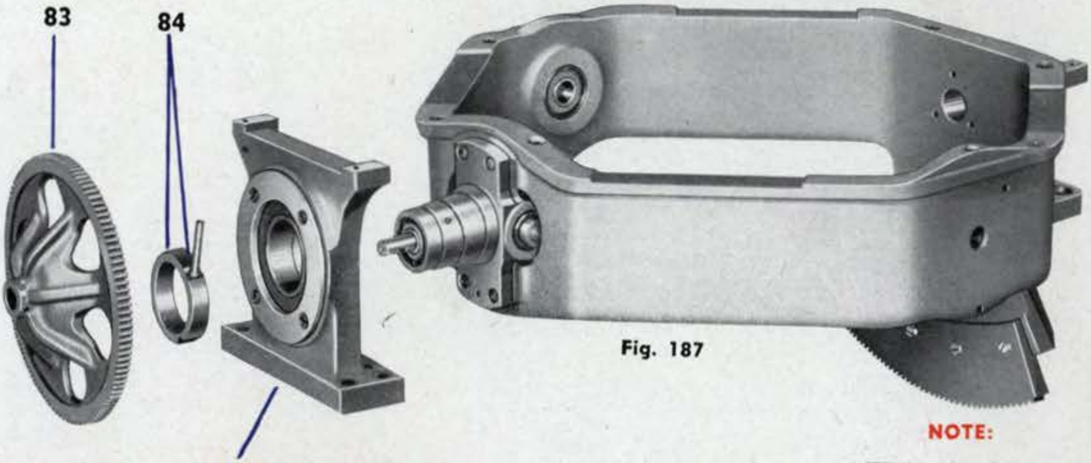

Fig. 187

85. REMOVE MOUNTING BRACKET

NOTE:

While the instrument is disassembled or during reassembly, advantage should be taken of this opportunity to lubricate the mechanism. Refer to Lubrication Log on page 131.

Fig. 188

86. REMOVE TAPER PIN, COLLAR AND MOUNTING BRACKET

from other side of gimbal.

on page 166

The reassembly of the Stable Element is accomplished by performing in reverse the disassembly procedure just outlined. (In general, substitute "replace" for "remove," "connect" for "disconnect," "tighten" for "loosen," etc., in the various steps.) As reassembly progresses, however, some of the adjustments described in the following pages must be made before certain steps of reassembly can be performed. The sequence of operations is as follows:

1. Perform steps 86 to 68 inclusive.
2. Install Latitude Motor base minus Latitude Motor and wiring (temporarily).
3. Perform Adjustment No. 2 (Alignment of gimbal bearings). This is most easily done on the bench, but can be performed after the Sensitive Element is re-installed if necessary or desirable.
4. Remove Latitude Motor base, install Latitude Motor and wiring in base. (Reverse of step 67)
5. Perform steps 66 to 61 inclusive.
6. Perform steps 60 to 45 inclusive. (See note below)
7. Perform Adjustment No. 10 (Setting of follow-up motor friction clutches).
8. Perform steps 44 to 20 inclusive.
9. Perform steps 19 to 11 inclusive.
10. Perform steps 8 to 2 inclusive.
11. Perform Adjustment No. 1 (Setting of Target Bearing dials).
12. Perform Adjustment No. 11 (Setting of stops, firing contacts and dials).
13. Perform steps 10 and 9 as part of Adjustment No. 11.
14. Perform remaining Adjustments as listed on the following pages.
15. Replace all covers.

NOTE: The "fit" on all meshed gears should be "Free Running—No Play." Whenever any of the gears are remeshed, they should, if possible, be spun by hand to check for binding, then lightly lubricated as recommended in the Lubrication Log on page 131.

NOTE: DURING RE-ASSEMBLY OF THE STABLE ELEMENT AFTER IT HAS BEEN DISASSEMBLED FOR REPAIRS, THE FOLLOWING ADJUSTMENT PROCEDURE SHOULD BE FOLLOWED* WHEN INSTALLING THE LEVEL GIMBAL.

(a.) ALIGN THE "V" COUNTERSINK IN THE GIMBAL PIVOT MOUNTING BUSHING WITH THE THREADED SET SCREW HOLE IN THE LEVEL GIMBAL.

(b.) ADJUST THE PIVOT STUDS IN THE LEVEL GIMBAL TO GIVE APPROX. 0.002 INCH PLAY BETWEEN OPPOSITE BEARINGS.

* See opposite page

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(C.) AFTER COMPLETION OF ASSEMBLY OF THE BUSHING AND PIVOT STUDS, CHECK THAT THERE IS A MINIMUM OF 1/32 INCH CLEARANCE AT ALL POINTS BETWEEN THE LEVEL GIMBAL AND THE ROTATING GYRO GIMBAL.

ADJUSTMENTS

Whenever adjustments are made in the instrument, only competent personnel should make them. Before making any changes a thorough check should be made to ascertain what adjustments are necessary to correct any trouble, thus decreasing chances of disarranging the entire system.

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Once the instrument has been reassembled according to the first 13 steps of the foregoing outline, it will be found necessary to make certain other adjustments. Any adjustment, if necessary because of a replacement or some similar reason not due to complete disassembly, may be made without recourse to other adjustments, provided all of the factors upon which the adjustment depends are correct. Otherwise they should be performed in numerical order, excepting only those which are performed *during* reassembly. No adjustment should be made by one not competent to do so.

Some of the adjustments must be made where no motion prevails, such as with the ship tied up at dock (provided the existing motion of the water is slight). The rest may be made anywhere, regardless of motion of the instrument, including with the ship under way at sea. The necessary conditions are stated in the explanation of each adjustment.

1. SETTING OF TARGET BEARING (DIRECTOR TRAIN) DIALS

(At sea, at dock or ashore)

By means of the Target Bearing input shaft train the Sensitive Element until the index mark on the training gear is accurately aligned with the lubberline engraved on the index plate. This definitely locates the zero position of the Target Bearing input shaft.

The inner (high speed) Target Bearing dial may now be set to zero degrees by loosening the securing nut with a Synchro wrench and adjusting the dial accordingly.

The outer (low speed) Target Bearing dial may be set to read zero degrees by loosening the four small round head screws which secure it to its clamping ring beneath, and adjusting the dial.

Both dials should then be secured in these positions.

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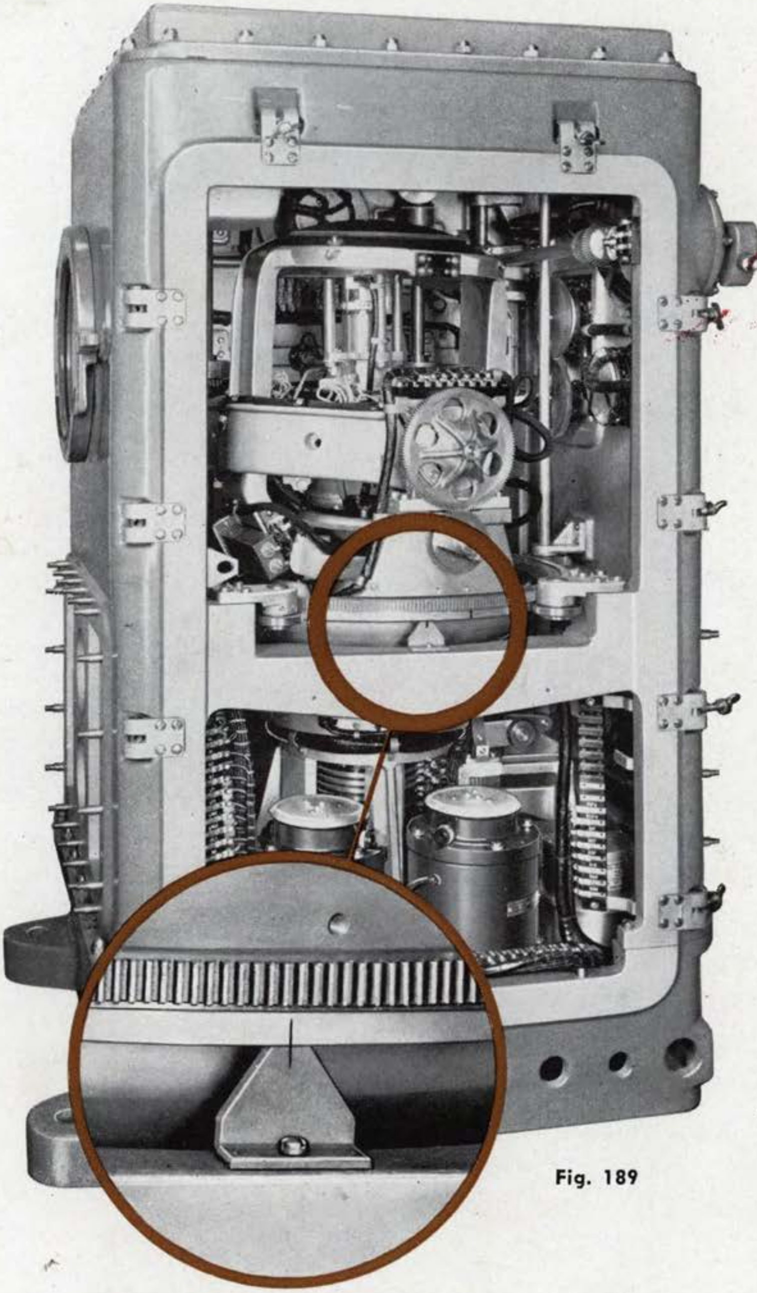

Fig. 189

Fig. 190

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2.

(At sea, at dock or ashore)

NOTE: This alignment is best accomplished by setting up the Sensitive Element on brackets on the bench.

Clamp or tie the gyro case to the rotating gimbal ring (gyro gimbal) and in turn clamp the gimbal ring to the arms of the rotating fork.

From the spare parts kit obtain the gyro gimbal bearing alignment disc and slip it over the four supporting studs for the follow-up magnet base, letting the plate rest in the mounting normally occupied by the latitude correction motor. Secure it evenly and gently in place with three screws making sure that it is not cocked or tipped in its base. Set up an indicator against the top horizontal surface of this alignment disc, fastening the indicator solidly to some part of the Level Gimbal. Adjust the gyro case clamps so that as the rotating fork assembly is turned through several revolutions the indicator will show NO deviation. The horizontal test surface is now parallel to the plane of rotation of the Sensitive Element.

Also set up an indicator against the vertical test surface of the alignment disc. The gyro case pivots and gyro gimbal pivots, which are mounted adjustably along their axes, should now be adjusted (one at a time through holes in the Level and Cross Level gimbals, as shown in Fig. 192) until the indicator needle shows no displacement for several complete turns of the rotating fork assembly. The vertical axis of the test surface is now coincident with the axis of rotation of the gimbal system.

With the instrument and bearings at room temperature, not having been heated by running, the play in each pair of bearings should be .006", and the indicator measurements should be made with the play divided equally between opposite bearings.

With the above alignment made, remove the indicator alignment disc and gyro clamps in that order and perform reassembly steps 67 to 61. If the Sensitive Element is out of the instrument, it may now be replaced, referring to the disassembly procedure in reverse.

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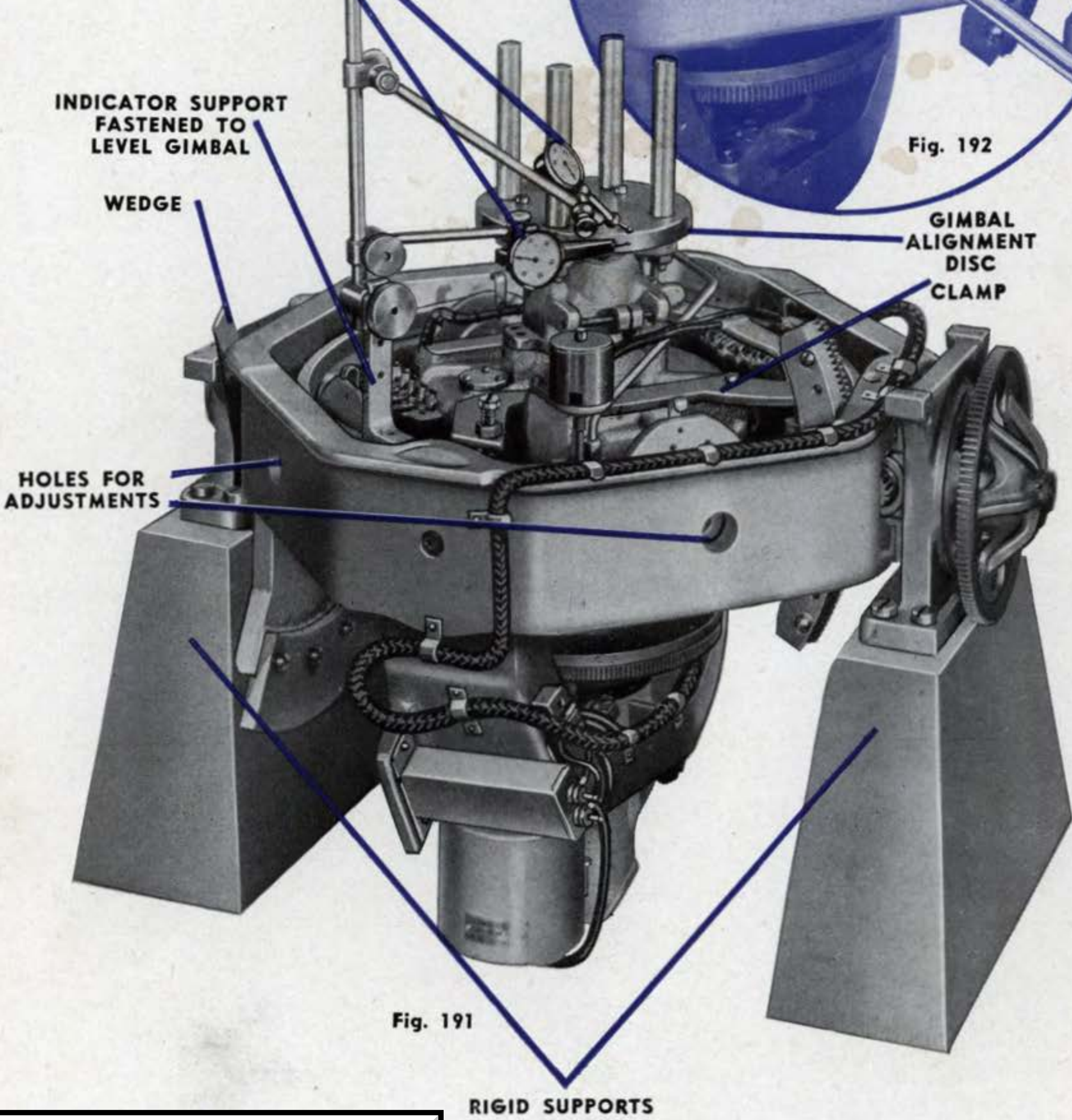

Fig. 191

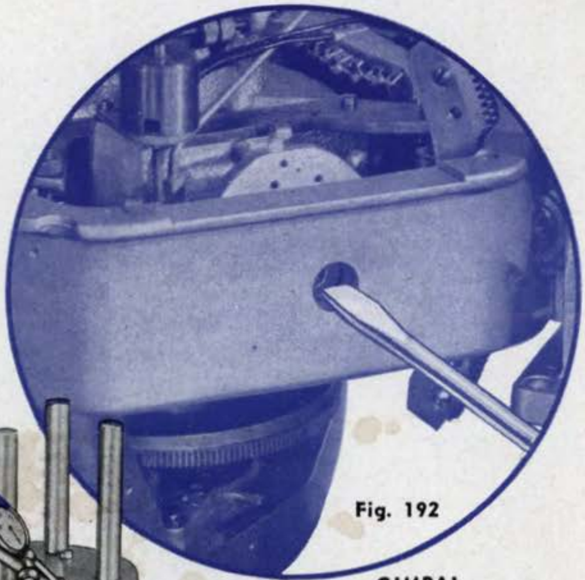

Fig. 192

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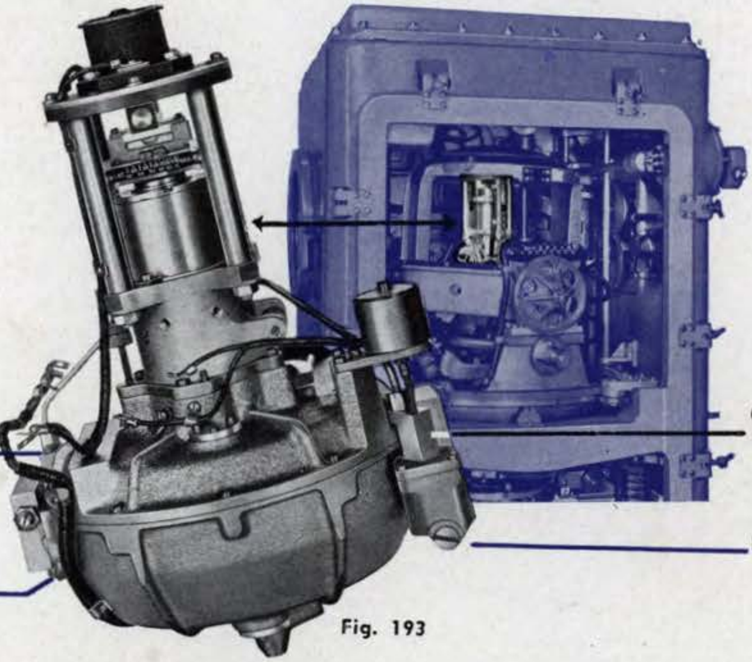

Fig. 193

3.

(At sea, at dock or ashore)

In order to drain the mercury from the damping tanks, the cutout valve must be de-energized and open. Remove the drain screw from the lower edge of the tank which supports the cutout valve. On some instruments a larger drain screw is located in the lower edge of the opposite tank. Removing either screw and tilting the gyro case so that the opening is lower than any other part of the damping system will completely drain the mercury from the system.

From the tank opposite the cutout valve, remove the cover by taking out the three securing screws and the equalizer tube. If desired, the system may now be blown out with low pressure filtered air or flushed out with clean mercury. After the drain plug(s) has been secured, carefully add exactly 11 ounces of clean mercury to the coverless tank, after which the cover and equalizing tube may be secured in place.

Only clean mercury should be used in the system as the slightest amount of dirt will prevent the flow from one tank to the other and consequently damping and settling will not take place. Extreme care should be exercised in replacing the mercury in order to prevent dropping any on the parts of the instrument situated below the Sensitive Element. In Fig. 193 the gyro is shown removed from the instrument merely to indicate the position of the drain plugs.

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4. NEUTRAL EQUILIBRIUM OF SENSITIVE ELEMENT

(At sea, at dock or ashore)

This adjustment is made to bring the center of gravity of the gyro case and gimbal rotation assembly as near as possible to the center of support.

Level the gyro case by hand, referring to the North-South and East-West levels on the latitude motor platform. After a few seconds, during which the mercury becomes equally distributed between the two tanks, energize and close the mercury cutout valve, leaving it closed throughout the adjustment procedure.

Tie the gyro gimbal to the arms of the rotating fork so that only the gyro case is free to move within the gimbal ring. Referring to Fig. 194, adjust the position of the horizontal adjustment weight No. 1 so that the gyro case will move from the vertical at approximately the same rate in either direction. With this adjustment made, position the vertical adjustment weight so that the gyro case will remain in any position in which it may be placed. (It may be necessary to again adjust the horizontal weight slightly before this condition can be satisfied.)

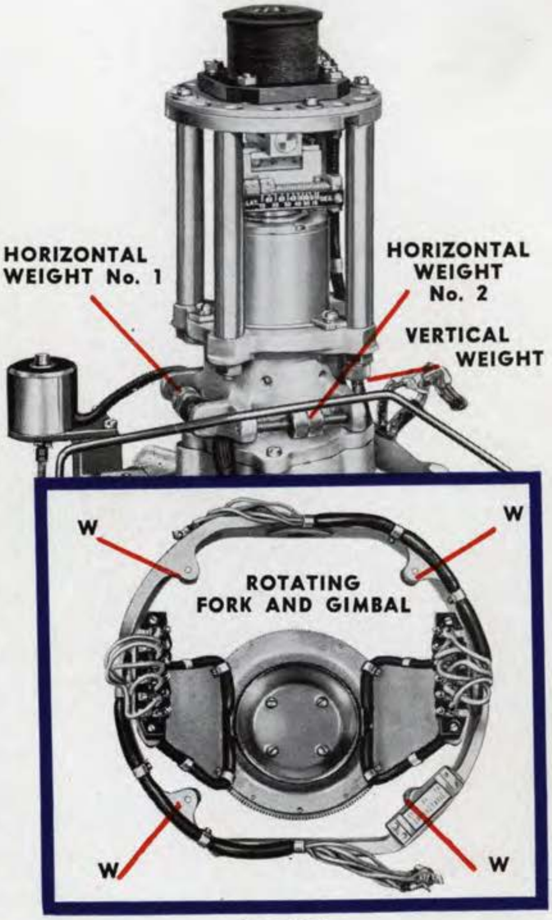

Fig. 194

Remove the ties between the gimbal ring and rotating fork and tie the gyro case to the gimbal ring so that only the gimbal ring is free to move (in the arms of the rotating fork). Adjust the position of the horizontal adjustment weight No. 2 so that the gyro case and gimbal ring will move from the vertical at approximately the same rate in either direction. With this adjustment made, position the four weights W (shown in insert) on the under side of the gimbal ring so that the gyro case and gimbal ring will remain in any position in which they may be placed. (It may be necessary to readjust the horizontal weight No. 2 slightly before this condition can be satisfied.)

Remove the ties between gyro case and gimbal ring. The Sensitive Element is now in a state of neutral equilibrium.

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5.

(At dock, or ashore) Referring to Fig. 195, train the Sensitive Element until the Level Gear is above the lubberline secured to the center of the left side of the case. Energize the gyro and follow-up amplifiers, and turn the Sensitivity Controls to their maximum settings (full sensitivity). With the gyro running but not necessarily settled, observe the motion of the Level Gear. If the flux axis of the magnet does not coincide with the axis of rotation of the Sensitive Element, the Level Gear will oscillate.

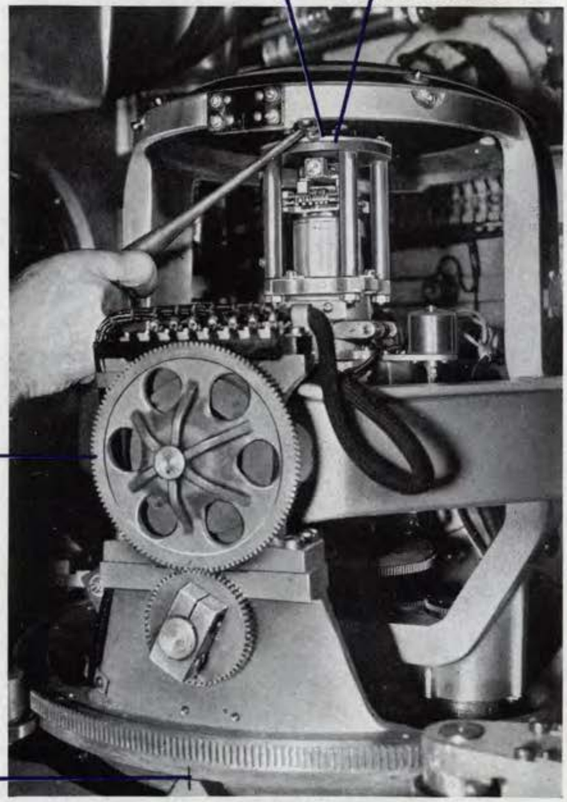

Fig. 195

Loosen *slightly* the four magnet hold-down screws (See Fig. 174 Page 159) by grasping the rotating fork of the gimbal system to prevent its rotating, and reaching through holes located in the umbrella with a screwdriver. (See Fig. 198. Page 176) With the screws slightly loosened, release the rotating fork. The magnet should now be shifted *away from* the Level Gear at the instant the Level Gear reaches its point of maximum clockwise rotation.*

When there is no further oscillation of the Level Gear, and all existing motion is in one direction due to the settling of the Sensitive Element, the axes of the magnet and gimbal rotation are concentric, and the four screws should be tightened, making certain that the magnet is not again shifted during the tightening procedure.

*This shifting of the magnet assembly can be done with a small non-metallic hammer, although it is more easily accomplished with the aid of a wooden or bakelite rod approximately ½" in diameter and one foot long. By holding one end of the rod a fraction of an inch away from the steel base plate of the magnet mounting, the other end may be tapped at the desired moment of shifting. Make certain that the inner end of the rod does not strike the aluminum support below the steel base plate.

6. POSITIONING OF NORTH-SOUTH LEVEL (At sea, at dock or ashore)

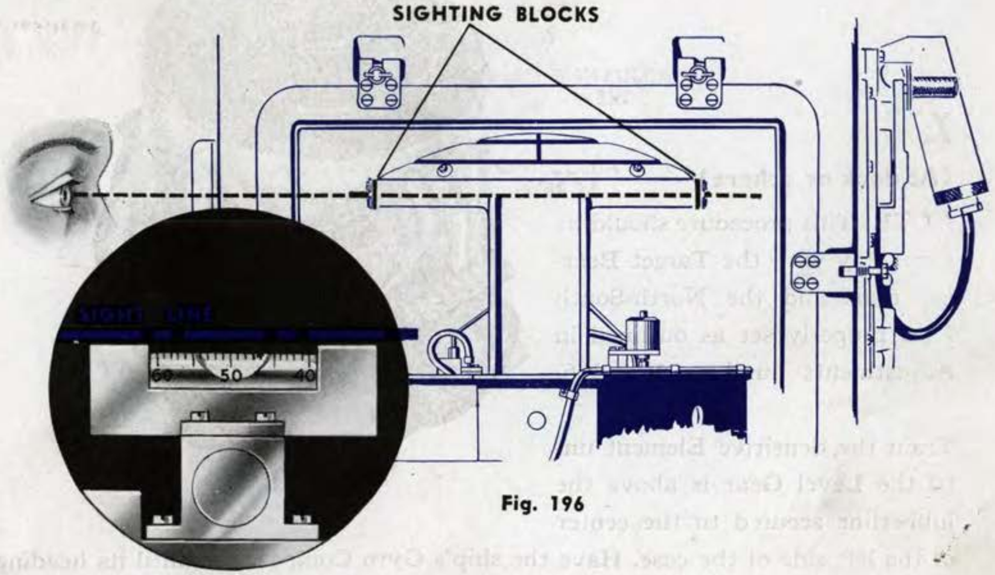

Fig. 196

Fig. 197

NOTE: This procedure should be done only with the Target Bearing dials properly set as outlined in Adjustment No. 1.

Disconnect the gimbal rotation motor from its terminal block on the Sensitive Element. Turn the Follow-up Switch on the Control Panel to "ON," which energizes the latitude correction motor and on some Mods., the gyro wheel. (On all Mark 7 Control panels except Mod. 4, energize the gyro wheel by turning the gyro supply switch to the operating position for either motor generator.)

Turn the Target Bearing input shaft until the Target Bearing dials of the Stable Element read either 90 or 270 degrees. Place the gyro case in the vertical position by hand. (Although the gimbal rotation motor is not in operation now, the gyro axis will remain nearly enough vertical to allow the adjustment to be made.)

Take a sight through the slots in the sighting blocks (See Fig. 196). The imaginary line drawn between these two slots must coincide with the longitudinal line along the top of the East-West (top) level when the graduated scale for the North-South (bottom) level is on the *East* side. See Fig. 197.

If such is not the case, loosen the three clamps which secure the 5DG Synchro differential generator to the left rear corner of the bottom chassis (refer to Fig. 210 on page 183) and turn the Synchro in the chassis until the sight lines do coincide. Then tighten the three Synchro securing clamps and reconnect the wiring of the gimbal rotation motor.

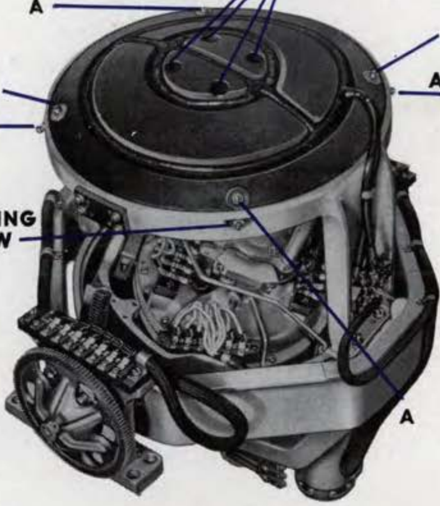

Fig. 198

7.

(At dock or ashore)

NOTE: This procedure should be done only with the Target Bearing dials and the North-South level properly set as outlined in Adjustments numbers 1 and 6.

Train the Sensitive Element until the Level Gear is above the lubberline secured to the center of the left side of the case. Have the ship's Gyro Compass set until its heading is equal to the reading of the Target Bearing dials.

With the gyro running and settled, the latitude motor energized, the gimbal system rotating, and the follow-up system turned on, observe the bubble levels on the latitude motor platform, and record their readings.

Leaving the Gyro Compass set as before, train the Sensitive Element to a position exactly 180 degrees from the former position, and again record the readings of the two bubble levels. If the two sets of recorded readings differ, the follow-up coil support must be adjusted until there is no difference.

NOTE: If the bubbles oscillate considerably, thus making readings difficult, perform Adjustment No. 9 before continuing with this adjustment.

Loosen the four screws which secure the umbrella to the aluminum support. (Screws marked A in Fig. 198.) If the bubble in either bubble level shifted when the Sensitive Element was trained 180 degrees, the follow-up coil support must be moved slightly in a direction which is 90 degrees clockwise (looking down from the top) from the direction in which the bubble moved. This statement applies to either bubble level, but as both the North-South and East-West bubbles will usually move at the same time, the follow-up coil support will quite often have to be moved in a direction which is a combination or resultant of the two individual corrections.

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After adjusting the follow-up coil support, the four screws A should be tightened and the procedure repeated until there is no difference in the bubble level readings.

Note: On some instruments adjusting screws with lock nuts are provided to facilitate shifting the follow-up coil support. (See Fig.198.) When tightening any of these adjusting screws (to shift the coil) the corresponding screws on the opposite side must be loosened. After any adjusting has been done, the lock nuts must be securely tightened, as well as the four securing screws for the support.

8. BALANCING OF LATITUDE MOTOR LEVEL PLATFORM

(At dock, or ashore)

Set the latitude weight on the motor platform to the proper latitude. Energize the latitude correction motor. The axis of the latitude weight screw should be in a true North-South direction with the scale on the East side. (Adjustment No. 6.) With the gyro running and settled and the follow-up system energized, close the mercury control cut-out valve (by turning its switch to "AUTO" and short circuiting terminals Nos. 1 and 2 on Mercury Control Sub-panel) and observe the latitude motor bubble levels.

At the end of five minutes of time the movement of either bubble should not exceed three minutes of arc.

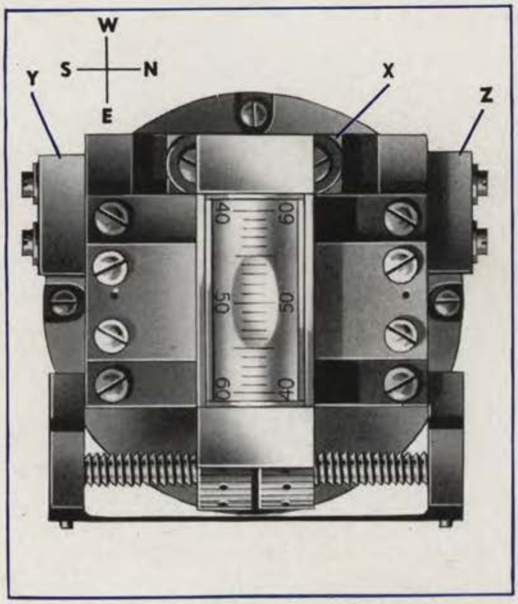

Fig. 199

If the movement of the East-West (top) bubble exceeds this value, the weight X must be shifted. If the bubble moves toward the East, shift the weight to the North, and vice versa. (See Fig. 199.)

If the movement of the North-South bubble is excessive, the weights Y and Z must be changed.

If the bubble moves toward the North, increase weights Y and Z in equal amounts or move both an equal distance to the West. If the bubble moves toward the South, remove weight from Y and Z in equal amounts North and South of the East-West axis.

Fig. 200

9.

(At dock or ashore)

With the gyro running and settled, the latitude motor energized, and the gimbal system rotating, observe the bubble levels on the latitude motor platform. If the bubbles of these levels oscillate as the gimbal system rotates, the axis of the latitude motor is not vertical, and the latitude motor must be shimmed to correct the error. Before shimming the motor it is advisable to examine the motor flange and the mounting bracket seat for burred edges or chips which would prevent proper seating of the motor. After correcting the oscillation of the bubbles, the levels themselves may be shimmed if necessary to bring the bubbles to the center of the scales of the levels.

10. SETTING OF FOLLOW-UP MOTOR FRICTION CLUTCHES

(At sea, at dock or ashore)

The Level and Cross Level follow-up motor friction clutches are both adjusted in the same manner, and set to slip under the same load. To remove a motor with its clutch, remove the two slip dowels and three securing screws (See Page 152) and lift out the motor with its mounting base as one unit. The friction torque of the clutch is increased by screwing in on the four nuts (marked A in figure 202), which increases the tension of the loading springs. Take up on all four nuts in equal amounts.

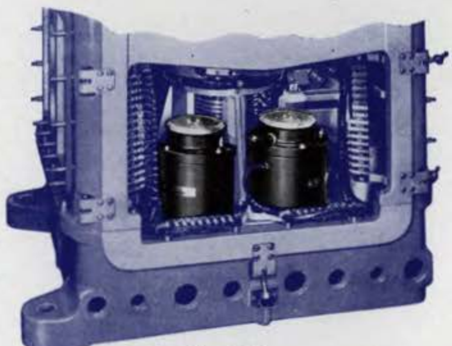

Fig. 201

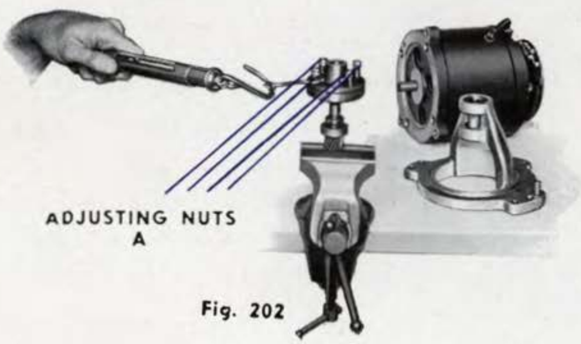

Fig. 202

The friction clutch should be adjusted to slip at a load of from 10 to 12 inch-pounds.

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11. SETTING OF STOPS, FIRING CONTACTS AND DIALS

(Ashore or in drydock)

The housing of the instrument must be leveled for this procedure so that when the Sensitive Element has settled it will be exactly perpendicular to the base of the instrument when the stops, firing contacts and dials are set at 2000 minutes. There are two ways to accomplish this leveling, the first of which is the more accurate as the second method depends upon the accuracy with which all preceding adjustments have been made.

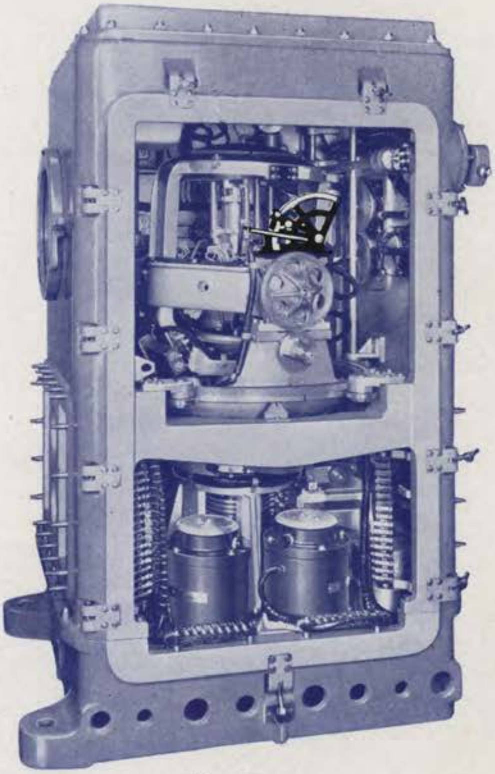

Fig. 203

Method 1: Remove the left side access cover. Remove the terminal strip from the top of either gimbal mounting block, and secure a gunner's quadrant to this block as shown in Fig. 203. Loosen the three mounting bolts which secure the instrument to the deck, and shim under the base until the quadrant shows the instrument to be level. Train the Sensitive Element 90 degrees and repeat the procedure. Add shims where necessary until the quadrant shows perfect level for any position of the training gear.

Method 2: Allow the gyro to run until completely settled, turn on the follow-up system, train the Sensitive Element assembly to 0 degrees and record the readings of both the Level and Cross Level dials. Train the Sensitive Element assembly to 180 degrees and again record the readings of both sets of dials. Compute to the nearest minute the average of the two readings of the Level dials and also of the Cross Level dials. Now shim under the base of the instrument until both sets of dials indicate the respective values just calculated for them.

When the case is finally adjusted properly by either method, the Level and Cross Level dials will not vary while the Sensitive Element assembly is trained through the complete

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360 degrees. *If both sets of dials should happen to read 2000′ no further adjustment is needed*. If they do not read 2000′ proceed as follows:

De-energize all circuits at the Control Panel, then remove the two generated stops if they are in place by referring to disassembly steps Nos. 9 and 10, page 140. Place the Selector Switch handle in the "Continuous Fire" position.

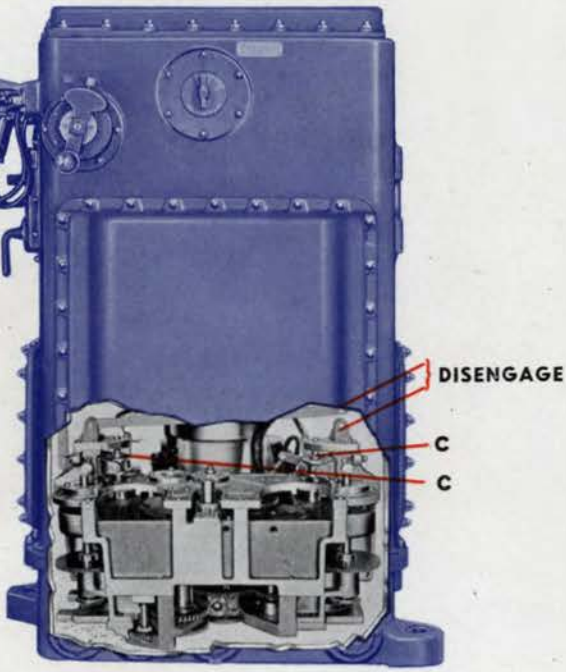

Fig. 204

NOTE:

As this is a rather difficult procedure, once the instrument has been newly assembled and before the dials have been set, the engagement of the clutches may be facilitated by disconnecting the cross bar (Fig. 204) and engaging each clutch separately. To engage a clutch, lock the corresponding hand input crank, and slowly turn the vertical shaft which drives the generated stop, at the same time pushing down on the spool of the clutch (C, Fig. 204) until the clutch engages. After both clutches are engaged, and with the Selector Switch in the "Continuous Fire" position, reconnect the cross bar.

Turn the Level and Cross Level hand input cranks in a *clockwise* direction until each selected stop has hit its upper limit.

To save confusion, the following procedure refers to one system (Level, for example), but as each *numbered* step is completed on the Level system, the same step should then be completed on the Cross-Level system before proceeding with the next step.

1. Secure the selected dial to its mounting so that the cutout is over the outer cam of its set of firing contacts. (See Fig. 206.)

2. Set this dial to read 3500′ by loosening the slip bevels located on the under side of the top plate. Secure the bevels. (See A, Fig. 205.)

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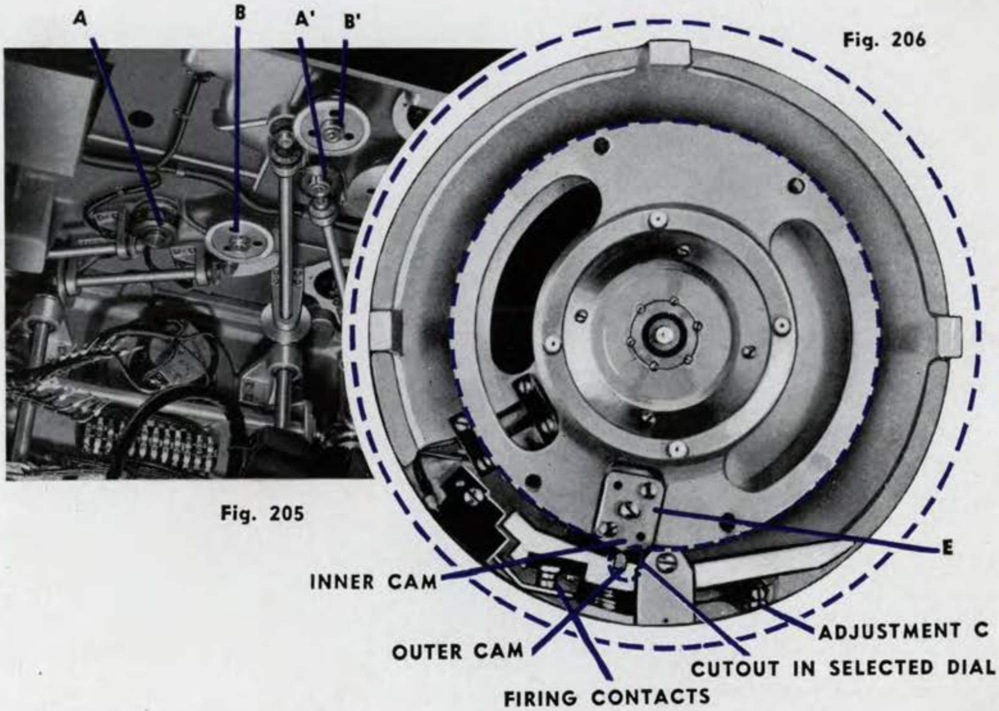


Fig. 205

Fig. 206

3. Then, by loosening a pair of slip spur gears similarly located (See B, Fig. 205) set the inner cam and its mounting plate (E, Fig. 206) until the tips of the cams just touch each other. Secure the slip spur gears.

4. Adjust the cams and points as follows:

- **A.** Remove the selected dial from its mounting plate.
- **B.** Place the Selector Switch in "Level Fire."
- **C.** Turn Level Hand Input Crank until the firing contacts are fully separated.
- **D.** Adjust these points to a gap of .040″ to .050″, using a feeler gauge to check the gap.
- **E.** Connect an electrical continuity indicator (Ohmmeter, buzzer and battery, or lamp and battery) in series with the contact points.
- **F.** Turn the hand input crank until the indicator shows that contact has been made. Read the inner (high speed) generated dial.
- **G.** Continue turning the crank until the indicator shows contact break. Read the inner (high speed) generated dial again.
- **H.** The elapsed angle of contact should be between 6′ and 8′ of arc. If it is not in this range, adjust the contacts (C, Fig. 206) until this angle of contact is obtained.

I. Contact the cams again, remove the indicator, and place the Selector Switch in the "Continuous Fire" position again.

J. Replace the selected dial, which should read 3500′.

K. Remove the inner (high speed) generated dial, using a Synchro wrench.

L. Set the outer (low speed) generated dial to 3500′ and secure its four clamp ring screws.

M. Replace and secure the inner generated dial while set to its zero position.

After the foregoing four steps have been completed on both systems, start up the Stable Element again, *waiting for the gyro to completely settle before energizing the follow-up system*. (Approx. 10 minutes.)

5. Loosen the micro-couplings (F, Fig. 207). These disconnect the Level and Cross-Level Gimbals from their respective driving gearing. (One only is visible here. Other is 180° from this one, and below training gear. Fig. 208 is an exploded diagram of this type of coupling.)

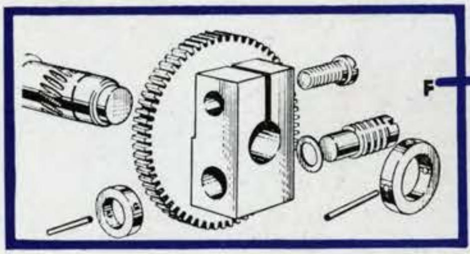
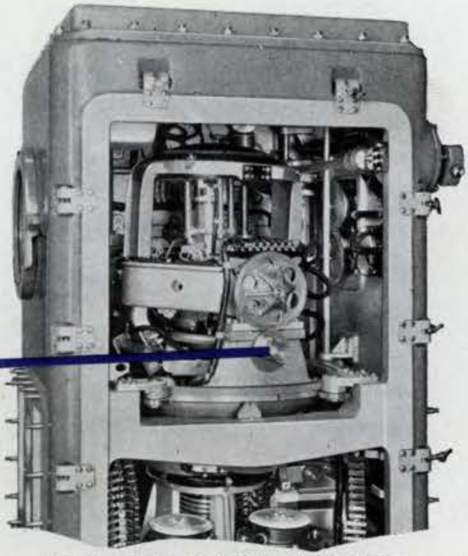


Fig. 208



Level micro coupling shown. Cross Level micro coupling opposite and below training gear.

Fig. 207

6. Turn the follow-up switches to "Manual."

7. Turn the hand input cranks counterclockwise to operate the mechanisms until the Level and Cross-Level dials all read 2000′.

8. Secure the micro-couplings.

CAUTION: The umbrella and gimbals should not be moved during this procedure or the follow-up motors will become energized and the 2000′ position of the umbrella will be lost. The entire procedure from step 5 on will then have to be repeated.

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Fig. 209

9. Turn the follow-up system off.
10. Crank both systems till their respective dials read 3350′.
11. Set the generated stops to their lower ends where the rotating dog just contacts the lug of the threaded piece attached to the spring (See Fig. 209), and install while in this position, with the dials all still set at 3350′.

The stops, firing contacts and dials are now all properly set, and the covers of the instrument may be replaced.

12. SETTING OF 6G SYNCHRO GENERATORS*

(At sea, at dock or ashore)

With the Selector Switch in the "Continuous Fire" position, turn the Cross Level follow-up switch to "Manual" and turn the Cross Level hand input crank until the generated dials read 2000′. This is the zero position of the gearing which drives the Synchro generators.

Electrically connect the Synchro generators (one at a time) to a standard Synchro motor.

Fig. 210

Remove the three clamps (See Fig. 210) which secure the Synchro generator being set, and remove the generator far enough for its driven gear to become unmeshed from the driving gear. Turn the shaft of the generator until the standard Synchro motor reads as closely as possible to zero and then replace the generator and remesh its gearing. Turn the case of the generator in the chassis of the bottom section until the standard Synchro motor reads exactly zero, and replace and secure the three securing clamps. On the Mark 5 and Mark 6 Mod. 1 Stable Elements, the same procedure must be followed for the Level systems, exactly as outlined, as well as for the Cross Level system on the Mark 6 Mod. 1.

*This procedure should be performed only with the Level and Cross Level dials properly set.

SEE PAGE 94-A FOR ADJUSTMENT OF TRAIN TRANSMITTING UNIT
SEE PAGE 94-L FOR ADJUSTMENT OF CONTINUOUS LEVEL TRANSMITTING UNIT

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CASUALTIES

Trouble-shooters' Guide to Ailments in Mechanical and Electrical Functions, with probable causes and remedies.

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GENERAL

The necessary initial settings and adjustments of the Stable Element are made when the instrument is first assembled. The settings and adjustments of the instrument necessary for alignment with the rest of the fire control system are made on installation.

Any mechanical trouble which might arise can usually be detected by a careful inspection of the various parts of the mechanism. If any of the initial settings have been disturbed, the adjustment procedures outlined in the preceding section should be carefully followed. Only on positive proof that it is necessary should adjustments or replacement of parts be attempted, and then only by one competent to do so.

Electrical troubles are not often easily detected. A superficial examination should first be made on the entire follow-up system. Note the condition of all tubes and determine if filaments are energized. (The filaments should all show a dull red color.) Examine the physical circuit for corrosion, insulation breaks or punctures, or foreign objects which might cause short circuits, loose connections, and damaged parts. Also determine if the switches on the panel and on the Stable Element seem to operate properly. If nothing unusual can be found visually, a more thorough check must be made to localize the trouble.

The following is an outline of the troubles that might arise in the operation of the follow-up system, together with their possible causes and remedies. Reference to page numbers indicate the page in this manual where the function or construction of the unit in question is described.

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SENSITIVE ELEMENT FAILS TO SETTLE

CAUSES	REMEDIES
1. Mercury control valve not functioning properly.  Fig. 211	(a) Check operation of control valve. (b) Short terminals #1 and #2 on Mercury Control Panel. When mercury control switch is thrown to "Auto" position, the valve should close (down). When in "ON" position, the valve valve should open (up).
2. Latitude weight incorrectly set.  Fig. 212	(a) Set weight to latitude corresponding to ship's position.
3. Latitude motor incorrectly set.	(a) See that when the motor is energized from the Gyro Compass, the latitude scale lies North-South with the zero latitude mark toward the North and the graduated scale on the East.
4. One or both follow-up systems not cut in.  Fig. 213	(a) Energize the follow-up.

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SENSITIVE ELEMENT FAILS TO SETTLE

CAUSES	REMEDIES
5. Gimbal bearings too tight.	(a) Check and correct. These bearings should have from .002″ to .004″ play when the instrument is cold.
6. Direction of rotation of gyro reversed.	(a) Both the gyro wheel and gimbal mountings should rotate clockwise as viewed from the top. If gyro rotation is correct, a torque applied from right to left will cause the gyro to erect.

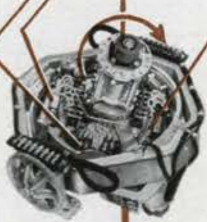

Fig. 214

SENSITIVE ELEMENT SHOWS ERROR ON TURN

CAUSES	REMEDIES
1. Mercury control valve not functioning properly.	(a) Check operation of control valve. (b) Mercury Control Switch should be in "Automatic" position.

Fig. 215

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SENSITIVE ELEMENT SHOWS ERROR ON TURN

CAUSES	REMEDIES
2. Sensitive Element out of balance.	(a) With the mercury evenly distributed in the tanks, the gyro and its mountings should be in a state of neutral equilibrium. (See Adjustment No. 4).

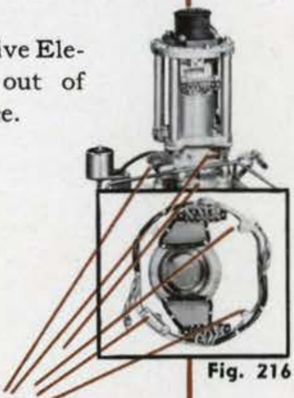

Fig. 216

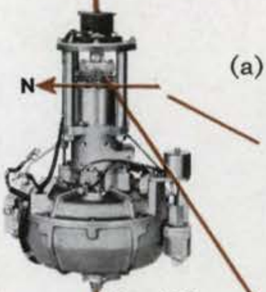

Fig. 217

CAUSES	REMEDIES
3. Latitude motor incorrectly set.	(a) See that when the motor is energized from the Gyro Compass, the latitude scale lies North-South with the zero latitude mark toward the North and the graduated scale on the the East.
4. Latitude weight incorrectly set.	(a) Set weight to latitude corresponding to ship's position.
5. Gyro speed incorrect.	(a) Gyro speed depends upon motor-generator speed. Check motor-generator speed, which should be approximately 1750 R.P.M.

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FOLLOW-UP FAILS COMPLETELY TO FUNCTION

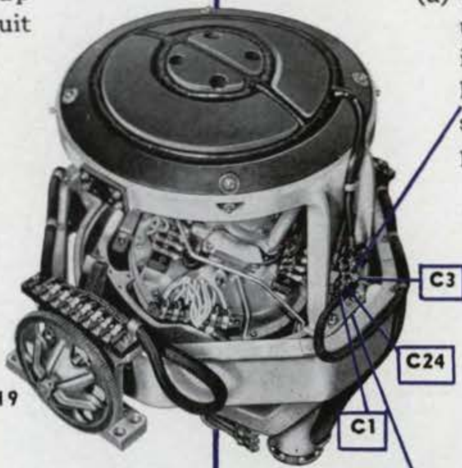

Fig. 219

CAUSES	REMEDIES
1. Follow-up Coil circuit open.	(a) Check for follow-up coil continuity. (Open follow-up coil should be replaced. (b) Check continuity of follow-up coil circuits through Stable Element to amplifiers.
2. Follow-up Coil Circuit shorted.	(a) Check for shorts in or across terminals of follow-up coils. Replace defective coil.
3. Follow-up magnet coil circuit open or shorted.	(a) Check for open in follow-up magnet coil or in leads to magnet coil. Replace coil if open. (b) Check for short in magnet coil. Replace coil if shorted, then— (c) Check 5 amp. S.E. A.C. fuses on Control Panel, and replace if blown.


Fig. 220

Fig. 221

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FOLLOW-UP FAILS COMPLETELY TO FUNCTION

CAUSES	REMEDIES
4. D.C. Supply voltage reversed.	(a) Check and correct polarity of D.C. leads.
5. Defective amplifier tubes.	(a) Replace defective tube or tubes.
6. Switches on Stable Element set on an unworkable combination.	(a) Level follow-up system will not work if Level Follow-up Switch is in "Manual" position with Selector Switch in "Level Fire." Cross Level follow-up system will not work if Cross Level follow-up switch is in "Manual" position with Selector Switch in "Cross Level Fire." Check positions of these three switches.
7. Follow-up will not drive but C6A tube passes current.	(a) Check power circuits. Common lead to follow-up motor open.
8. Follow-up will not drive and C6A tube does not pass current.	(a) Check pre-amplifier. Plate transformer open.

8a

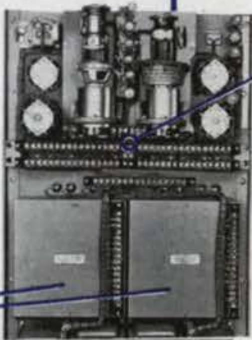

Fig. 222

Fig. 223

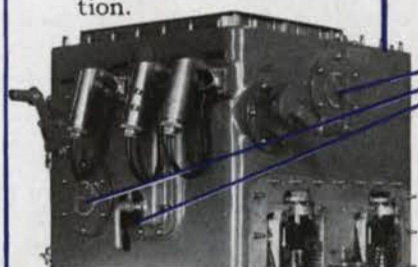

Fig. 224

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FOLLOW-UP TENDS TO RUN IN ONE DIRECTION

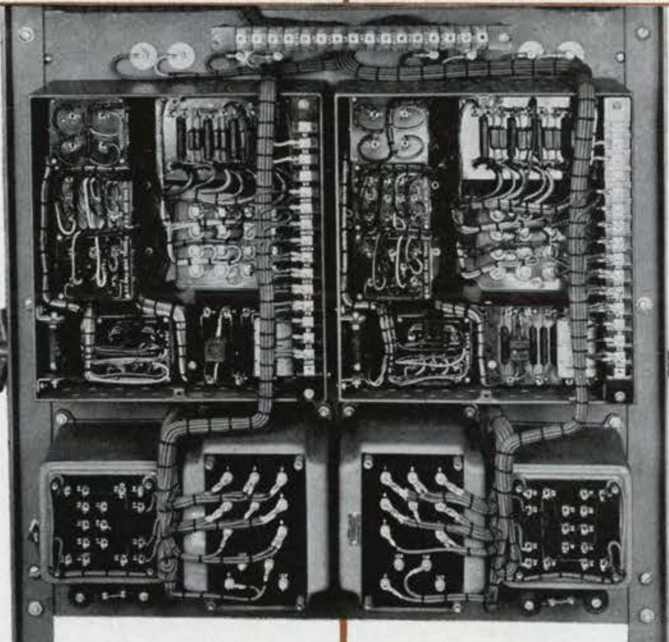

Fig. 225

CAUSES	REMEDIES
1. Defective insulation between follow-up coil circuits and other circuits.	(a) Check for grounds and punctures in shielding. (b) Make continuity checks according to Resistance Check Chart, page 214.
2. Grid circuits of grid-controlled rectifiers open.	(a) Perform voltage tests according to Voltage Check Chart, page 208.
3. Defective grid shielding in first stage of pre-amplifier.	(a) Make sure cable shield is grounded.

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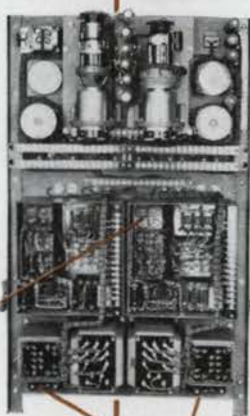
CAUSES	REMEDIES
1. Sensitivity of amplifier too great.	(a) Re-adjust Sensitivity (see page 125).

Fig. 226

CAUSES	REMEDIES
2. Short or open in circuits to anti-hunt unit.	(a) Check continuity of anti-hunt circuits. (b) Perform resistance checks according to Resistance Check Chart, page 214.



4a

Fig. 227

ANTI-HUNT

CAUSES	REMEDIES
3. Short or open in anti-hunt unit.	(a) Check for open circuit and correct or replace unit.
4. Excessive A.C. ripple on the D.C. supply for the pre-amplifier.	(a) Replace D.C. Rectifier Unit.

FOLLOW-UP NOT SMOOTH

CAUSES	REMEDIES
1. Excessive variation in amplitude and frequency of A.C. supply voltage.	(a) Trace cause and correct.
2. Incorrect D.C. bias.	(a) Make voltage checks. (See pages 200 and 210).
3. Excessive vibration of Stable Element case or deck.	(a) Increase "Dead Space" by lowering Sensitivity until roughness just stops.
4. Gyro vibrating.	(a) Check bearings for excessive looseness; adjust, align and balance. (b) Replace gyro.

Fig. 228

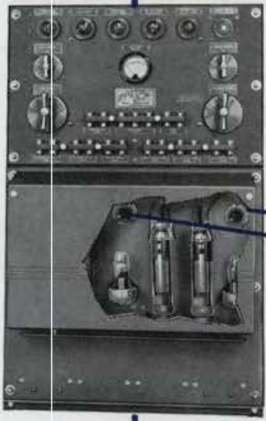


Fig. 229

Fig. 230

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EXCESSIVE ECCENTRICITY (Over 1 minute on dial)

CAUSES	REMEDIES
1. Magnet axis does not coincide with axis of rotation.	(a) Check and adjust as outlined in Adjustment No. 5, page 174.

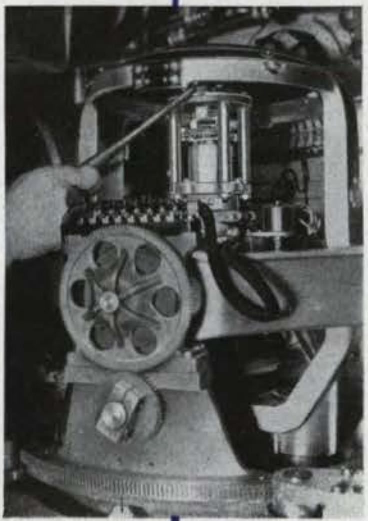

Fig. 231

CAUSES	REMEDIES
2. Gimbal bearings too loose.	(a) Check and correct. Play should be .006″ per pair of bearings, equally divided between the two.

Fig. 232

FOLLOW-UP NOT SMOOTH

EXCESSIVE ECCENTRICITY

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1
C6A TUBES DO NOT FIRE

The following applies to either Level or Cross Level follow-up amplifiers and rectifiers, since the circuits of the two systems are identical. If both C6A tubes in either rectifier circuit fail to pass current (as indicated by absence of a bluish glow), perform the voltage checks outlined in the Voltage Check Chart on page 208. By this means a faulty bias unit, transformer, or interconnecting lead can be quickly isolated and repaired or replaced. If one C6A is inoperative proceed as follows:

With the follow-up circuits energized, place a 0.1 mfd. condenser, a 50,000 ohm resistor, or the fingers of one hand across the plate and grid prongs at the top of the tube. (This has the effect of putting an in-phase voltage on the grid and should cause the tube to carry current.) Passage of current indicates trouble in the grid circuit, in which case the fault should be isolated according to the procedure outlined on page 204 under "one C6A tube passing Excessive Current." Failure to pass current indicates either a defective tube or an open in the plate circuit. Sectionalize the circuit in the following manner:

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C6A TUBES DO NOT FIRE

A. A tube suspected of being defective may be checked by replacing it with one known to be good, if available. Otherwise, disconnect the grid and plate leads, connect a 0.1 mfd. condenser or a 50,000 ohm resistor across the grid and plate terminals, and connect a 115 volt A.C. supply, with a 40 ohm resistor in series, across the plate and one filament terminal. (See Figs. 233, and 234, page 199.) Passage of current indicates a good tube.

B. With a good tube in place and connected properly, place a 40 ohm resistor across terminals #5 and #8 of the plate transformer (See Fig. 235, page 199.)

1. Failure of the tube to fire indicates an open transformer winding, or an open in the circuit wiring between the tube and the transformer.
2. Passage of current indicates trouble in the anti-hunt circuit, in the Stable Element, or in the circuits leading to the Stable Element.

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C. Place the 40 ohm resistor across the armature terminals on the rear of the Control Panel. (For Level follow-up trouble, use terminals LA and LA1 or LA2; for Cross Level follow-up trouble use CLA and CLA1 or CLA2.) See Fig. 235.

1. If the tube fails to pass current, the anti-hunt unit is at fault. Check for open circuit and repair or replace.

2. If the tube passes current, it indicates an open circuit in the wiring of the Stable Element or in the connections to it.

D. Trouble in the Stable Element can be sectionalized by placing the 40 ohm resistor across the armature leads on the Stable Element terminal block in the same combinations as in the preceding step and in combinations of "M" terminals (LA and LMA1 or LMA2; CLA and CLMA1 or CLMA2); also across the common terminal and each outside terminal of each limit switch in turn, and across terminals D3 and E3 of the respective follow-up switch. If any of these connections causes the tube to fire, the trouble lies in that unit.

C6A TUBES DO NOT FIRE

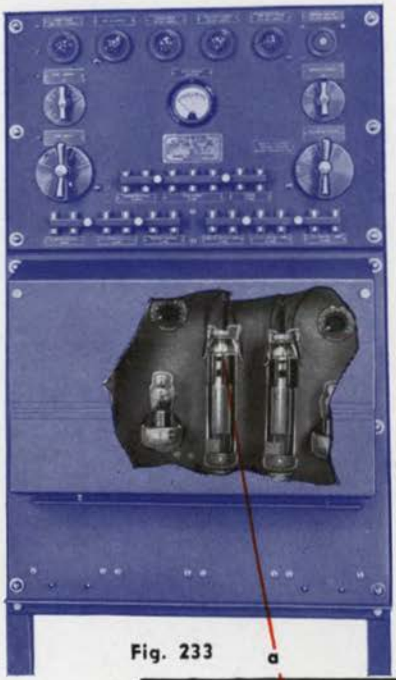

Fig. 233

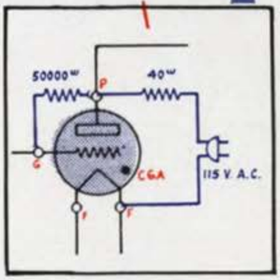

Fig. 234

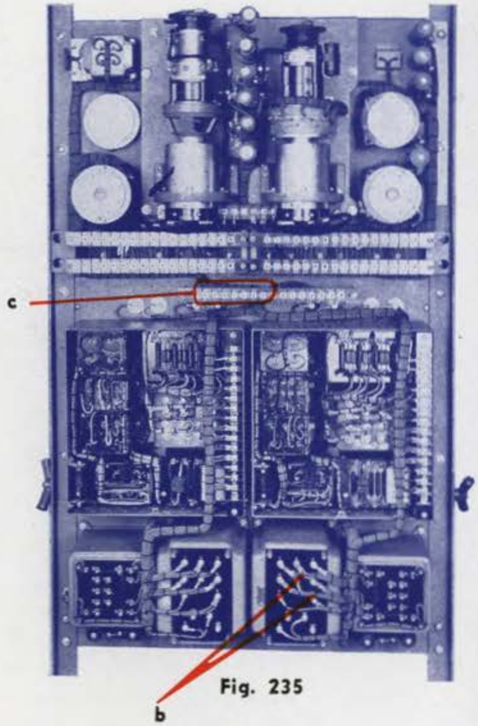

Fig. 235

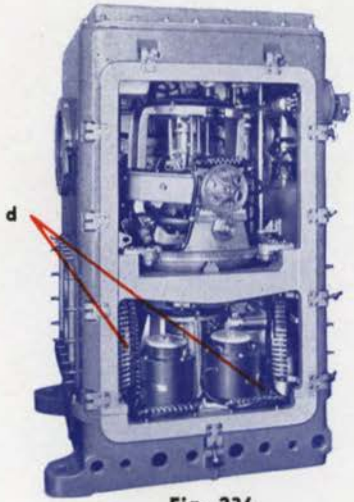

Fig. 236

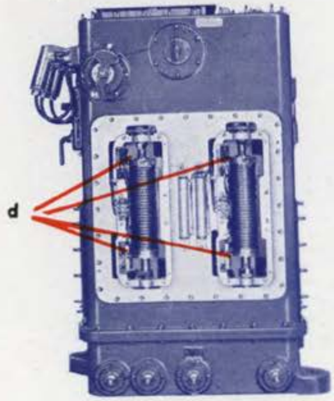

Fig. 237

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BOTH C6A TUBES PASSING EXCESSIVE CURRENT

This condition may be caused by any of the following. Refer to Figs. 238 to 240. (Only general conditions are listed under this heading as it can be assumed that defective operation of both tubes would be due to failure in the primary or common circuits. Faulty operation of one tube indicates trouble in the individual secondary circuits, as outlined on the preceding page.)

A. Too little or no D.C. grid bias, caused by open or short circuit in the transformer windings or connections to them. Make tests number 20 to 24 outlined in Voltage Check Chart, pages 209 and 210.

B. A.C. bias voltage too high, or of improper phase angle. Perform tests number 15 to 19 listed in Voltage Check Chart, page 209. Also check the 185 ohm resistor (R-29) and the 4 mfd. condenser (C-13). Replace if defective or if suspected of being defective.

C. Anti-hunt circuit open or voltage too small, preventing damping of the hunting oscillations. Check windings of anti-hunt transformer and check condensers and resistors in this circuit. (Tests number 34 to 37 and 42 to 48 of Resistance Check Chart, page 216.)

D. Amplifier circuit not functioning properly. Check voltage across primary of interstage transformer (Test number 34 of Voltage Check Chart, page 210). (A.C. voltage should be zero when signal is short-circuited.) If trouble appears to be in this circuit, localize the fault area as follows:

1. Adjust the potentiometer to zero sensitivity. If the trouble disappears it is an indication that the fault is in the first stage of the amplifier circuit, and checks should be made for an open grid, grounded grid, defective input transformer, defective copper oxide rectifier in the D.C. supply, shorts or opens in the wiring, etc.

   The simplest method for checking this circuit is a voltage analysis under two conditions. Disconnect the wires from the plate and grid terminals of the rectifier tubes. Obtain voltage measurements first with the signal input terminals short-circuited and then with the signal circuit functioning when the Level and Cross Level dials are offset from the 2000′ mark. (Tests number 29 to 40 of the Voltage Check Chart, page 210.) In all cases the readings should be a maximum of 1 volt with the signal terminals shorted, and as indicated in the "Required" column with the Follow-up Coils in operation.

2. Another step in testing the first stage of amplification is to localize the signal circuit external to the amplifier unit. Disconnect the

follow-up coil at its terminals in the Stable Element, replacing it with a 200 ohm resistor. If the trouble disappears, the fault can be attributed to a defective follow-up coil. If not, sectionalize the circuit further by disconnecting the signal leads from terminals LS1 and Gnd. (or CLS1 and Gnd.) on the Control Panel and placing the 200 ohm resistor across these terminals. If the trouble disappears under these conditions, check the signal leads between Control Panel and Stable Element for grounds, punctured cable, or improper pickup due to stray fields or contact with other energized circuits.

3. If trouble is not eliminated by decreasing potentiometer to zero, remove the 6A6 amplifier tube from its socket. Disappearance of the trouble under this condition indicates a fault in the second stage of amplification. A voltage analysis, similar to that made in checking the first stage, will help in locating faults.

A general check should also be made on all circuit components, these tests being outlined in the Resistance Check Chart starting on page 214.

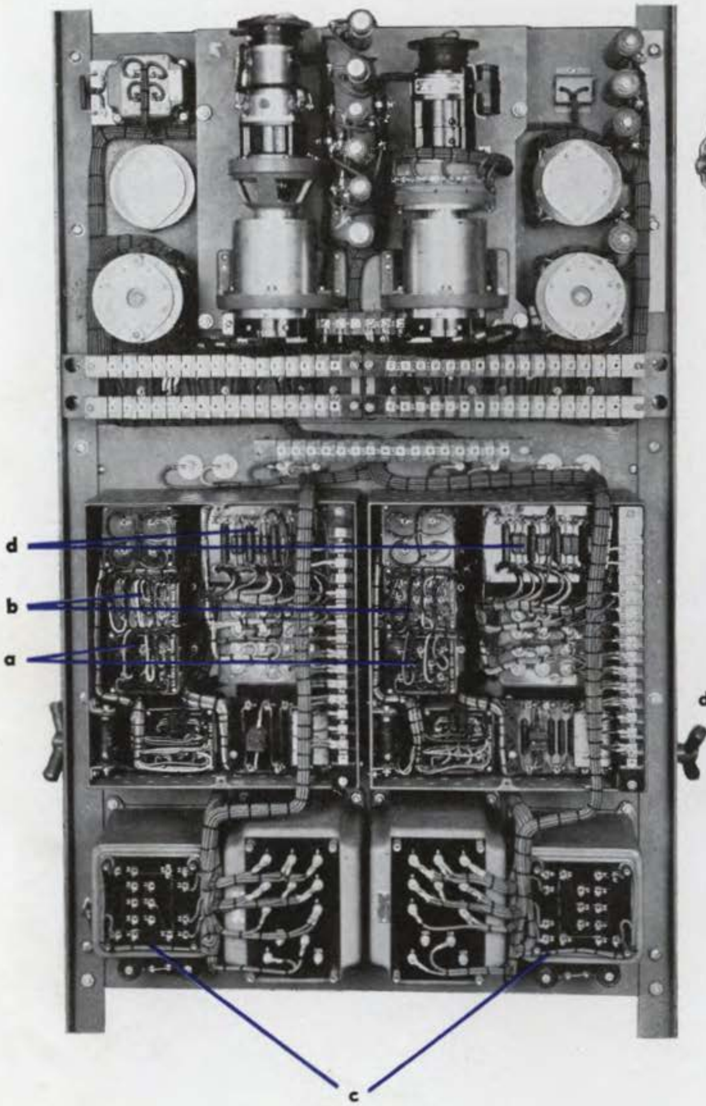

Fig. 238

Fig. 239

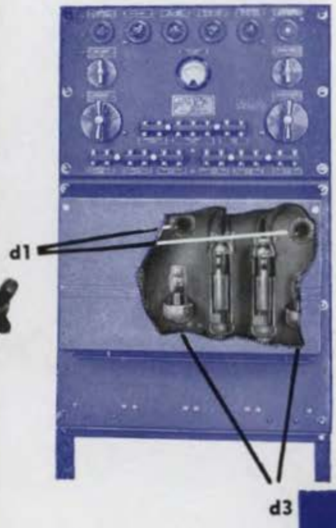

Fig. 240

BOTH C6A TUBES PASSING EXCESSIVE CURRENT

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With no signal from the follow-up coil, both rectifier tubes should be passing a small amount of current as indicated by a faint blue glow. If one tube appears to be much brighter than the other, check both the plate and grid circuits as follows:

ONE C6A TUBE PASSING EXCESSIVE CURRENT

Plate: Check for shorts in the leads to the follow-up motor in the Stable Element. Trouble in this circuit usually manifests itself in erratic performance of the follow-up motor, causing it to run in one direction only, or to operate jerkily.

Grid: Check the secondary circuits of the D.C. bias, A.C. bias, anti-hunt, and interstage transformer windings of the tube in question. Voltages in the branches should be approximately the same as those listed in the Voltage Check Chart, page 208, and also similar to those of the satisfactory tube in the same follow-up circuit. An examination should also be made of the grid wires for punctures shorting the wires to their shields.

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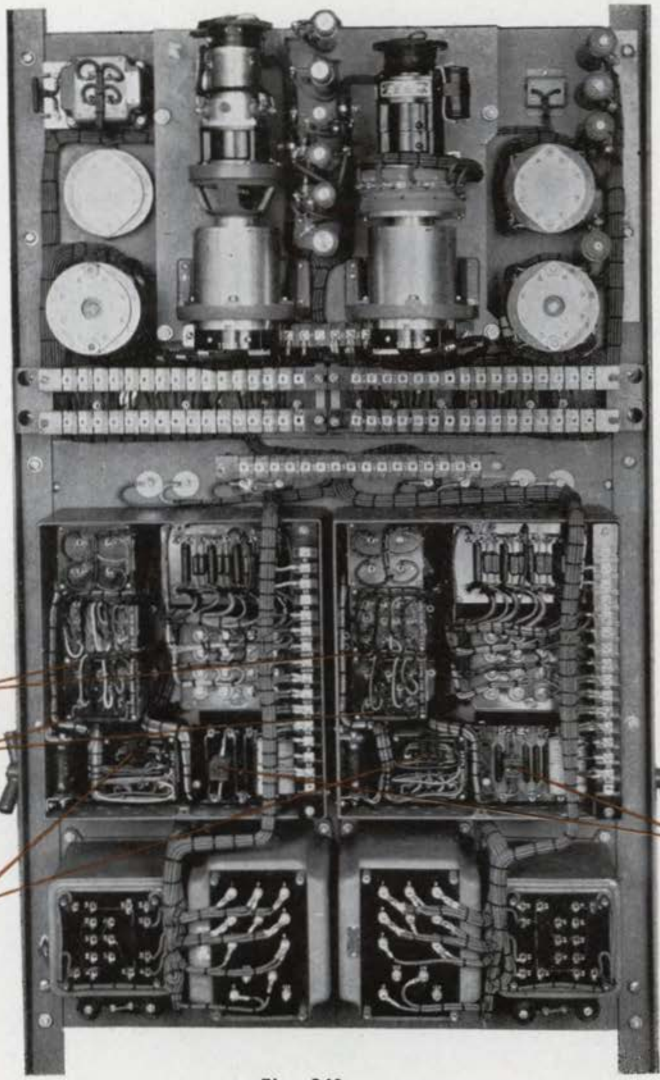

Fig. 241

ONE C6A TUBE PASSING EXCESSIVE CURRENT

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FOLLOW-UP NOT SENSITIVE AND DEAD SPACE TOO LARGE

Set potentiometer at zero sensitivity and note the appearance of the rectifier tubes. All tubes should pass an equal and small amount of current as determined by a faint bluish glow. This condition indicates that the grid biasing on all tubes is correct and that only a very small signal is necessary to cause follow-up driving. If this condition does not exist, and a voltage check-up reveals no other apparent fault, the D.C. bias voltage should be reduced as follows:

Remove the 5000 ohm resistors across terminals 1 and 7, and 2 and 8. Replace with 6000 ohm resistors. If the tubes still do not pass current, this resistance (for each tube) should be increased still more in 1000-ohm steps until the blue glow is obtained.

The follow-up system should then be sensitive with the potentiometer set at a low value such as 3 or 4, and the dead space will be cut down to a minimum.

See Fig. 241, Page 205.

CROSS FIRING

If follow-up action during synchronizing is accompanied by intermittent firing of the tube which is not synchronizing, it is an indication that the phase angle of the signal voltage is not correct. This can be corrected by changing condensers C-7 and C-8 in 0.001 mfd. steps until this condition is eliminated.

An examination should also be made on the resistors and condensers in the anti-hunt unit. Opens or shorts in this circuit will cause cross-firing of the tubes.

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FOLLOW-UP GOES WILD

This condition manifests itself in loss of control, with the generated stops oscillating within the limits of their travel. It may be caused by excessive roll or pitch of the ship (more than 22½ degrees from horizontal), shocks beyond the rated shock loading of the instrument, or lack of sensitivity of the follow up amplifiers (caused by too low a setting of the Sensitivity Control or faults in the follow up system).

If the follow-up system is at fault, manual operation may be resorted to. If the condition is due to lack of sensitivity initiated by other causes, the following procedure may be attempted to make the system operative again:

1. De-energize the follow-up system.
2. Set the gyro upright by grasping the rotating fork, and manually straightening the gyro case.
3. Manually turn the follow-up systems to 2000′ as indicated on the Level and Cross Level dials.
4. Turn the Sensitivity Controls to 9 or 10.
5. As the ship reaches an almost even keel, energize the follow-up system.
6. If, on the first attempt, the instrument does not regain immediate control, repeat the procedure.
7. If motion of the ship is greater than plus or minus 22½ degrees, do not attempt to use the Stable Element until the condition alleviates. Lash the Sensitive Element and secure the equipment.

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Gene Slover's US Navy Pages

VOLTAGE CHECK CHART

The voltage readings indicated below are those which should be obtained with a voltmeter of 1000 ohms per volt sensitivity and with A.C. and D.C. scales of 0-10, 0-25, 0-50, 0-100 and 0-250 volts. (Weston #665 Analyzer or equivalent).

These are average readings. Individual units may have slightly different characteristics and thus give slightly different readings. It is suggested that after installation of a Stable Element, and while it is operating perfectly, the following tests be run and a record be kept of the readings. This record can then act as a voltage standard for future reference.

If the line supply voltage varies, the entire series of readings will vary proportionally. Similarly, if a meter of higher or lower sensitivity is used, higher or lower readings respectively will be encountered. Particular attention should be paid to the column marked "Meter Scale" as the use of a scale other than that indicated will result in different readings than shown in the "Required" column.

SUPPLY CIRCUITS

TEST NO.	CIRCUIT	METER SCALE	FROM	TO	RE-QUIRED	PROBABLE CAUSE OF TROUBLE
1	Level Motor Field	DC 250	DC4 (+)	DCC4 (–)	115	Failure of D.C. Supply
2	Cross Level Motor Field	DC 250	DC5 (+)	DCC5 (–)	115	Failure of D.C. Supply
3	Mercury Control	DC 250	DC3 (+)	DCC3 (–)	115	Failure of D.C. Supply
4	A.C Supply	AC 250	AC	ACC	115	Failure of A.C. Supply
5	Lighting Circuit	AC 10	L	LL	6-8	Transformer or Failure of A.C. Supply
6	Gyro Supply Panel to Gyro	AC 100	G1 G2	G2 G3	70	Failure of 3 Supply

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AMPLIFIER CIRCUITS

TEST NO.	CIRCUIT	METER SCALE	FROM	TO	RE-QUIRED	PROBABLE CAUSE of TROUBLE
7	Input Plate Supply Circuit	AC 250	Rectifier Unit #1	Rectifier Unit #2	113	Open connection in Amp. To Rectifier Unit
8	Output Plate Supply Circuit	DC 250	Rectifier Unit #3 (+)	Rectifier Unit #4 (−)	110	Defective Rectifier or C-11, C-14, C-15
9	Plate Supply Filtered Output	DC 250	Choke Unit #6 (+)	Choke Unit #7 (−)	105	Shorted or Open L-1, L-3
10	Plate Voltage 1st Stage	DC 250	Choke Unit #3 (+)	Choke Unit #7 (−)	103	Shorted or Open L-2
11	Plate Voltage 1st Stage	DC 100	Choke Unit #8 (+)	Choke Unit #7 (−)	42	Open or Shorted R-15
12	Grid Bias (6A6) Voltage	DC 10	Choke Unit #1 (+)	Choke Unit #7 (−)	1.4	Open or Shorted R-24
13	Plate Voltage 2nd Stage	DC 100	Interstage Trans. #1 (+)	Choke Unit #7 (−)	94	Open Primary Interstage Transformer T-2
14	Filament Supply (6A6)	AC 10	A.C. Bias Unit #4	A.C. Bias Unit #10	6	Open Pri. or Sec. of Filament Transformer T-4
15	A.C. Bias Input	AC 50	A.C. Bias Unit #2	A.C. Bias Unit #3	32	Shorted or Open R-29
16	A.C. Bias Output	AC 10	A.C. Bias Unit #6	A.C. Bias Unit #9	8.4	Faulty Secondary (T-4)
17	A.C. Bias Output	AC 10	A.C. Bias Unit #12	A.C. Bias Unit #9	8.4	Faulty Secondary (T-4)
18	A.C. Bias Output	AC 10	A.C. Bias Unit #5	A.C. Bias Unit #8	8.4	Faulty (T-4) Secondary or R-29
19	A.C. Bias Output	AC 10	A.C. Bias Unit #8	A.C. Bias Unit #11	8.4	Open Leads from AC or ACC
20	D.C. Bias Input	AC 250	D.C. Bias Unit #4	D.C. Bias Unit #5	115	Open Leads from AC or ACC

VOLTAGE CHECK CHART

AMPLIFIER CIRCUITS

TEST NO.	CIRCUIT	METER SCALE	FROM	TO	RE-QUIRED	PROBABLE CAUSE of TROUBLE
21	D.C. Bias Output	DC 10	D.C. Bias Unit #3 (+)	D.C. Bias Unit #1 (–)	8	Faulty E-1
22	D.C. Bias Output	DC 10	D.C. Bias Unit #6 (+)	D.C. Bias Unit #2 (–)	8	Faulty E-2
23	D.C. Bias Output	DC 10	Terminal F2 (+)	Terminal AH22 (–)	2-4	Open R-21 or Shorted C-21
24	D.C. Bias Output	DC 10	Terminal F5 (+)	Terminal AH23 (–)	2-4	Open R-20 or Shorted C-20

Faulty Potentiometer setting

RECTIFIER POWER CIRCUITS

TEST NO.	CIRCUIT	METER SCALE	FROM	TO	RE-QUIRED	PROBABLE CAUSE of TROUBLE
25	A.C. Input	AC 250	Trans. T-5 Terminal #0	Terminal #115	115	Open A.C. Supply
26	Plate Supply	AC 250	Trans. T-5 Terminal #7	Terminal #8	125	Faulty Secondary Winding
27	Filament Supply	AC 10	Trans. T-5 Terminal #1	Terminal #3	2.5	Faulty Secondary Winding
28	Filament Supply	AC 10	Trans. T-5 Terminal #4	Terminal #6	2.5	Faulty Secondary Winding

SIGNAL CIRCUITS

TEST NO.	CIRCUIT	METER SCALE	FROM	TO	RE-QUIRED	PROBABLE CAUSE of TROUBLE
29	*Level Follow-up Coil	AC 10	S1	S2	2.0	Open or Shorted Follow-up Coil
30	*Cross Level Follow-up Coil	AC 10	S1	S2	2.5	Open or Shorted Follow-up Coil
31	Secondary of Input Transformer	AC 10	Ter. Block-over Input Trans. #2	Ter. Block-over Input Trans. #3	1.8 to 2.3	Open or Shorted Secondary
32	First Stage Output	AC 25	Choke Unit #2	Ter. Block-over Input Trans. #5	6 to 8	Defective Amplification first Stage
33	First Stage Output	AC 10	Choke Unit #3	Choke Unit #8	6 to 8	Defective—Amp. First Stage
34	Second Stage Output	AC 25	Int. Stage Trans. #1	Int. Stage Trans. #2	11-16	Defective—Amp. Second Stage
35	Sec. of Interst. Trans. Sec. Stage Output	AC 25	Int. Stage Trans. #3	Int. Stage Trans. #4	11-16	Faulty Secondary Winding

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SIGNAL CIRCUITS

TEST NO.	CIRCUIT	METER SCALE	FROM	TO	RE-QUIRED	PROBABLE CAUSE OF TROUBLE
36	Second Stage Output	AC 25	Int. Stage Trans. #4	Int. Stage Trans. #8	14-18	Faulty Secondary Winding
37	Second Stage Output	AC 25	Int. Stage Trans. #12	Int. Stage Trans. #16	14-18	Faulty Secondary Winding
38	Signal Passage	AC 10	Int. Stage Trans. #9	Int. Stage Trans. #10	1.5-3	Open R-16 or Shorted C-16
39	Signal Passage	AC 10	Int. Stage Trans. #13	Int. Stage Trans. #14	1.5-3	Open R-17 or Shorted C-17
40	PRIMARY Signal Input Trans.	AC 10	S1	S2	1	Open or Shorted follow-up Coil
41	*Stray Signal Pick-up	AC 10	Int. Stage Trans. #3	Int. Stage Trans. #4	1 Max.	Defective Shielding

***NOTE ON TESTS NO. 29 & NO. 30:**

Disconnect CLA or LA, depending upon unit being tested. Disconnect S1 and S2 at amplifier terminal block. Switch at *MANUAL*. Move follow-up coil off to give maximum signal on galvanometer, put follow-up switch to *AUTOMATIC* and read voltage across S1 and S2. This is signal in coil being tested. On Tests 31 to 40 inclusive follow same procedure as above, except S1 and S2 are connected.

***NOTE NO. 41:**

Allow follow-up system to synchronize—Short-circuit CLS1 or LS1 to ground in the Stable Element.

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MARK 6 STABLE ELEMENT AND CONTROL PANELS

The following point to point continuity checks are designed to determine circuit resistance values and continuity of connecting leads. All units and connecting leads are included in this series of checks. If an incorrect reading is obtained, from the column "Incorrect" and "Probable Cause of Incorrect Reading" the trouble may be found. These are not all of the possible causes, but are the most probable. Remember to consider the connecting leads between units and test points in analyzing an incorrect reading, also consider any circuits parallel to the one being tested. This requires that a print of the circuit be studied when using these tests to locate trouble.

When checking a circuit containing a condenser, the meter may give a momentarily low reading and then start creeping back to a higher resistance reading. This is normal. A good condenser when in a discharged state can store current, the current being supplied by the battery in the meter. As the condenser reaches its full charge the current drain from the meter decreases, giving a higher resistance reading. Wait until the meter pointer settles before reading. If a condenser is *shorted* it reads zero. If good and of sufficient capacity it should act as stated. If open, however, no deflection of the meter will be apparent. Since the resistance of a condenser is normally almost infinite, to check for open, examine leads going into condenser carefully. If they are O.K. remove condenser and connect it in *series* with an A.C. voltmeter of 115 volt range or greater. If no voltage is indicated on the meter when placed across line the condenser is open.

Few of these checks will show *open* in the primary of a transformer. Since other primaries are across the line (or a low resistance such as R-12 in the Anti-Hunt primary) an open in any one winding would not show "infinity" as the meter will read the resistance of all other units in parallel. To check for *open,* one side must be disconnected from the circuit.

When checking a circuit containing a dry rectifier unit, two readings may be taken by switching leads. This is because the rectifier offers high resistance to current in one direction, and low resistance in the other direction. The meter contains a battery and furnishes current, hence the two readings.

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CONTINUITY CHECKS

TUBE AND SOCKET CONNECTIONS FOR 6A6 VOLTAGE AMPLIFIER

To make continuity check at tube socket, remove tube and insert test lead of meter into proper socket connection hole.

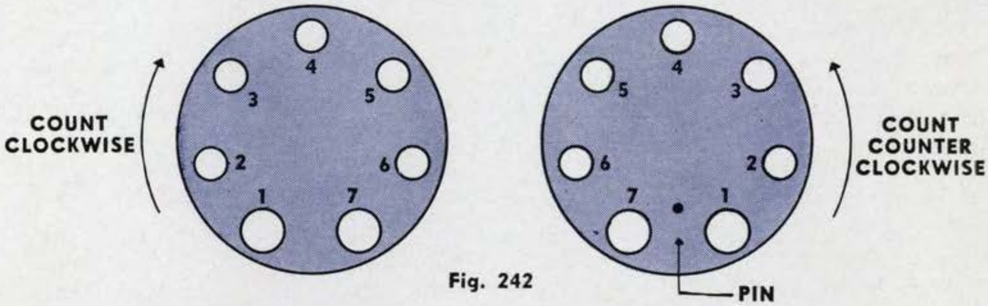

Fig. 242

TUBE (Bottom View) SOCKET (Top View)

1 and 7. Filament (Large Prongs)
2. First Plate
3. First Grid
4. Cathode
5. Second Grid
6. Second Plate

CAUTION: In making continuity tests or resistance checks make certain that there is no voltage on the equipment under test. Check switches and pilot lights on the panel to be sure they are in the "OFF" position.

NOTE: Filaments, Lights and Gyro Switch on Control Panel shall be in "OFF" position and Follow-up Switches on Stable Element in "Automatic" unless otherwise stated in notes.

The resistance values in the "Correct" column were taken from one Stable Element circuit and may vary slightly on other circuits. For this reason it is important to take a separate series of "Correct" readings on each circuit when the unit is working perfectly and keep them for reference when trouble shooting at a later date on that circuit.

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RESISTANCE CHECK CHART

INPUT AND 1ST STAGE SIGNAL CIRCUIT

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
1	Input Transformer (Primary)	S1 Terminal (with lead disconnected)	S2 Lead	22	11 Inf. 0	½ Primary Shorted Primary open Shorted Leads
*2	Follow-up Coil	S1 Lead (disconnected)	S2 Lead	370	Inf. 0	Open in coil or leads Shorted coil or leads
3	Input Transformer (Secondary)	#3 Terminal Block	#2 Terminal Block	4,600	Inf. 0	Open in winding Shorted winding or leads
4	R-14, C-7	#3 of Tube Socket	#3 Terminal Block	504,600	4,600 Inf. 0	Shorted R-14 Open R-14 Shorted C-7
5	R-22, C-9, C-10 Filament Trans. (Center Tap—C.T.)	#3 Terminal Block	#4 A.C. Bias Unit	100,000	500 Inf. 0	Shorted R-22 Open R-22 or R-24 or C.T. of filament transformer. Shorted C-9 or C-10
*6	C-11	#1 Choke Unit	#3 Choke Unit	250,000	0	Shorted

(D.C. SUPPLY)

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
*7	Rectifier Unit (Rectox E-3) C-14 & C-15	#5 Choke Unit	#4 Choke Unit	250,000	1,600 0	Shorted C-15 Shorted C-14 or Rectox
8	L-1	#4 Rectifier Unit	#7 Choke Unit	800	0 Inf.	Shorted Open
9	L-2 & L-3	#3 Rectifier Unit	#3 Choke Unit	1,600	800 Inf.	Shorted L-2 or L-3 Open L-2 or L-3
10	R-24	#4 of Tube Socket	Ground	500	0 1,000 Inf.	Shorted ½ of R-24 Open Open R-24 (Both Resistors) or No Ground Connection

NOTES: #2 "Follow-up Switch" on Stable Element in "Automatic."

#6 & #7 Change leads, use lower reading (Rectox unit E-3 is parallel to these circuits).

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SECOND STAGE SIGNAL CIRCUIT

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
11	R-23	#4 Terminal Block	#5 Terminal Block	100,000	Inf. 0	Open Shorted
12	R-15	#2 of Tube Socket	#3 Choke Unit	100,000	Inf. 0	Open Shorted
13	C-8	#2 Choke Unit	#8 Choke Unit	750,000	0	Shorted
14	P-1	#2 Choke Unit	#5 Terminal Block	125,000	Inf. Low. to 0	Open Partial Short of P-1
15	P-1 to Grid (Sensitivity to Maximum = 10)	#2 Choke Unit	#5 of Tube Socket	0	Inf.	Open in P-1 or Leads
16	C-12	#1 Choke Unit	#5 Terminal Block	100,000	0	Shorted
17	Interstage Trans. (Primary)	#6 Choke Unit	#6 of Tube Socket	1,500	0 Inf.	Shorted Open

POWER CIRCUIT (Signal and A.C. Bias)

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
18	Secondary & R-32	#3 Interstage Trans.	#4 Interstage Trans.	2,000	60,000 0	Open Winding Shorted Winding
19	Secondary & R-25	#7 Interstage Trans.	#8 Interstage Trans.	2,000	60,000 0	Open Winding Shorted Winding
20	Secondary & R-26	#11 Interstage Trans.	#12 Interstage Trans.	2,000	60,000 0	Open Winding Shorted Winding
21	Secondary & R-31	#15 Interstage Trans.	#16 Interstage Trans.	2,000	60,000 0	Open Winding Shorted Winding
22	R-30	#4 Interstage Trans.	#5 Interstage Trans.	60,000	Inf. 0	Open Shorted
23	R-16 and Grid Circuit	#8 Interstage Trans.	Grid Cap of Tube #1	60,000	Inf. 0	Open R-16 or Grid Circuit Shorted R-16
24	C-25	#5 Interstage Trans.	F2 on Conn Block	70,000	0	Shorted
25	C-16 and Lead	#9 Interstage Trans.	#2 on Plate and Fil. Trans.	70,000	Inf. 0	Open Lead Shorted C-16
26	R-17 and Grid Circuit	#12 Interstage Trans.	Grid Cap of Tube #2	60,000	Inf.	Open R-17 or Grid Circuit. Shorted R-17
27	R-33	#16 Interstage Trans.	#17 Interstage Trans.	60,000	Inf. 0	Open Shorted
28	C-26	#17 Interstage Trans.	F5 on Conn. Block	70,000	0	Shorted
29	C-17 and Lead	#13 Interstage Trans.	#5 on Plate and Fil. Trans.	70,000	0 Inf.	Shorted C-17 Open Lead

RESISTANCE CHECK CHART

POWER CIRCUITS (Signal and A.C. Bias)

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
30	Secondary A.C. Bias	#3 Interstage Trans.	#7 Interstage Trans.	110	Inf. 0	Open Winding Shorted
31	Secondary A.C. Bias	#11 Interstage Trans.	#15 Interstage Trans.	110	Inf. 0	Open Winding Shorted
32	C-13, R-29 and A.C. Bias Primary	#2 A.C. Bias Unit	#3 A.C. Bias Unit	65	0 100 185	Shorted C-13 or R-29 Open R-29 Open Primary

D.C. BIAS AND ANTI HUNT

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
33	Grid Circuit Tube #1 to #2	#1 D.C. Bias Unit	#2 D.C. Bias Unit	Inf.	0	Short between two Grid Circuits
34	C-18, R-18 and Anti-Hunt Secondary	AH23 on Conn. Block	AH24 on Conn. Block	3,400	60,000 0	Open Anti-Hunt Winding Shorted C-18, R-18 or Anti-Hunt Winding
35	Lead and A.C. Bias Secondary Center Tap	AH24 on Conn. Block	#5 A.C. Bias Unit	55	Inf. 0	Open Center Tap on A.C. Bias Secondary or lead ½ A.C. Bias Sec. Shorted
36	C-19, R-19 & Anti-Hunt Secondary	AH21 on Conn. Block	AH22 on Conn. Block	3,400	60,000 0	Open Anti-Hunt Winding Shorted C-19, R-19 or Anti-Hunt Winding
37	Lead & A.C. Bias Secondary (Center Tap)	AH21 on Conn. Block	#12 A.C. Bias Unit	55	Inf. 0	Open center tap on A.C. Bias Secondary or lead ½ A.C. Bias Sec. Shorted
*38	R-28("K" Unit) *Resistor Replaced By Potentiometer*	#1 D.C. Bias Unit	#7 D.C. Bias Unit	4,000 to 12,000	Check Against Previous Reading	Rectox Unit E-1 C-21 or R-21
*39	R-27 ("K" Unit) *Resistor Replaced By Potentiometer*	#2 D.C. Bias Unit	#8 D.C. Bias Unit	4,000 to 12,000	Check Against Previous Reading	Rectox Unit E-2 C-20 or R-20
*40	Rectox Unit	#1 D.C. Bias Unit	#3 D.C. Bias Unit	1,000 to 1,500	Same Reading as Check #38	Shorted C-21 or R-21
*41	Rectox Unit	#2 D.C. Bias Unit	#6 D.C. Bias Unit	1,000 to 1,500	Same Reading as Check #39	Shorted C-20 or R-20
*42	C-21, R-21	AH22 on Conn. Block	F2 on Conn. Block	1,000 to 3,500	0 Inf.	Shorted C-21 or R-21 Open Lead
*43	C-20, R-20	AH23 on Conn. Block	F5 on Conn. Block	1,000 to 3,500	0 Inf.	Shorted C-20 or R-20 Open Lead

NOTES: #38, #39, #40—Change leads, use lower reading
#41, #42, #43—(Rectox units E-1 or E-2 are parallel to these circuits.) All six readings are directly affected by the setting of "K" units R-27 & R-28 and will vary as the "K" units are varied. To check, compare present readings with previous readings taken on these tests.
"K" Units—Values differ with different amplifiers.

D.C. BIAS AND ANTI-HUNT

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
44	Anti-Hunt Primary (First Trans.) R-12	#35 Anti-Hunt Unit	#36 Anti-Hunt Unit	3	0 6 1,000	Shorted Winding ½ of R-12 Open R-12 Completely Open
45	Anti-Hunt Secondary (First Trans.)	#33 Anti-Hunt Unit	#34 Anti-Hunt Unit	18,000	0 Inf.	Shorted Winding Open
46	Anti-Hunt Primary (Second Trans.) R-11	#25 Anti-Hunt Unit	#26 Anti-Hunt Unit	6,000	0 100,000 6,500	Shorted Winding Open Winding Open R-11
47	C-22	#29 Anti-Hunt Unit	#30 Anti-Hunt Unit	Inf.	0	Shorted
48	C-23	#31 Anti-Hunt Unit	#32 Anti-Hunt Unit	Inf.	0	Shorted

POWER CIRCUIT—C6A TUBE PLATE & CATHODE CIRCUIT—LIMIT SWITCH—MOTOR ARMATURE AND ANTI-HUNT RESISTORS (R-12)

TEST NO.	UNIT UNDER TEST	FROM	TO	READING IN OHMS CORRECT	READING IN OHMS INCORRECT	PROBABLE CAUSE OF INCORRECT READING
49	Plate transformer (Secondary) Center tap on Fil. Winding to #1 Tube	#1 Plate and Fil. Trans.	Ground	1	0 Inf. Inf.	Shorted Winding Open-Winding or center Tap on Fil. Trans. Open Ground Connection
*50	#1 Tube Plate Cir. Center Tap on Fil. Winding to #2 Tube	Plate Cap on #1 Tube	#4 Plate & Fil. Trans.	0	Inf. Inf. Inf. 4	Open Center Tap on Fil. Trans. Open Leads LA1 or LA2 (L) CLA1 or CLA2 (Zd) Open Motor Armature Open Limit Switch
50-A	#2 Tube Plate Circuit	Plate Cap on #2 Tube	#7 Plate and Fil. Trans.	0	Inf.	Open Lead
*51	Limit Switch and Resistors	LA1 CLA1 (on Panel)	LA2 CLA2 (on Panel)	0	4 Inf.	Limit Switch Open Open Leads
*51-A	Crank into Stops Both Minimum & Maximum	LA1 CLA1 (on Panel)	LA2 CLA2 (on Panel)	4	0 Inf.	Limit Switch not Opening Open Limit Switch Resistor
*52	Motor Arm. & R-12 (Do Not Turn F.U. Crank)	LMA1 CLMA2 (On Limit Switch)	Ground	5 to 15	High Inf. 1,000	Dirty Armature Brushes Motor Armature Open R-12 Completely Open
*53	Motor Fields Clutch F.U. Switch in Auto.	LF1 CLF1 (In S.E.)	LF2 CLF2 (In S.E.)	200	400 0	Open Motor Field or Clutch Shorted Motor Field or Clutch
*53-A	Throw F.U. Switch To Manual	LF1 CLF1 (In S.E.)	LF2 CLF2 (In S.E.)	400	Inf. 0	Open Motor Field Shorted Motor Field

NOTES: #50, #51, #51A, & #52, Filaments, lights, and gyro switch on panel must be in *"On"* position, and "F.U. Switch" on Stable Element in *"Automatic"* position. (CHECK TO MAKE CERTAIN SUPPLY VOLTAGES TO PANEL ARE *OFF* BEFORE TURNING SWITCH TO *"ON"* POSITION.)
#53 & #53-A, Turn filament, lights and gyro switch on panel to *"OFF"* position.

AMPLIFIER CIRCUIT

CONDENSERS—VALUE		THEIR PURPOSE AND LOCATION
C- 7	0.02 to 0.05 mfd., 200 volts	"K" calibration and phase shift for the signal. (1 to 3 on panel over input transformer.)
C- 8	0.02 to 0.05 mfd., 200 volts	"K" calibration and coupling for second stage. (2 to 8 on choke unit.)
C- 9 and C-10	4 mfd., 200 volts	By-pass of signal voltage to cathode (6A6). Aids in maintaining the D.C. bias voltage constant on the 6A6 developed by the IR drop of R-24. (#3 & #2 second row of condenser bank.)
C-11	4 mfd., 200 volts	By-pass of signal in plate circuit of first stage to cathode. Additional filter for first stage plate circuit (#4 second row of condenser bank).
C-12	4 mfd., 200 volts	By-pass of signal in sensitivity control second stage. (#1 second row of condenser bank.)
C-14	4 mfd., 200 volts	Filter for D.C. supply to amplifier. (#2 first row of condenser bank.)
C-15	8 mfd., 200 volts	Filter for D.C. supply to amplifier. By-pass of signal in plate circuit of second stage to cathode. (#1 first row of condenser bank.)

RESISTORS—VALUE		THEIR PURPOSE AND LOCATION
R-14	500,000 ohms, 1 watt	Phase shift for signal voltage to first stage. (1 to 2 on panel over input transformer.)
R-15	100,000 ohms, 1 watt	Plate load resistor of first stage. (3 to 8 on choke unit.)
R-22	100,000 ohms, 1 watt	Filter or blocking resistor for signal circuit first stage. (3 to 4 on panel over input transformer.)
R-23	100,000 ohms, 1 watt	Filter or blocking resistor for signal circuit second stage. (4 to 5 on panel over input transformer.)
R-24	500 ohms, 2 watts (2-1000 ohms in parallel)	Grid bias resistor for the 6A6 vacuum tube. (1 to 7 on choke unit.)
P- 1	125,000 ohms	Sensitivity control to control the overall amplification. (Sensitivity control is secured to pre-amplifier case in back of rectifier unit.)

POWER AND BIAS CIRCUITS

CONDENSERS—VALUE		THEIR PURPOSE AND LOCATION
C-13	4 mfd., 200 volts	Phase shift in the A.C. bias for the power tubes. (#3 first row of condenser bank.)
C-16 and C-17	0.015 mfd., 200 volts	Blocking condensers for D.C. bias and by-pass for A.C. bias and signal voltage. (9 to 10 and 13 to 14 on interstage transformer.)

C-18 and C-19	0.1 mfd., 200 volts	Filters for any 60 cycle ripple in the anti-hunt voltage. Have no effect on anti-hunt voltage (4 cycle). (6 to 7 and 8 to 9 on panel over input transformer.)
C-20 and C-21	0.5 mfd., 200 volts	Filters for the D.C. bias and by-pass for the anti-hunt voltage. (6 to 8 and 3 to 7 *INSIDE* D.C. bias unit.)
C-22 and C-23	1.0 mfd., 200 volts	Phase shift for the anti-hunt voltage. (Used in conjunction with R-11.) (29 to 30 and 31 to 32 *INSIDE* anti-hunt unit.)
C-24	1.0 mfd., 200 volts	Spare in anti-hunt unit.
C-25 and C-26	0.015 mfd., 200 volts	Blocking condensers for D.C. bias and by-pass for A.C. bias and signal voltage. (5 to 6 and 17 to 18 on interstage transformer.)

RESISTORS—VALUE		THEIR PURPOSE AND LOCATION
R-11	100,000 ohms, 1 watt	Phase shift for the anti-hunt voltage. (25 to 26 anti-hunt unit.)
R-12	3 ohms, 120 watts (2-6 ohms in parallel)	Supplies the voltage drop for the anti-hunt signal. (Two resistors under anti-hunt unit.)
R-16 and R-17	60,000 ohms, 1 watt	Grid stabilizing resistors for the power tubes to prevent grid current if grid is driven positive with large signal. (8 to 9 and 12 to 13 on interstage transformer.)
R-18 and R-19	60,000 ohms, 1 watt	Transformer regulating or loading resistors for the anti-hunt secondaries. (6 to 7 and 8 to 9 on panel over input transformer.)
R-20 and R-21	4,000 ohms, 1 watt	Loading resistors for the D.C. bias voltage unit. Used in conjunction with R-27 and R-28. (6 to 8 and 3 to 7 *NSIDE* D.C. bias unit.)
R-25 and R-26	60,000 ohms, 1 watt	Transformer regulation or loading resistors for the secondaries of the interstage transformer. (7 to 8 and 11 to 12 on interstage transformer.)
R-27 and R-28	~~4,000 to 12,000 ohms, 1 watt~~ 25,000 ohms 2.25 watts	"K" D.C. bias calibration Potentiometer ~~resistors~~. Used for determining the amount of D.C. bias voltage applied to power tubes. (2 to 8 and 1 to 7 on D.C. bias unit.)
R-29	185 ohms, 25 watts	Phase shift for the A.C. bias. (Lower left-hand corner of pre-amp.)
R-30 and R-33	60,000 ohms, 1 watt	Grid stabilizing resistors for the power tubes to prevent grid current if grid is driven positive with large signal. (4 to 5 and 16 to 17 on interstage transformer.)
R-31 and R-32	60,000 ohms, 1 watt	Transformer regulating or loading resistors for the secondaries of the interstage transformer. (15 to 16 and 3 to 4 on interstage transformer.)

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CIRCUIT COMPONENTS IN THE FOLLOW-UP SYSTEM THEIR PURPOSE AND LOCATION

TRANSFORMERS

T-1	Signal input transformer from the follow-up coil to the first stage. A step-up ratio. (Lower right-hand corner of pre-amp. unit.)
T-2	Interstage transformer. Primary winding is the plate load for the second stage of amplification. The secondaries apply the signal to the grid circuit of the power tubes. Turn ratio 1-1. (Upper right-hand corner of pre-amp. unit.)
T-3	A step-down transformer for the filament supply of the amplifier tube 6A6. (Inside of A.C. bias unit.)
T-4	A. C. bias for the power tubes. (Inside of A.C. bias unit.)
T-5	Filament and plate transformer for the power tubes, C6A grid controlled rectifiers. (Under pre-amp. unit.)
T-6	Step-down transformer for the D.C. bias rectifier unit of the power circuit. (Inside D.C. bias unit.)
T-7	Anti-hunt transformer. (Inside anti-hunt unit under pre-amp. unit.)
T-8	Step-up transformer for the D.C. rectifier unit which provides plate supply voltage for the amplifier. (Inside rectifier unit in upper left-hand corner or pre-amp. unit.)

COILS IN FILTER SYSTEM

L-1	3 hen., 800 ohms	Choke coil for the negative side of the D.C. supply.
L-2	3 hen., 800 ohms	Additional part of the filter system of the plate circuit of the first stage.
L-3	3 hen., 800 ohms	Choke coil for the positive side of the D.C. supply, (all coils located inside A.B.C. choke unit).

COPPER OXIDE RECTIFIERS

E-1 and E-2	Copper oxide rectifiers (rectox units). Used for supplying D.C. bias voltage to power tubes. (Inside D.C. bias unit.)
E-3	Copper oxide rectifier (rectox unit). Used for supplying D.C. voltage to amplifier section. (Inside rectifier unit.)

TUBES

V-1	Twin-triode vacuum tube for two stages of amplification. 6A6.
V-2 and V-3	Gas (xenon) filled grid controlled rectifier tubes for operating follow-up motor. C6A.

See change back of book

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INFORMATION

This supplement to OP 1063 describes the features of the Stable Element Mark 6 Mod 4 and Mod 6 which distinguish them from the other Mods of this instrument.

STABLE ELEMENT MARK 6 MOD 4

The material of OP 1063 applies generally to the Stable Element Mark 6 Mod 4, the important exceptions being noted below.

EXCEPTIONS

1. The sensitive element is rotated 90° so that level is measured about an axis in the deck. From a functional standpoint this converts the instrument to a stable vertical.

2. On the top of the instrument the location of the level and cross level dials are interchanged. Note that the level dials are calibrated so that they rotate counterclockwise for increasing readings.

3. On the front of the instrument the hand firing key, automatic firing key, and salvo signal key have been removed; cover plates protect the openings in the case at these points. The wiring and terminal tubes associated with the firing keys have also been removed.

4. The level and cross level handcranks are interchanged, as are the engravings on the selector switch.

5. Reference to the gear diagram BuOrd Dwg. 318101, Fig. 1, will show that level and cross level are transmitted electrically both at 2 speed and 36 speed.

6. The functions transmitted by the output shafts are interchanged with respect to the Mod. 1.

7. The electrical connections from the level transmitters to their associated receivers are shown on BuOrd Dwg. 317947, Fig. 3.

8. All electrical service or repair work must be done with the aid of the wiring diagrams listed below.

Elementary Wiring Diagram BuOrd Dwg. 317946 Fig. 2
External Wiring Diagram BuOrd Dwg. 317947 Fig. 3
Schematic Wiring Diagram BuOrd Dwg. 317948 Fig. 4
Internal Wiring Diagram BuOrd Dwg. 317928 Fig. 5

STABLE ELEMENT MARK 6 MOD 6

1. The Stable Element Mark 6 Mod 6 is the Mod 4 modified by the addition of a hand firing key (see Ordalt 2371).

2. The applicable drawings are as follows:

Elementary Wiring Diagram BuOrd Dwg. 549199
External Wiring Diagram BuOrd Dwg. 549200
Schematic Wiring Diagram BuOrd Dwg. 549201
Outlines BuOrd Dwg. 603697, 8, 9

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GENERAL INFORMATION

NOTES:

1. Location of Stable Element—in Plotting Room
2. Location of Control Panel—in Plotting Room
3. Location of Motor-Generators—in Plotting Room, I.C. Room, or Central Stations
4. Illumination in Stable Element—3 TS-20, 3 c.p., volt lamps
5. Control Panel Information:
   - (a) Mk. 7 Mods. 1, 2, and 3 are identical in appearance
     Mk. 7 Mod. 4 has no gyro supply switch
     Mk. 7 Mod. 5 has deeper follow-up tube cabinet
   - (b) Mk. 8 Mods. 2, 4, and 6 are identical in appearance
     Mk. 8 Mods. 3, 5, and 7 are identical in appearance
     Mk. 8 Mod. 8 has deeper follow-up tube cabinet
   - (c) Mk. 8 Mod. 1 is a spare for Mk. 8 Mod. 0
     Mk. 8 Mod. 3 is a spare for Mk. 8 Mod. 2
     Mk. 8 Mod. 5 is a spare for Mk. 8 Mod. 4
     Mk. 8 Mod. 7 is a spare for Mk. 8 Mod. 6
     There is no special spare panel for Mk. 8 Mod. 8
     Each spare panel has only one follow-up panel instead of two
6. Charts included in this section:
   - (A) Equipment installed on various ships, with accompanying drawings
   - (B) Weights and Dimensions
   - (C) Differences in Control Panel Mods.
   - (D) Motors, Synchros and Dials of Stable Elements
   - (E) Motor Generator Specifications
   - (F) Principal Drawings and Numbers

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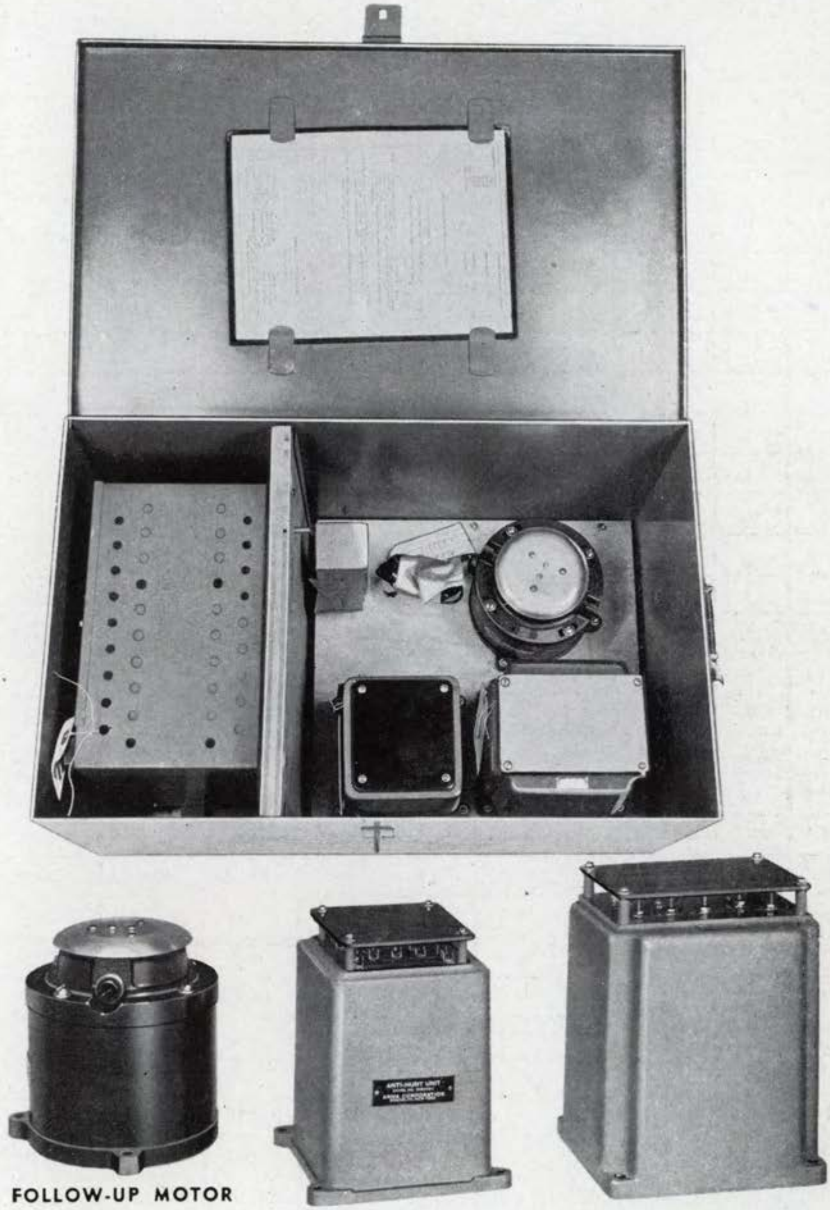
The figures on these two pages illustrate some of the more essential spare parts supplied with an installation which includes a Mark 6 Stable Element and a Mark 7 Mod. 3 Control Panel.

Fig. 243

In the event of minor casualty, the Stable Element or its Control Panel usually may be repaired with parts included in these kits. In case of more serious damage, replacement parts not included in the Vessels' spare parts boxes must be obtained from the Tender or Repair Ship or the Naval Gun Factory.



FOLLOW-UP MOTOR

ANTI-HUNT UNIT

PLATE AND FILAMENT TRANSFORMER

Fig. 244

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CHART (A) EQUIPMENT INSTALLED ON VARIOUS SHIPS

SHIPS		STABLE ELEMENT			CONTROL PANEL			M.G. SETS		DRAWINGS			
Type	No.	Type		No.	Type		No.	Type	No.	Dwg. List Sk. No.	Wiring Diagrams		
		Mk.	Mod.		Mk.	Mod.					Elem.	Ext.	Schem.
AD	14	6		1	7	3	1	145	2	91431	270199	270200	270201
AD	15	6		1	7	0	1	135	2	60218	228010	228011	228012
AG	17	6		1	7	5	1	138	2	91431	262363	262364	262365
AO	22-23	6		1	7	0	1	135	2	60218	228010	228011	228012
AO	24	6		1	7	3	1	145	2	91431	270199	270200	270201
AR	5	6		1	7	3	1	145	2	91431	270005	270007	270006
AS	11	6		1	7	1	1	145	2	91431	270202	270203	270204
AS	12	6		1	7	1	1	145	2	91431	291100	291102	291101
AV	4	6		1	7	3	1	145	2	91431	270199	270200	270201
AV	5	6		1	7	0	1	135	2	60218	228010	228011	228012
BB	36-46	6	1	4	8	6 or 8	2	146	2	91442	269942	269944	269943
BB	48	6	1	4	8	6 or 8	2	146	2	91442	269942	269944	269943
BB	55-56	6		4	8	0	2	141	2	60232	228004	228006	228005
BB	57-60	6		4	8	4	2	146	2	91431	263556	263558	263557
BB	61-66	6	1	4	8	6 or 8	2	143	4	91442	269942	269944	263943
CA	68-75	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198
CA	122-142	6	1	2	8	8	1	143	2	91442	270196	270197	270198
CB	1-3	6	1	2	7	4	2	143	4	91442	291107	291109	291108
CL	51-54	6		2	8	2	1	143	2	91431	263556	263558	263557
CL	55-58	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198
CL	60	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198
CL	62-67	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198
CL	80-83	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198
CL	86-87	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198
CL	89-94	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198
CL	95-96	6		2	8	6 or 8	1	143	2	91431	270536	270538	270537
CL	97	6	1	2	8	8	1	143	2	91442	262369	262370	262371
CL	98	6		2	8	6	1	143	2	91431	270536	270338	270537
CL	101-102	6	1	2	8	6 or 8	1	143	2	91442	270196	270197	270198

*See chart E for M.G. Specifications

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NAMEPLATE

Stable Elements Mark 6 Mod. 4 which have been modified to Mark 6 Mod. 6 should be checked to see that their nameplates have been replaced with Stable Element Mark 6 Mod. 6 nameplates as directed by OrdAlt 2544. (The nameplate is located on the top access cover of the Stable Element.) This modification is applicable to the following vessels:

LSM (R) 401	LSM (R) 411	LSM (R) 509
LSM (R) 402	LSM (R) 412	LSM (R) 510
LSM (R) 403	LSM (R) 501	LSM (R) 511
LSM (R) 404	LSM (R) 502	LSM (R) 512
LSM (R) 405	LSM (R) 503	LSM (R) 513
LSM (R) 406	LSM (R) 504	LSM (R) 514
LSM (R) 407	LSM (R) 505	LSM (R) 515
LSM (R) 408	LSM (R) 506	LSM (R) 516
LSM (R) 409	LSM (R) 507	LSM (R) 517
LSM (R) 410	LSM (R) 508	LSM (R) 518

TRAIN TRANSMITTING UNIT

Upon installation of the Train Transmitting Unit (page 94-A), the data in CHART (A) EQUIPMENT INSTALLED ON VARIOUS SHIPS (pages 224 to 227) changes as follows for the ships listed below:

The number "1" becomes the number "7" and the number "8" becomes the number "9" in the column headed "STABLE ELEMENT, Type, Mod."

The number "105404 A" is added to the column headed "DRAWINGS, Dwg. List Sk. No."

The number "698314" is added to the column headed "DRAWINGS, Wiring Diagrams, Elem."

The number "698313" is added to the column headed "DRAWINGS, Wiring Diagrams, Ext."

The foregoing data changes apply to the following vessels:

DD 764	DD 861	DDE 466	DDE 510
DD 765	DD 871	DDE 468	DDE 517
DD 818	DDE 445	DDE 470	DDE 576
DD 819	DDE 446	DDE 471	DDE 577
DD 820	DDE 447	DDE 498	DDE 719
DD 847	DDE 449	DDE 499	DDE 824
DD 858	DDE 450	DDE 507	EDD 837
DD 859	DDE 465	DDE 508	EDD 848
DD 860			

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CONTINUOUS LEVEL TRANSMITTING UNIT

The Level Transmitting Unit (page 94-C) is installed in the following vessels if they are equipped with Stable Element Mark 6 Mod 0:

DD 764	DD 871	DDE 466	DDE 507
DD 765	DDE 445	DDE 468	DDE 508
DD 818 - 820	DDE 446	DDE 470	DDE 510
DD 837	DDE 447	DDE 471	DDE 517
DD 848	DDE 450	DDE 498	DDE 576
DD 858 - 861	DDE 465	DDE 499	DDE 577

The data shown in CHART (A) EQUIPMENT INSTALLED ON VARIOUS SHIPS (pages 224 to 227) changes as follows for vessels fitted with the Continuous Level Transmitting Unit:

The blank space in the column headed "STABLE ELEMENT, Type, Mod." bears the number "8".

The numbers "105597" and "105609" are added under the column headed "DRAWINGS, Dwg. List. Sk. No."

The number "878299" is added to the column headed "DRAWINGS, Wiring Diagrams, Elem."

The number "878297" is added to the column headed "DRAWINGS, Wiring Diagrams, Ext."

The number "878298" is added to the column headed "DRAWINGS, Wiring Diagrams, Schem."

CHART (A) EQUIPMENT INSTALLED ON VARIOUS SHIPS

SHIPS		STABLE ELEMENT			CONTROL PANEL			M.G. SETS		DRAWINGS			
Type	No.	Type		No.	Type		No.	Type	No.	Dwg. List Sk. No.	Wiring Diagrams		
		Mk.	Mod.		Mk.	Mod.					Elem.	Ext.	Schem.
CL	103-118	6	1	2	8	8	1	143	2	91442	270196	270197	270198
CL	119-121	6	1	2	8	8	1	143	2	91442	262369	262370	262371
CL	143-149	6	1	2	8	8	1	143	2	91442	262409	262410	262411
CM	5	6		1	7	1	1	145	2	91431	263559	263561	263560
CV	6	6		2	8	8	1	108	2	91431	270536	270538	270537
CV	8	6		2	8	2	1	143	2	91431	263556	263558	263557
CV	9-21	6 6	 1	2 1	8 7	6 or 8 5	1 1	143 143	2 2	91431 91442	270536 262403	270538 262404	270537 262405
CV	31-37	6 6	1 1	2 1	8 7	8 5	1 1	143 143	2 2	91442 91442	262369 262403	262370 262404	262371 262405
CV	38	6 6	 1	2 1	8 7	8 5	1 1	143 143	2 2	91431 91442	270536 262403	270538 262404	270537 262405
CV	39-40	6 6	1 1	2 1	8 7	8 5	1 1	143 143	2 2	91442 91442	262369 262403	262370 262404	262371 262405
CV	45-47	6 6	1 1	2 1	8 7	8 5	1 1	143 143	2 2	91442 91442	262369 262403	262370 262404	262371 262405
CVB	41-43	6	1	4	8	8	2	143	2	91442	262406	262407	262408
DD	357	6	1	1	7	5	1	145	2	91442	262363	262364	262365
DD	358	6		1	7	2	1	145	2	91431	270188	270189	270190
DD	359-363	6	1	1	7	5	1	145	2	91442	262363	262364	262365
DD	372	6	1	1	7	5	1	145	2	91442	262363	262364	262365
DD	375	6	1	1	7	5	1	145	2	91442	262363	262364	262365
DD	381	6	1	1	7	5	1	145	2	91442	262363	262364	262365
DD	383	6	1	1	7	5	1	145	2	91442	262363	262364	262365
DD	394-396	6	1	1	7	5	1	145	2	91442	262363	262364	262365
DD	421-428	5		1	7	0	1	145	2	60224	227801	227802	227803
DD	429-436	6		1	7	0	1	145	2	60218	228010	228011	228012
DD	437-444	6		1	7	2 or 5	1	145	2	91431	263697	263699	263698
DD	445-482	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190

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CHART (A) EQUIPMENT INSTALLED ON VARIOUS SHIPS

SHIPS		STABLE ELEMENT			CONTROL PANEL			M.G. SETS		DRAWINGS			
		Type			Type						Wiring Diagrams		
Type	No.	Mk.	Mod.	No.	Mk.	Mod.	No.	Type	No.	Dwg. List Sk. No.	Elem.	Ext.	Schem.
DD	483-497	6		1	7	2 or 5	1	145	2	91431	263697	263699	263698
DD	498-502	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	507-522	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	526-538	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	539	6	0	1	7	2 or 5	1	196	2	91431	270188	270189	270190
DD	540-541	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	544-547	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	550-566	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	567-568	6	1	1	7	2 or 5	1	145	2	91442	262363	262364	262365
DD	569-592	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	593	6	1	1	7	2 or 5	1	145	2	91442	262363	262364	262365
DD	594-650	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	651-652	6		1	7	2 or 5	1	196	2	91431	270188	270189	270190
DD	653	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	654	6		1	7	2 or 5	1	196	2	91431	270183	270189	270190
DD	655-656	6	1	1	7	2 or 5	1	196	2	91442	262363	262364	262365
DD	657-661	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	662-664	6		1	7	2 or 5	1	196	2	91431	270188	270189	270190
DD	665-671	6		1	7	2 or 5	1	145	2	91431	270188	270189	270190
DD	672-674	6		1	7	5	1	196	2	91431	270188	270189	270190
DD	675-678	6		1	7	5	1	145	2	91431	270188	270189	270190
DD	679-680	6		1	7	5	1	196	2	91431	270188	270189	270190
DD	681-683	6		1	7	5	1	145	2	91431	270188	270189	270190
DD	684	6		1	7	5	1	196	2	91431	270188	270189	270190
DD	685-691	6		1	7	5	1	145	2	91431	270188	270189	270190
DD	692-697	6		1	7	5	1	196	2	91431	270188	270189	270190
DD	698	6	1	1	7	5	1	196	2	91442	262363	262364	262365
DD	699	6		1	7	5	1	196	2	91431	270188	270189	270190
DD	700-721	6	1	1	7	5	1	196	2	91442	262363	262364	262365
DD	722-730	6		1	7	5	1	196	2	91431	270188	270189	270190
DD	731-743	6	1	1	7	5	1	196	2	91442	262363	262364	262365
DD	744-746	6		1	7	5	1	196	2	91431	270188	270189	270190

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CHART (A) EQUIPMENT INSTALLED ON VARIOUS SHIPS

SHIPS		STABLE ELEMENT			CONTROL PANEL			M.G. SETS		DRAWINGS			
Type	No.	Type		No.	Type		No.	Type	No.	Dwg. List Sk. No.	Wiring Diagrams		
		Mk.	Mod.		Mk.	Mod.					Elem.	Ext.	Schem.
DD	747-791	6	1	1	7	5	1	196	2	91442	262363	262364	262365
DD	792	6		1	7	5	1	145	2	91431	270188	270189	270190
DD	793-798	6		1	7	5	1	196	2	91431	270188	270189	270190
DD	799-890	6	1	1	7	5	1	196	2	91442	262363	262364	262365

CHART (B) WEIGHTS AND DIMENSIONS

MK6 MOD 4 895 LBS
MK6 MOD 5 980 LBS
MK 6 MOD 6 900 LBS
MK6 MOD 7 928 LBS
MK6 MOD 8 893 LBS
MK6 MOD 9 898 LBS

STABLE ELEMENT

TYPE	WEIGHT	HEIGHT	WIDTH	DEPTH
Mk. 5	880 lbs.	47½"	29½"	33"
Mk. 6	873 lbs.	47½"	29½"	33"
Mk. 6, Mod. 1	923 lbs.	47½"	29½"	34½"

CONTROL PANELS

Mk. 7, Mod. 0	289 lbs.	5'6"	26"	13¾"
Mk. 7, Mod. 1	315 lbs.	5'6"	26"	13¾"
Mk. 7, Mod. 2	315 lbs.	5'6"	26"	13¾"
Mk. 7, Mod. 3	315 lbs.	5'6"	26"	13¾"
Mk. 7, Mod. 4	306 lbs.	5'6"	26"	13¾"
Mk. 7, Mod. 5	315 lbs.	6'6"	26"	15¾"
Mk. 8, Mod. 0	529 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 1	308 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 2	548 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 3	327 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 4	548 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 5	327 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 6	548 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 7	327 lbs.	6'6"	26"	13¾"
Mk. 8, Mod. 8	548 lbs.	6'6"	26"	15¾"

CHART (C) CONTROL PANEL EQUIPMENT and Special Characteristics

Control Panel Mk. and Mod.	Synchros 5N Mk. 6 Mod. 1A		Electronic Tubes		Own Ship's Speed	R.P.M. of A.C. Motor	Gyro Supply Completed Through	Shock Test
	Co	So	6A6 (Navy 38616)	C6A	Knots			ft.-lbs.
Mk. 7, Mod. 0	1	0	2	4			Gyro Supply Switch	250
Mk. 7, Mod. 1	1	1	2	4	0—25	0.106	Gyro Supply Switch	250
Mk. 7, Mod. 2	1	1	2	4	0—40	0.067	Gyro Supply Switch	250
Mk. 7, Mod. 3	1	1	2	4	0—22	0.120	Gyro Supply Switch	250
Mk. 7, Mod. 4	1	1	2	4	0—40	0.067	Follow-up SystemSwitch	250
Mk. 7, Mod. 5	1	1	2	4	0—40	0.067	Gyro Supply Switch	2000
Mk. 8, Mod. 0	1	0	4	8			Follow-up System Switch	250
Mk. 8, Mod. 1	1	0	2	4			Follow-up System Switch	250
Mk. 8, Mod. 2	1	1	4	8	0—35	0.078	Follow-up System Switch	250
Mk. 8, Mod. 3	1	1	2	4	0—35		Follow-up System Switch	250
Mk. 8, Mod. 4	1	1	4	8	0—30	0.089	Follow-up System Switch	250
Mk. 8, Mod. 5	1	1	2	4	0—30		Follow-up System Switch	250
Mk. 8, Mod. 6	1	1	4	8	0—40	0.067	Follow-up System Switch	250
Mk. 8, Mod. 7	1	1	2	4	0—40		Follow-up System Switch	250
Mk. 8, Mod. 8	1	1	4	8	0—40	0.067	Follow-up System Switch	2000

CHART (D)—MOTORS, SYNCHROS and DIALS of STABLE ELEMENT

	SYNCHROS						MOTORS	
Stable Element Mk. and Mod.	1-DG Mk. 1 Mod. 1 (a)	1-F Mk. 8 Mod. 1 (b)	5-D Mk. 7 Mod. 1 (c)	5-DG Mk. 4 Mod. 1 (d)	6-G Mk. 2 Mod. 1 (e)	6-G Mk. 2 Mod. 1A (f)	Arma Follow-up Type S 3.5, ¼ HP. 5000 RPM Free Speed 110 in.-oz. stall torque 115 v.d.c. field 55 v.d.c. armature	Gimbal Rotation G.E. Type KSP Model 5KSP 32 DA-1
Mk. 5	1	1	1		3		2	1
Mk. 6	1	1		1		2	2	1
Mk. 6 Mod. 1	1	1		1		4	2	1

(a) Gimbal rotation differential

(b) Latitude Correction motor

(c) Training differential

(d) Training differential

(e) Level or Cross Level Transmitter

(f) Level or Cross Level Transmitter

DIALS

1—Target Bearing Outer Dial:	1 speed—360° per turn—graduated every 10°, 0° to 360°—numbered every 10°, 0° to 360°.
1—Target Bearing Inner Dial:	36 speed—10° per turn—graduated every 5′, 0° to 10°—numbered every 20′, 0° to 10°.
1—Selected Level Dial:	6 speed—3600′ per turn—graduated every 10′, 500′ to 3500′—numbered every 100′, 500′ to 3500′.
1—Generated Level Outer Dial:	6 speed—3600′ per turn—graduated every 100′, 500′ to 3500′—numbered every 100′, 500′ to 3500′.
1—Generated Level Inner Dial:	72 speed—300′ per turn—graduated every 10′, 0′ to 300′—numbered every 10′, 0′ to 300′.
1—Selected Cross-Level Dial:	6 speed—3600′ per turn—graduated every 10′, 500′ to 3500′—numbered every 100′, 500′ to 3500′.
1—Generated Cross-Level Outer Dial:	6 speed—3600′ per turn—graduated every 100′, 500′ to 3500′—numbered every 100′, 500′ to 3500′.
1—Generated Cross Level Inner Dial:	72 speed—300′ per turn—graduated every 10′, 0′ to 300′—numbered every 10′, 0′ to 300′.

CHART (E) HOLTZER-CABOT MOTOR GENERATOR SPECIFICATIONS

MODEL	MOTOR						GENERATOR					Wt. Lbs.	Gyros No.
	Volts	Amps.	Ø	~	RPM	HP	Volts	Amps.	Ø	~	KVA		
MG135	115	2.0	3	60	1750	¼	70	1.15	3	146	0.14	105	1
MG141	115	4.2	3	60	1750	¾	70	6.90	3	146	0.84	250	6
MG143	115	3.0	3	60	1750	½	70	4.60	3	146	0.56	225	4
MG145	115	2.0	3	60	1750	¼	70	1.15	3	146	0.14	105	1
MG146	115	4.2	3	60	1750	¾	70	6.90	3	146	0.84	250	6

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CHART (F) PRINCIPAL DRAWINGS & NUMBERS

Functional Diagram, Mark 5	227800
Functional Diagram, Mark 6 and Mark 6 Mod. 1	166849
Gear Diagram, Mark 5	227804
Gear Diagram, Mark 6 and Mark 6 Mod. 1	228008
S 3.5 Motor Assembly	212733
KSP Motor Assembly	227943
FUNCTIONAL DIAGRAM, MK6 MODS 4 & 6	317240
FUNCTIONAL DIAGRAM, MK6 MODS 7, 8 & 9	FIG 78D OP1063 (2)
GEAR DIAGRAM MK6 MOD 7	698315
GEAR DIAGRAM MK6 MOD 8	878295
GEAR DIAGRAM MK6 MOD 9	FIG 7C OP1063 (2)
1G SYNCHRO GENERATOR	213036
5G SYNCHRO GENERATOR	698727

1 DG Synchro Ordnance Description	O.D. #2598
1 F Synchro Ordnance Description	O.D. #2598
5 D Synchro Ordnance Description*	O.D. #3030
5 DG Synchro Ordnance Description	O.D. #2598
5 N Synchro Ordnance Description	O.D. #2598
6 G Synchro Ordnance Description*	O.D. #3033
6 G Synchro Ordnance Description	O.D. #2598

MG135 General Assembly	† 28275
MG141 General Assembly	† 30051
MG143 General Assembly	† 30049
MG145 General Assembly	† 30050
MG146 General Assembly	† 30052

*DD's 421-428 only

† Indicates ~~Bureau of Ships~~ ARMA CORP. Drawing Number

EXERCISING OF INSTRUMENT

1. EQUIPMENT REQUIRED

(a) A gyro motor-generator set delivered with the Stable Element for installation in the same or similar ship.

(b) A test cart (supplied only to Navy Yards) manufactured by the Navy Yard, New York.

(c) Portable leads and terminals for connecting the gyro motor generator set.

(d) A crank handle for driving the Target-Bearing (Director Train) gearing in the Stable Element through the input stub shaft.

2. EXERCISE PROCEDURE—ONCE A MONTH

(a) With the Selector Switch in the "continuous" position crank the Level and Cross-Level handles through their entire ranges.

(b) Place the crank handle (item 1 (d) above) in place on the Target Bearing (Director Train) shaft and crank the shaft approximately 20 turns in each direction.

(c) Open the Sensitive Element access door and turn rotor of the latitude correction a few turns.

(d) Using the portable leads, connect the motor generator set and energize the gyro for about 2 minutes. At the same time energize the gimbal rotation motor from a 115 volt, single phase A. C. power supply.

(e) Using the test cart (item 1 (b)) facilities, energize all synchros successively for approximately one minute each.

NOTE: 1. Great care must be exercised to insure that no dirt is allowed to enter an instrument case during the exercise period.

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*Applicable Ships

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