ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

Technical Note CT-2

MODIFICATION OF AIR FORCE TYPE J-8 ATTITUDE HORIZON INDICATOR FOR AEROBEE ASPECT INSTRUMENTATION

J. A. Foster
H. S. Sicinski
H. F. Schulte

Approved by
N. W. Spencer
Project Supervisor

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TABLE OF CONTENTS

TABLE OF CONTENTS (Concl.)

ABSTRACT

This report presents the procedures necessary for the modification of a standard Air Force type J-8 attitude horizon indicator for Aerobee aspect instrumentation. The gyro as manufactored is a "vertical gyro" which, as such, is not satisfactory for missile use. The modification procedure converts the instrument to a "free gyro" which is suitable for Aerobee missile use. Detailed drawings, photographs, and a description of special equipment and test procedures are included so that a well-trained technician or an engineer can achieve the desired result.

PROJECT OBJECTIVE

The objective of this project is research in temperature, wind, and related properties of the atmosphere and ionization in the upper atmosphere.

INTRODUCTION

This technical note describes the modifications and special techniques which have been developed by this project to convert aircraft-type attitude gyros for the in-flight photographic recording of Aerobee rocket aspect data. The basic conversion procedure was originally worked out for the Sperry F-4A which is no longer in production. Thus, a major part of the report which follows is concerned with the procedural refinements and new techniques applied to the successor of F-4A. The new unit carries the designation: attitude horizon indicator, AF Type J-8, Eclipse-Pioneer Type 14602-1J-B1, manufactured by the Eclipse-Pioneer Division of Bendix Aviation Corporation, Teterboro, New Jersey.

As received from the manufacturer, the J-8 is a vertical-seeking gyro with two axes of freedom, pitch and roll. It portrays the attitude of the aircraft relative to the earth's tangent plane during any aircraft maneuver throughout 360 degrees. The phrase "vertical seeking" is actually somewhat of a misnomer since the gyro rotor is precessed by an automatic erection system so as to maintain the rotor axis parallel to the resultant acceleration force field experienced by the gyro. The resultant acceleration force vector will necessarily be "vertical" with respect to the earth's tangent plane when the aircraft is in normal, level flight attitude.

By removing the automatic erection system and rebalancing the gyrostat, the J-8 is converted to a "free" gyro whose rotor position is virtually unaffected by the high acceleration forces encountered during the powered portion of rocket flight. In addition, other modifications are necessary to make the instrument suitable for aspect measurement. These modifications are as follows:

1. The manual caging assembly normally supplied with the gyro is converted to a motor-driven system designed for remote-control operation from the blockhouse. Appropriate electrical circuitry is included to provide remote indication in the blockhouse of the relative gyro rotor speed and position of the caging assembly.

2. The J-8 is normally equipped with a visual flag-alarm indicator ("off") actuated by a low inertia motor, to warn the pilot when the gyro is not receiving operating power. Since this function is performed by the electrical circuitry of Part 1 above, the complete flag-alarm system is removed.

3. The gyro sphere and a fixed outer scale are suitably engraved to allow measurement of the angular position of the gyro rotor.

The techniques and methods described in this report should, if properly carried out, lead to an acceptable aspect instrument. They are described in detail to guide the person who with little gyro experience desires to achieve a useable aspect gyro. Although these methods do not necessarily represent the best way of realizing the end product, they have proved satisfactory in practice. It is fully expected and anticipated that a person familiar with these methods can and will proceed to modify, improve, and simplify them. When more than one or two units are to be prepared, further improvements and shortcuts are possible.

Figures 1, 2, and 3 show three views of the Bendix J-8 gyro prior to and after modification. Detailed steps in the modification procedure, along with necessary acceptance tests and comments on the anticipated gyro accuracy during flight, are contained in the following sections.

EQUIPMENT

On the basis of ideas acquired and techniques learned during a visit to the Pioneer Central Division of the Bendix Aviation Corporation, and from past gyro experience of this project certain equipment is considered helpful during modification and testing of rocket aspect gyros.

Figure 4 shows a cabinet providing an illuminated working space (approximately 26 x 12 x 14 inches) reasonably free of dust and lint. A centrifugal blower draws room air through a filter (1) and forces it through the cabinet and out the opening at the lower front. To prevent any unfiltered room air from entering the cabinet at the front opening, it is necessary to add a flap (5). This flap has the added advantage of closing off the opening when the cabinet is not in use. An internal control panel (7) provides remote control of power sources external to the cabinet and enables the operator to monitor gyro phase voltages and currents.

Figure 5 shows an interior view of the cabinet with most of the hand tools used in this work. Also shown is the cleaning solvent (1), wash

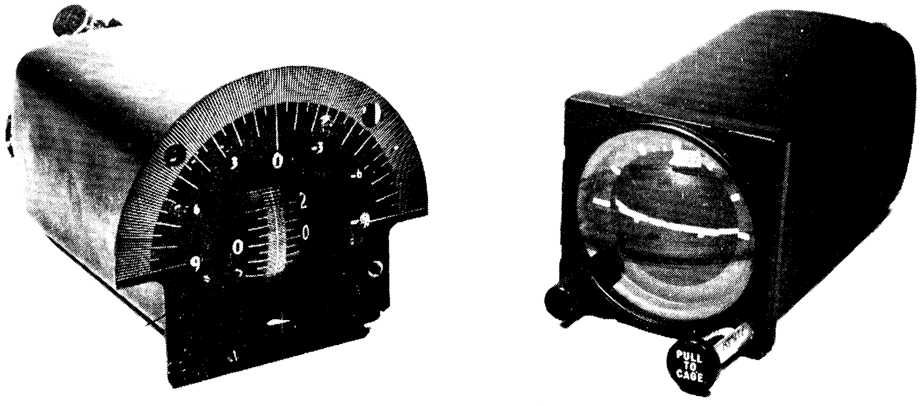
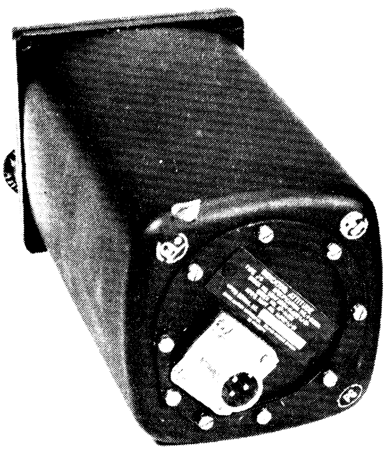


FIG. 1



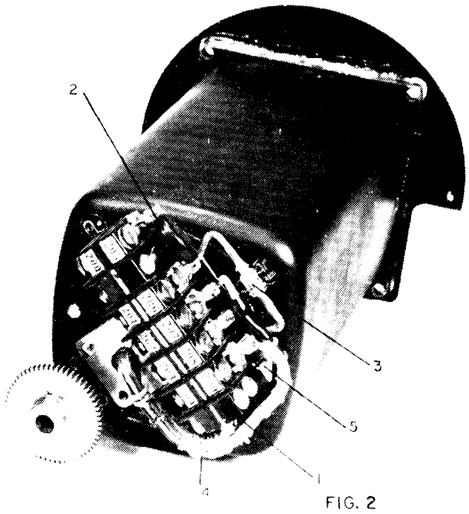
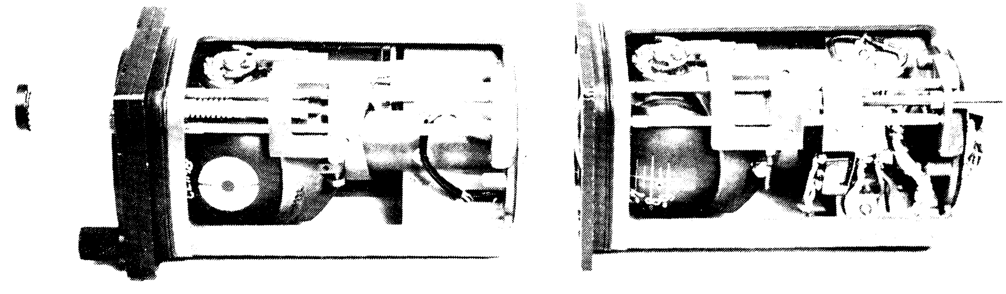


FIG. 2



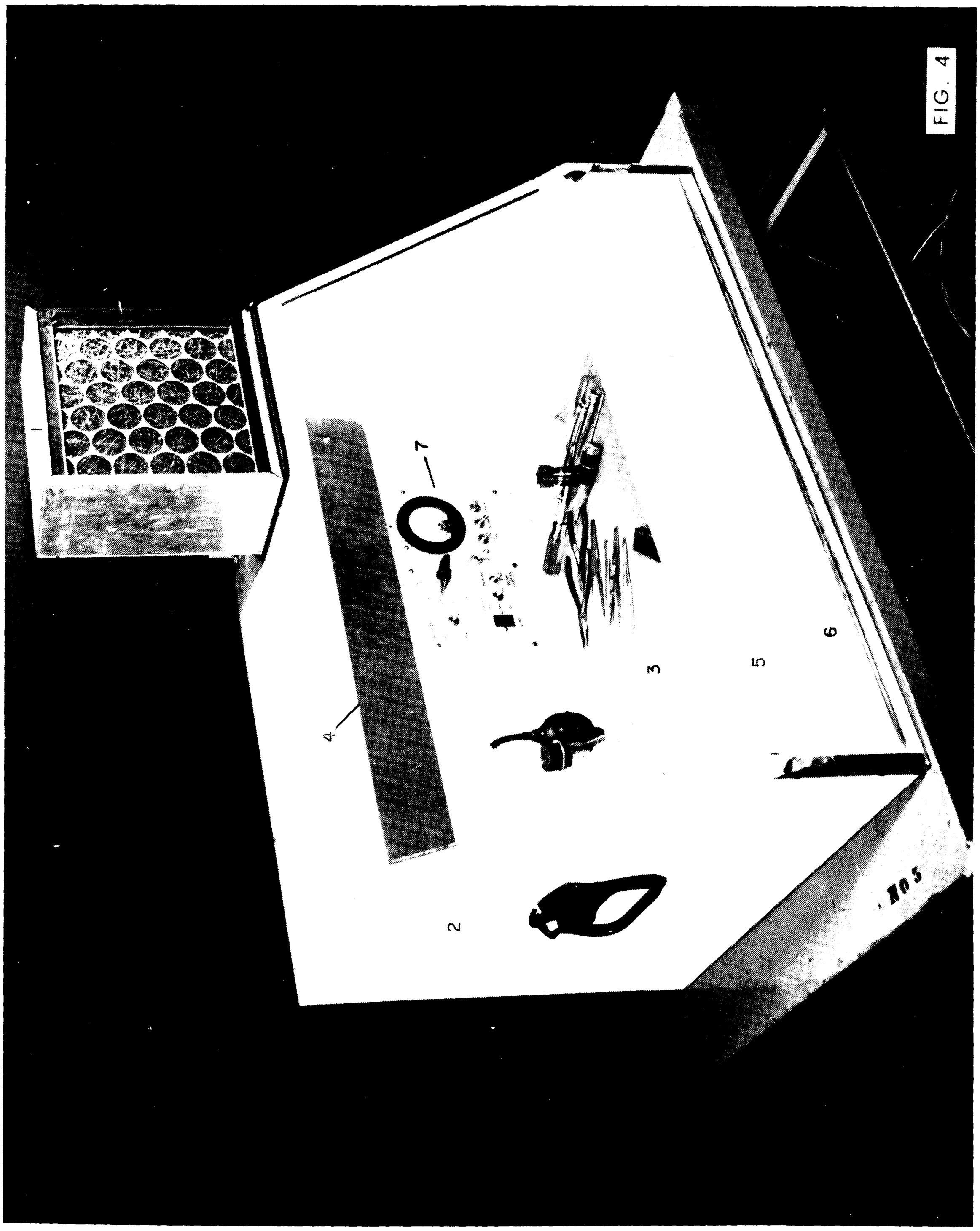


FIG. 4

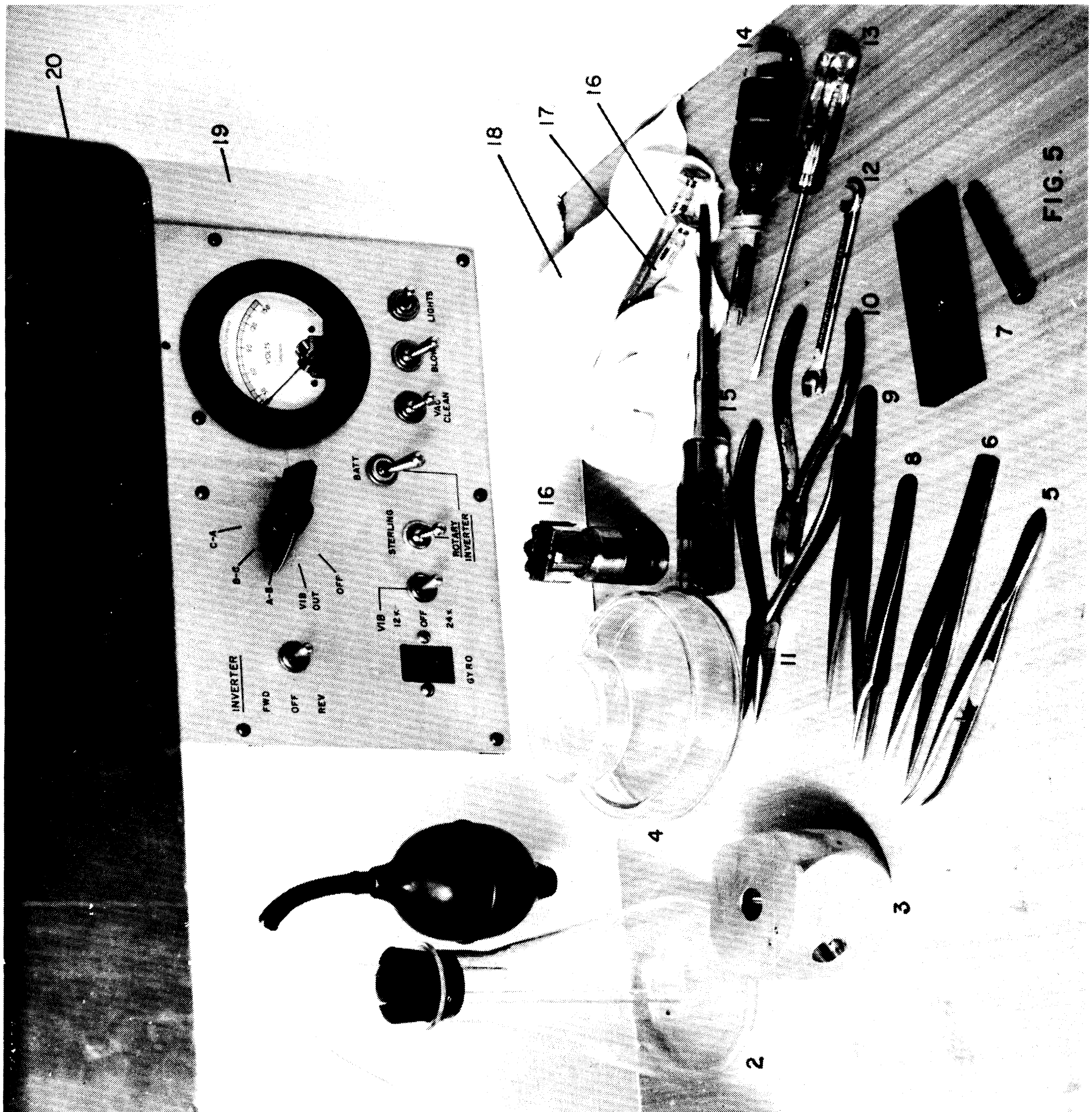

INVERTER
FWD
OFF
REV
C-A
B-C
A-B
VIB OUT
OFF
BATT
VAC CLEAN
BLOW
LIGHTS
VIB
12 K
OFF
24 K
GYRO
STERLING
ROTARY INVERTER
VOLTS
ENG-SOL
SOLUTION No. 16
CLEANING PRECISION PARTS
VOLATILE SOLVENT
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FIG. 5

bottle (2), and the fixture (3) for holding the gyro sphere during the engraving operation. The cabinet is to be used for all dismantling, reassembly and testing operations.

DISMANTLING PROCEDURE

REMOVING THE DUST COVER

Holding the instrument vertically with the face down cut and remove all seal wire. Remove the nine drilled screws (3, Fig. 6) and take off the reinforcing ring (2). Unscrew the plastic cap (4D)* and gently but firmly slide the dust cover (5) from the mechanism. This is most easily accomplished by pushing the thumbs against the cover plate (12) and pulling on the cover with the fingers. However, keep the thumbs away from the immediate center of the cover plate because it is unsupported in that region.

REMOVING THE BEZEL ASSEMBLY

Remove the clip (1D) from the front of the instrument and place the instrument on its side permitting easy access to the centering bracket assembly (43). The next step will allow the gyro to uncage, so it is advisable to loosen the screws slowly. Loosen and remove the two screws (40D), the clamp plate (41D), and the clamp block (42D).

Before continuing the dismantling, it is advantageous at this time to mark the guide block (32, Fig. 7) for modification according to drawing no. 48-100-210.** Observe the bearing post on the back side of the centering bracket (12, Fig. 12) which slides into the guide block during the caging operation. Deposit a thin layer of Prussion blue on the surface of this bearing where it contacts the guide block. Cage and uncage the gyro several times until the extent of travel of the bearing post into the guide block is well defined on the internal sides of the block. These marks will be utilized later in the modification.

Loosen and remove the two locknuts (19D, Fig. 6) located between the arms of the centering bracket assembly (43), and draw out the knob and shaft assembly (18D) from the bezel, catching the springs (29, 31D) and the special washer (30D) with the other hand.

*Whenever a part number is followed by the letter "D", that part is to be discarded since it is of no further use on the modified instrument.

**All modification drawings are contained in the Appendix.

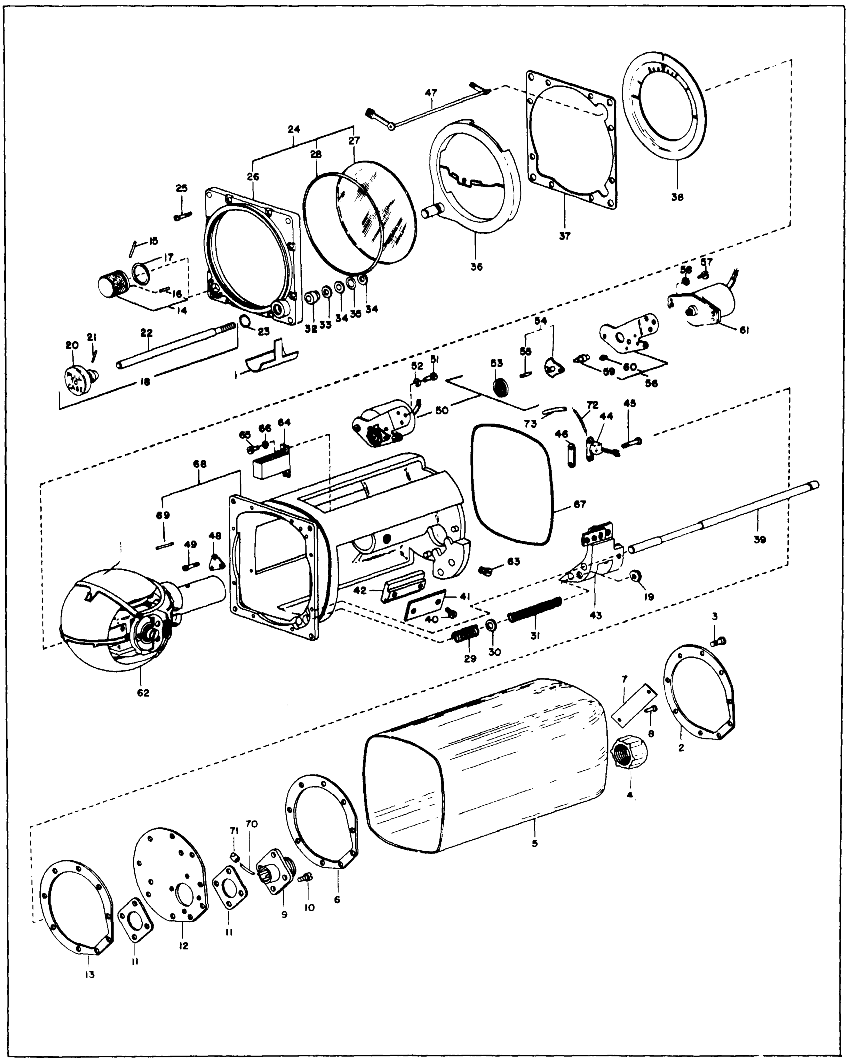
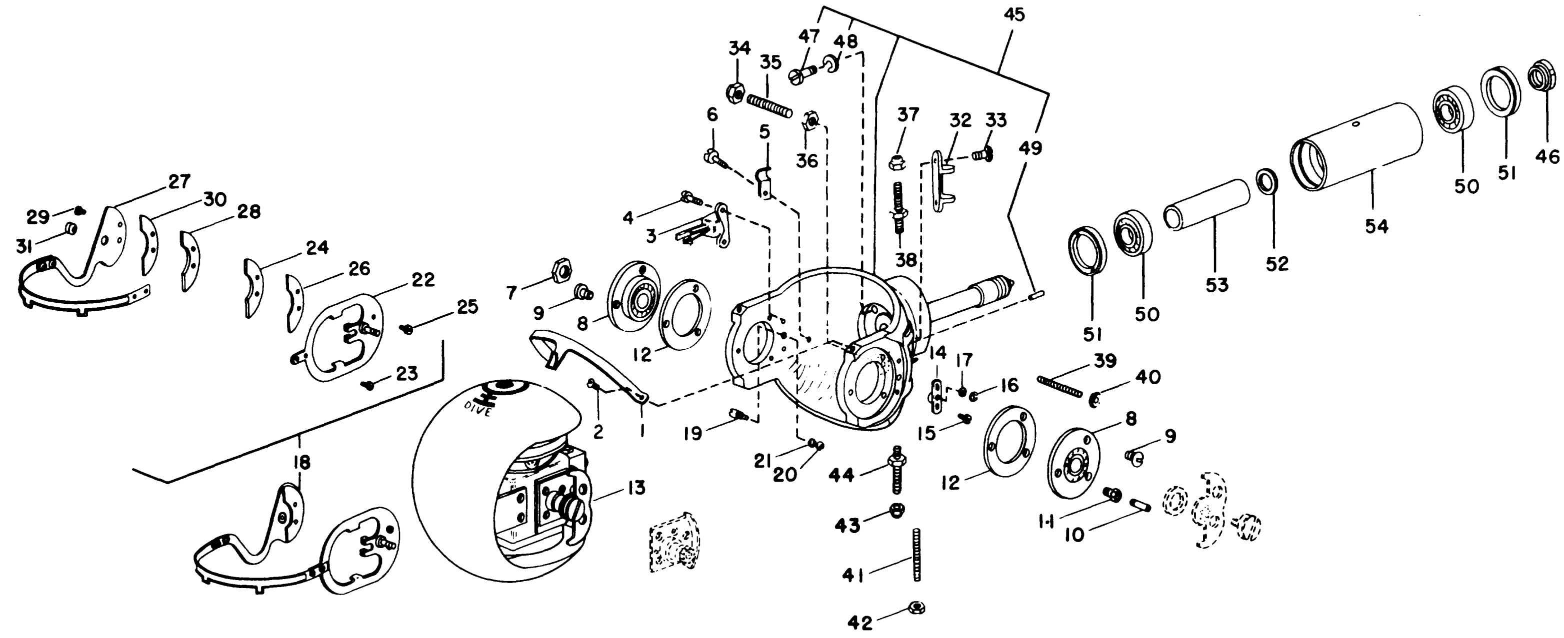


FIG. 6 Exploded View - Indicator Assembly

1 Clip
2 Reinforcing plate
3 Screw
4 Plastic cap nut
5 Cover
6 Gasket
7 Name plate
8 Rivet
9 Receptacle
10 Screw
11 Receptacle gasket
12 Cover plate
13 Gasket
14 Knob and pin assembly
15 Pin
16 Pin
17 Spacer
18 Knob and shaft assembly
19 Locknut
20 Knob
21 Pin
22 Shaft
23 "O" ring seal
24 Bezel assembly
25 Screw
26 Bezel
27 Cover glass
28 Gasket
29 Spring
30 Special washer
31 Spring
32 Spacer
33 Seal washer
34 Gasket
35 "O" ring seal
36 Attitude bar assembly
37 Bezel gasket
38 Dial
39 Guide shaft
40 Screw
41 Clamp plate
42 Clamp block
43 Centering bracket assembly
44 Brush block
45 Screw
46 Laminated shim
47 Shaft assembly
48 Bearing plate
49 Screw
50 Bracket and motor assembly
51 Screw
52 Lock washer
53 Hairspring
54 Sector assembly
55 Hairspring stud
56 Bracket assembly
57 Screw
58 Lock washer
59 Idler stud
60 Stop pin
61 Low inertia motor assembly
62 Gyro and yoke assembly
63 Screw
64 Plate and lug assembly
65 Screw
66 Lock washer
67 Gasket
68 Frame assembly
69 Pin
70 Lead wire
71 Insulating sleeving
72 Lead wire
73 Insulating sleeving

KEY TO FIG. 6



1 Index
2 Screw
3 Brush block
4 Screw
5 Clamp
6 Screw
7 Nut
8 Flanged bearing
9 Screw
10 Screw
11 Nut
12 Shim
13 Gyro and sphere assembly
14 Jewel
15 Screw
16 Retaining ring
17 Shim
18 Horizon bar assembly
19 Pivot screw
20 Retaining ring
21 Shim
22 Frame assembly
23 Screw
24 Counterweight
25 Screw
26 Shim
27 Horizon bar and arm assembly
28 Counterweight
29 Screw
30 Counterweight shim
31 Jewel
32 Centering block
33 Screw
34 Elastic stop nut
35 Setscrew
36 Nut
37 Elastic stop nut
38 Stud
39 Setscrew
40 Nut
41 Setscrew
42 Nut
43 Elastic stop nut
44 Stud
45 Yoke and pivot assembly
46 Nut
47 Screw
48 Lock washer
49 Pin
50 Ball bearing
51 Locking nut
52 Spacer
53 Spacer
54 Bearing sleeve

FIG. 7 Exploded View - Gyro and Yoke Assembly

Take out the eight screws (25) and lift the bezel assembly (24) and attitude bar assembly (36D) from the gyro frame (68). Remove the "O" ring-gasket (28) from behind the cover glass (27D) and discard the rest of the bezel assembly.

FRAME

Draw out the guide shafts (39), removing the centering bracket assembly (43) at the same time.

To remove the shaft assembly (47) which rides through the smaller diameter hole in the bearing plate (48), remove the two screws (49D) and the bearing plate (48D). Disengage the slotted arm from the stud of the sector assembly (54), turn the arm away from the motor (61), and draw out the shaft (47D) from the rear of the mechanism.

Unsolder all leads to the plate and lug assembly (64), remove the two screws (65D), lock washers (66D), and the plate and lug assembly (64D).

To remove the motor and bracket assembly (50D), remove the three screws (51D) and lock washers (52D) which secure the assembly to the gyro frame (68).

In taking off the brush block (44), remove the four screws (10) at the rear of the mechanism and draw out the electrical receptacle (9D) with its associated leads. Lift off the two receptacle gaskets (11), the cover plate (12), and cover plate gasket (13). For future reassembly it will be very convenient if the cover plate gasket (13) is cemented inside the dust cover (5). Rubber weather-strip adhesive produced by 3-M Corporation is excellent for this purpose. Remove the two screws (45) and carefully withdraw the brush block (44) with its associated leads and the laminated shim (46). If there appears to be any danger of breaking off the delicate brush block lugs, unsolder the leads before removal.

To separate the gyro and yoke assembly (62) from the frame (68), remove the two screws (63), rotate the gyro and yoke assembly (62) 45 degrees clockwise with respect to the frame viewed from the front. Carefully remove the gyro and yoke assembly with one hand pushing against the back side of the yoke and the other hand in front of the frame to complete the removal. Place the assembly in a fixture such as that shown in Fig. 8 to facilitate further dismantling.

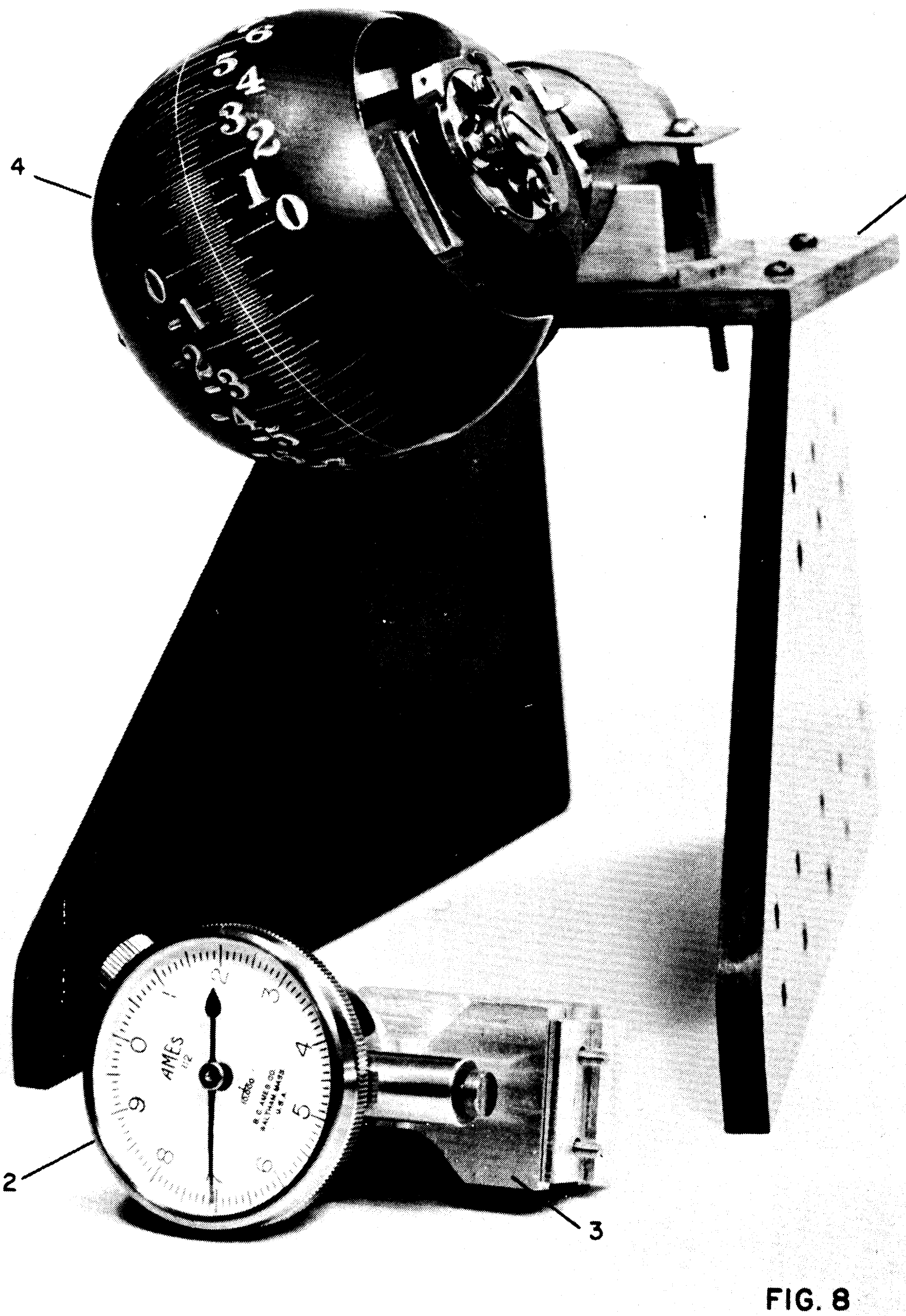


FIG. 8

DISASSEMBLY OF GYRO-YOKE MECHANISM

Remove the two screws (2D, Fig. 7) and lift off the index (1D). Unsolder the three leads of the yoke and pivot assembly (45) from the brush block (3). Take out the two screws (4) and remove the brush block (3) carefully avoiding damage to the brushes or slip rings. During all work on the gyro, one must be very careful not to damage the slip rings, both on the gyrostat and at the rear of the yoke. Fold the three unsoldered leads back against the yoke frame and secure with tape or place under clamp (5).

Rotate the assembly so that the flanged bearings (8) lie in a vertical line with the brush-block side of the yoke (45) on top. Hereafter the flanged bearings (8) will be called the pitch bearings and the axis of rotation through their centers, the pitch axis. To differentiate between pitch bearings, the one on the cam side of the yoke will be called the "cam" bearing and the opposite one, the "brush" bearing.

Remove the nut (7) and the three screws (9). There is one note of caution before removing the brush bearing (8); to avoid corrosion and contamination never handle the pitch bearings directly with the fingers. Always use nonmagnetized tweezers (5, 6, and 9, Fig. 5) or the lint-free cloth (18).

Using the bearing puller (16) remove the brush bearing (8, Fig. 7) and shim or shims (12). Place this bearing, shims (12), three screws (9), and nut (7) in a dustproof container such as (4, Fig. 5). The associated parts help identify that particular pitch bearing as being the brush bearing.

Steadying the gyrostat assembly (13, Fig. 7) by hand, invert the yoke assembly (45) thereby placing the cam side of the yoke on top. Remove the two screws (9) and the eccentric screw with its locknut (10, 11). Loosen and remove the screw (9, Fig. 9), lift off the cam (8), shims, if present, and special washer (10). Gently allow the gyro assembly to settle on to the lower yoke arm. Remove the cam bearing (8, Fig. 7) and shim or shims (12). Place the cam bearing, shims, two screws (9), eccentric screw and locknut (10, 11), cam, special washer, and screw (9, Fig. 9) in a dustproof container.

Insert a screw driver through the yoke cam bearing bore, loosen and remove the four screws (50, Fig. 10) which secure the pivot and pin assembly (49) to the side of the gyro housing (54). Grasp the gear of the pivot and pin assembly and carefully loosen it from its doweled seat on the side of the gyro housing. Shifting the gyro-sphere assembly toward the cam side of the yoke to free the slip-ring pivot (11, Fig. 9) from the yoke and rotating the assembly upward will permit its removal. Now the pivot assembly (49, Fig. 10) can be removed from its position in the fork of the frame assembly (22, Fig. 7).

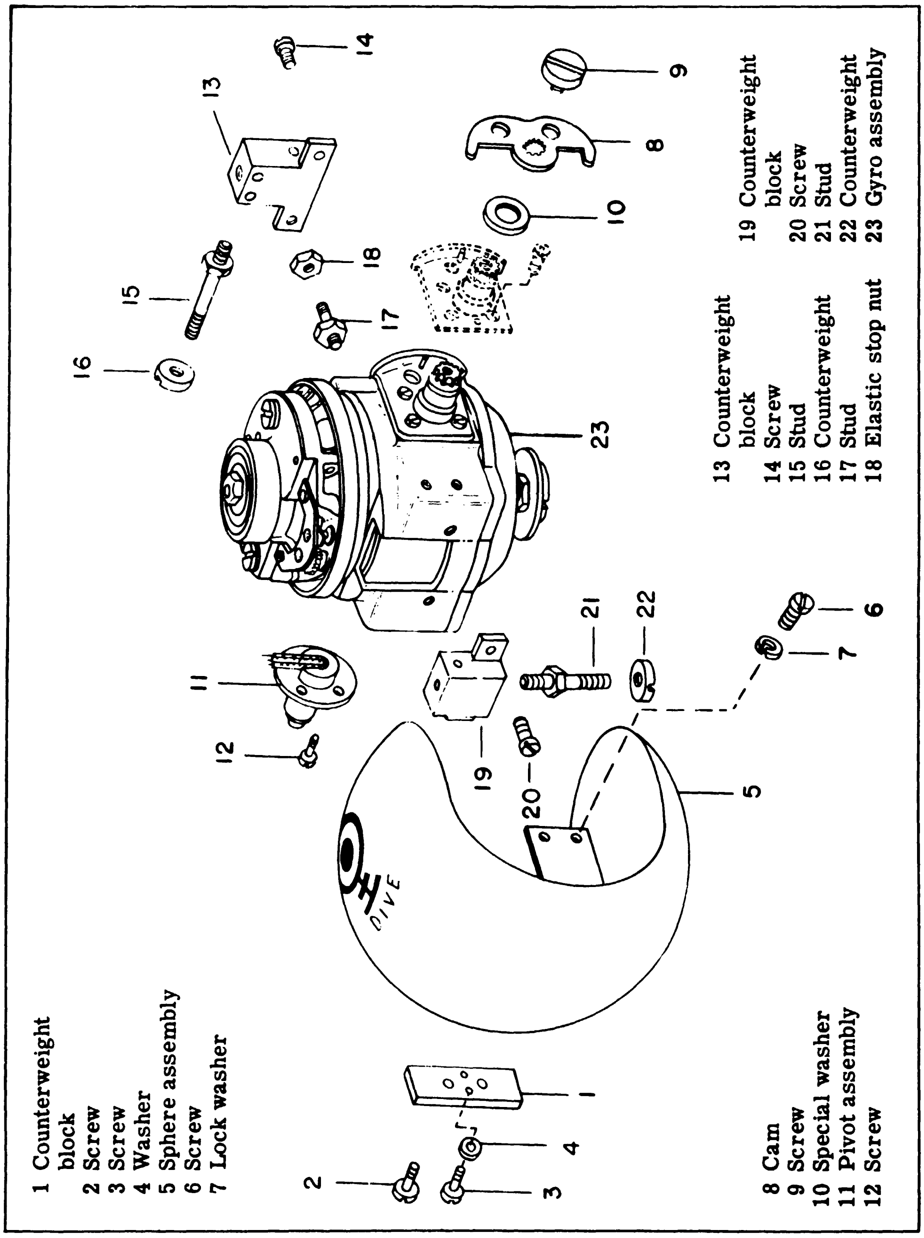


FIG. 9 EXPLODED VIEW - GYRO & SPHERE ASSEMBLY

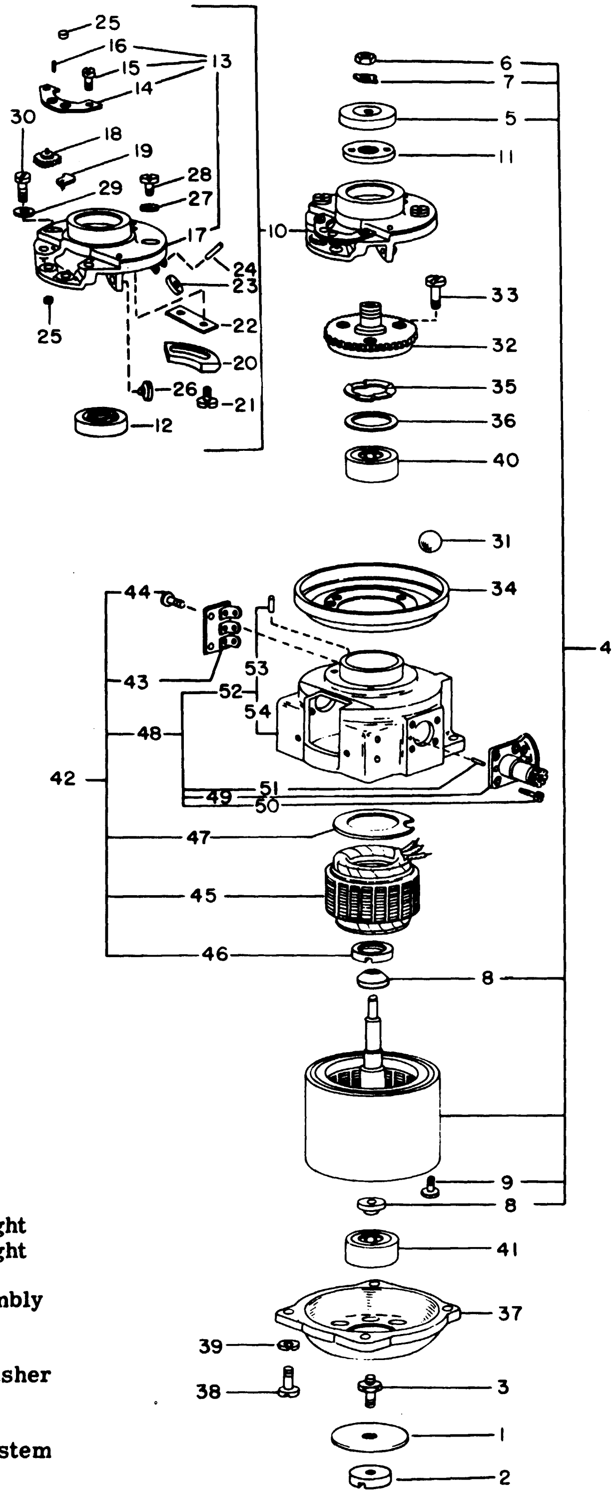


FIG. 10

1 Counterweight
2 Counterweight
3 Stud
4 Rotor assembly
5 Magnet
6 Nut
7 Coupling washer
8 Cone
9 Screw
10 Erection system assembly
11 Nut
12 Ball bearing
13 Bracket and plate assembly
14 Erection system top plate
15 Screw
16 Carrier pin
17 Erection system plate
18 Pinion and ratchet assembly
19 Pawl assembly
20 Counterweight
21 Screw
22 Shim
23 Erection system roller
24 Roller bracket pivot
25 Ball bearing
26 Insert
27 Sieve washer
28 Screw
29 Sieve washer
30 Screw
31 Ball
32 Gear
33 Screw
34 Ball track
35 Spring washer
36 Shim
37 Housing cover
38 Screw
39 Lock washer
40 Cup and ball assembly
41 Cup and ball assembly
42 Stator and housing assembly
43 Terminal board assembly
44 Screw
45 Stator assembly
46 Nut
47 Insulating washer
48 Housing and pivot assembly
49 Pivot and pin assembly
50 Screw
51 Pin
52 Housing and pin assembly
53 Pin
54 Housing

Exploded View - Gyro Assembly

In removing the jewel (14D), take off the retainer ring (16D), lift off the shim or shims (17D), and remove the two screws (15D).

Pry off the retainer ring (20D) and lift off the shim or shims (21D). Remove the horizon bar assembly (18D) by springing the arms inward slightly. Remove the pivot screw (19D).

After taking note of the approximate location of the centering block (32) relative to its two retaining screws (33) and to the yoke, remove the screws and the block.

GYROSTAT DISASSEMBLY

To take off the sphere (5, Fig. 9) remove the two screws (2) and lift off the counterweight block (1). Take out the two screws (6) and lock washers (7). Remove the spherical section by rotating it toward the erection assembly (10, Fig. 10) and springing the sphere slightly. Do not force unnecessarily.

With the erection assembly (10) facing upward, remove the nut (6D), and lift the coupling washer (7D) and magnet (5D) out of the assembly. Using a fixed pin spanner or the points of a pair of jeweler's pliers, remove the nut (11) and carefully slide the erection assembly (10D) off the shaft of the bracket and plate assembly (13). Remove the two balls (31D).

This completes the dismantling procedure recommended for nonfactory personnel. Any further dismantling of the gyro assembly (Fig. 10) or the yoke sleeve and sleeve bearings (Fig. 7) should only be done by properly equipped personnel trained by the manufacturer.

To determine if further dismantling and overhauling are necessary, a few indicative tests may be made.

Gyro rotor speed should not be less than 21,000 rpm, as checked by a strobotac, three minutes after applying rated voltage. Any lower speed is probably due to faulty bearings or worn cones. Also, the voltage required for rotor "breakaway" should not exceed 75 volts.

The sleeve bearings (50, Fig. 7) should be tested for cleanliness and the yoke-axis* end play should be checked. An approximate determination of sleeve bearing cleanliness can be made by holding the sleeve (54) lightly in the fingers with the roll axis vertical and impulsing the yoke into very slow rotation and noting vibration, roughness, or jerky, uneven motion. Invert the assembly and repeat. Clean bearings will produce a smooth, even rate of rotation.

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*Also called the bank axis or roll axis.

Yoke-axis end play may be measured by clamping a dial indicator (2, Fig. 8) to the sleeve (54) with the anvil resting on the slip-ring end button. With roll axis vertical, read the indicator. Invert the assembly and again read the indicator. The difference in readings is the roll-axis end play should be about 0.0015 inch. Excessive end play means essentially that good balance about the roll axis cannot be achieved. If the end play is too small then thermal expansion of the parts will cause high bearing friction. The value of 0.0015 is recommended by the manufacturer.

MODIFICATION OF PARTS AND NEW PART CONSTRUCTION

FRAME

Figure 11 and drawing nos. 48-100-100 through -109 give details concerning the modifications associated with the frame.

Caging System.—The hole (1, Fig. 11) in the casting providing bearing support for the caging system drive shaft (48-100-101) can be located by various methods. One of the better ways is to fabricate the drive block (48-100-109) leaving the center hole undrilled. Mount both the drive block and the unmodified caging bracket on the guide shafts in the frame. Move both pieces to the rear inside surface of the frame casting, and clamp in position. From the dimensions given on 48-100-109, prick punch a locating point on the rear surface of the frame casting. Using a No. 20 drill, drill through the frame casting, drive block and caging bracket as indicated on 48-100-106 and -109, making certain that the drill runs parallel to the guide shafts. After this initial pilot hole is located in the individual parts, the finishing operations as detailed in the aforementioned drawings can be completed. The drive shaft hole (1, Fig. 11) in the frame casting should be drilled and reamed for a "running" fit with the drive shaft. On some castings the "draft" may be such as to require some spot facing on both ends of the drive shaft hole.

In locating the drag-link pin (5, Fig. 12), assemble the spring (1), drive block (2), and caging bracket (3) with the drag link (4) on to the guide shafts (9); see also drawing 48-100-100. Clamp the drive block and caging bracket together so that the spring is relaxed without excessive play. Drill and ream the drag-link pinhole for a light press fit with a 3/32 straight dowel (5).

To locate the retaining-collar set screw hole in the drive shaft, install the drive shaft in the frame bearing hole (1, Fig. 11). Add drive shaft washer (48-100-102), two thicknesses of paper (about 0.005 inch), and

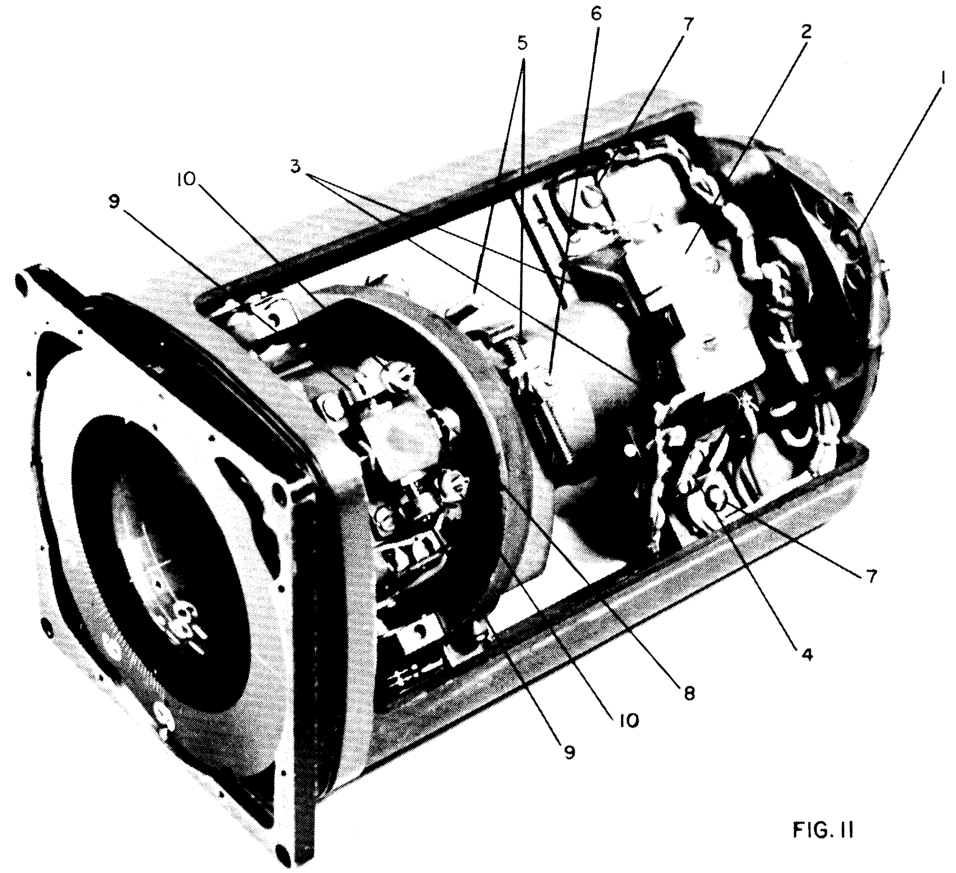

FIG. 11

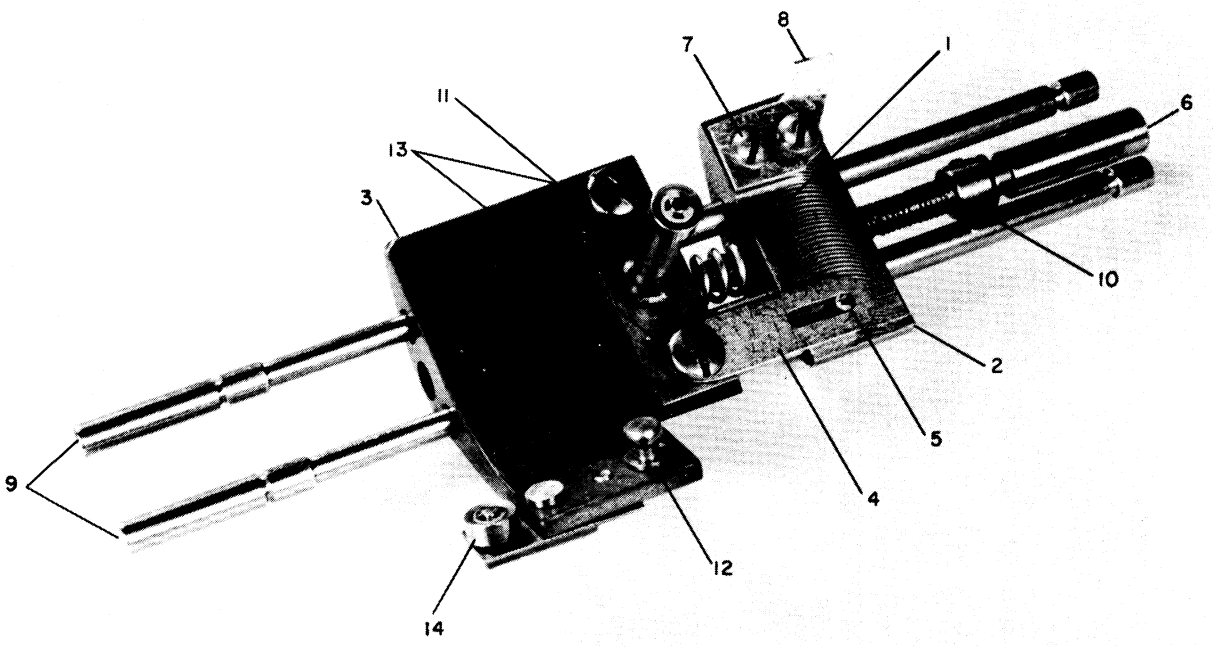

FIG. 12

retaining collar (10, Fig. 12) without the set screw (48-100-104). Compress the parts together and clamp in position. Using a No. 51 drill and working through the set screw hole in the collar, drill a shallow hole in the drive shaft.

Mount the GE CR-1070-C103 switch on the switch support bracket (48-100-108) as indicated in Fig. 11. Mount the 1SM1 microswitch and JS-2 actuator on the microswitch support bracket (48-100-107). Assemble the two brackets with switches. Using parallel clamps, locate and clamp the switch assembly in a position on the frame approximating that shown in Fig. 11. The final position will be determined after the caging drive system is assembled on the frame.

Degrease the caging drive block (2, Fig. 12) and drive shaft (6). Coat the threaded portions of the drive shaft and the drive block with type Z Molykote dry lubricant. Thread the shaft in and out of the drive block several times and blow off the excess lubricant with compressed air. Coat the portion of the drive shaft that will be in contact with the frame casting with type G Molykote (greaselike mixture). Insert the drive shaft in the frame bearing hole, and rotate the shaft working the mixture on to all the contacting surfaces. Remove the shaft and wipe off the excess lubricant from the frame and the shaft. Reinsert the shaft in the frame casting, and add the washer, retaining collar, and set screw. Partially thread the drive block (2) on to the drive shaft (6) and insert the spring (1) in the counterbored end of that block. Install the guide shafts (9) from the rear of the frame until they pass through the drive block. Relieved sections of the guide shafts should be in the forward position (Fig. 12). Assemble the caging bracket on to the mechanism by locating the other end of the spring in its counterbored hole, slipping the drag link over the pin on the drive block and completing insertion of the guide shafts into position (Fig. 1).

Turn the drive shaft until the drive block is about one thread (1/32 inch) from the retaining collar (10, Fig. 12) (uncaged position). Loosen the parallel clamps and reposition the switch bracket so that the hub post (11) of the centering bracket assembly (3) has just actuated the GE uncaged limit switch. Tighten the parallel clamps; using a 4-40 tap drill, drill three holes through the switch bracket pads and frame webbing, one on the microswitch (4, Fig. 11) side of the bracket and two on the other. Advantage may be taken of one of the existing-inertia motor-bracket mounting holes.

Disassemble the caging drive system except for the drive shaft. Remove the switch bracket assembly and drill clearance holes (No. 32 drill) in the pads. These "loose" clearance holes in the bracket pads will permit a small amount of adjustment in bracket position during the caging system checkout. Tap the holes in the frame webbing. Thoroughly clean the frame of chips and dirt. Reinstall the switch bracket assembly with 4-40 screws and lock washers.

Bushings.—Fabricate two bushings as shown on drawing 48-100-110. These bushings serve to lock the yoke spindle in place in the instrument frame and thus prevent undesired axial movement caused by accelerations encountered during rocket flight.

Electrical Wiring.—For wiring and cabling information refer to the gyro control schematic (48-050-050), pictoral of electrical modifications (48-050-051), and Fig. 11. Plastic-coated AWG No. 22 stranded wire is used throughout on the model shown in Fig. 11 but a smaller wire size (i.e., No. 24) would be desirable for the three roll-axis brush-block connections. The cable is left sufficiently long to complete the external terminal connections later (Fig. 3). Slip a short section of sleeving over the cable section where it passes through the frame. The cable port (48-100-201) will be installed during final assembly.

After the completion of wiring and cabling, make a visual check of all soldered terminals for possible shorts. Especially note the two terminals and nearby surroundings of the uncaged limit switch on the micro-switch end of the switch bracket. A strip of electrical tape on the bracket beneath those two terminals may be desirable. The terminal nearest the JS-2 actuator may have to be bent away from the actuator to provide proper clearance.

Perhaps it should also be noted here that the switch bracket assembly obstructs accessibility to the two frame holes through which the gyro-yoke spindle sleeve is secured to the frame (3, Fig. 11). Consequently, whenever the gyro-yoke assembly is installed or removed from the frame, the screws fastening the switch bracket assembly to the frame webbing must be removed and the assembly shifted sufficiently toward the rear of the frame.

ERECTION SYSTEM

For reasons stated in the "Introduction" the erection system must be inactivated or removed entirely. The latter was chosen for its simplicity.

To avoid serious balancing difficulties an equivalent weight (48-100-203) replaces the erection assembly. The disc diameter indicated in the drawing is slightly larger than necessary and must later be machined down as discussed under "Static Balance."

GUIDE BLOCK

The modification on the guide block consists simply of grinding relief angles on the inside shoulders of the guide block as shown on drawing 48-100-210. It was found that this procedure prevented pitch axis precession due to a mechanical "nudge" during the uncaging operation.

BETA SCALE

The angle defined by an angular variation about the roll axis will be called the "beta" angle in this report. Thus the plexiglas scale (1, Fig. 2) provides an angular reference for the roll axis and hence is called the "beta" scale.

Engraving the beta scale (48-100-202) requires a dividing head, fixture for clamping the plexiglas to an arbor plate chucked in the dividing head, an engraving point and point holder, and a vertical mill if an engraving machine is not available.

The engraving point used is a Stellite phonograph cutting needle reground to a 30-degree included angle and having appropriate relief angles. The 30-degree angle was chosen because the depth of cut is then greater than the line width. Hence line width is not so dependent on nonuniform material thickness. For the desired line width of 0.005 inch the depth of cut is 0.009 inch.

After the engraving operation the line edges must be deburred. Light buffing using jeweler's rouge on a high-speed wheel is sufficient. One must not use excessive force for too much material will then be removed.

Clean the grooves of rouge and foreign particles using a bristle brush and warm, soapy water or an acceptable solvent. In this operation and all subsequent handling of the scale, avoid scratching the front surface.

Smear on white printer's ink such as Flint opaque mixing white E-9839 and rub it into the engraved lines. Excess can be removed with the fingers followed by gentle rubbing with lens paper. Tissues such as Kleenex are too fuzzy and tend to wipe the ink out of the grooves. Allow at least an hour, but preferably overnight, for the ink to dry.

For a horizontal "cross hair" an 0.002-inch Moly-G wire was selected because of its high tensile strength and ductile characteristics. The 0.002-inch diameter was chosen on the basis of photographic tests. Wire preparation involves a thorough degreasing followed by an airbrush application of a very thin coat of white lacquer. The initial tendency is to make the coating too thick and nonuniform around and along the wire, so caution is required.

From the engraved side of the scale install two 0-80 round-head screws. Cut a section of the cross-hair wire slightly longer than the outside diameter of the scale plate. From the front of the scale insert the ends of the wire through the two 0.006-inch holes so that the wire extends across the center opening. Draw one end of the wire out through the center opening, loop it around the adjacent 0-80 screw and tighten the screw. Similarly for the other end of the wire. By making the turns of the wire about the screw in the direction in which the screw is tightened, one may put considerable tension on the wire. To prevent wire breakage during scale installation on the frame, it is advisable to leave the last screw loose and some slack in the wire. Trim off excess wire length.

DUST COVER

After the hole is drilled in the cover according to drawing 48-100-204, a neoprene-caging drive shaft sealing gasket having a 7/32-inch shaft clearance hole is cut to fit inside the dust cover.

Using 3-M weather-strip or some other suitable adhesive, cement the gasket in position with the gasket clearance hole centered over the dust cover hole. The area close around the gasket clearance hole is thoroughly coated with dry-type Z Molykote lubricant. The 1/4-inch diameter section of the caging drive shaft (6, Fig. 12) is also liberally coated with type Z Molykote, inserted into the gasket, rotated, and removed, thus depositing a thin layer of the lubricant on the contacting parts. Remove the excess from the gasket with compressed air. Carefully clean the dust cover of dirt and lint then store in a dust-free location.

SPHERICAL SECTION

Mark the internal surface of the sphere for proper orientation on the gyrostat during reassembly. The "dive" end of the sphere will be adjacent to the brass replacement weight.

Remove all the fluorescent paint markings and the black paint, using a liquid-type paint remover, such as acetone or any other good paint remover. Avoid scraping with metallic objects to prevent damage to the dichromate undercoat.

Using an air brush or spray gun, deposit a very thin coat of black enamel on the outer surface of the sphere. Be careful not to apply a heavy coating for it will peel during the engraving operation. Use only enough to blacken the surface; then allow it to dry under dust-free conditions.

REASSEMBLY

YOKE

<u>Preparation</u>.—Check the yoke spindle slip rings for pitting, burned

spots, or scored surfaces using about 10X magnification. If rework is necessary, mask off the adjacent spindle bearing and polish the slip rings with 4-0 polishing paper. When the slip rings are deeply scored, they may require rough finishing with 0-type polishing paper. An alternate conditioning method is to burnish the slip rings with a highly polished, slim-tapered scribe or needle. This produces a very smooth surface, even better than the polishing paper. The end contact button may also require some smoothing.

Carefully check the pitch-bearing seats and holes in the yoke for dents, nicks, embedded pieces of metal or any other condition which will not allow the pitch bearings to seat properly and consistently in one position. Of course, such defects must be eliminated. Scraping, peaning, light sanding, and other techniques may have to be employed in severe cases.

Install the modified guide block (48-100-210) with its two holding screws (33, Fig. 7) on the gyrostat in the approximate position it occupied previous to disassembly.

Using a small nylon brush and the Eng-Sol 16 (1, Fig. 5) cleaning solvent, thoroughly clean all parts of the yoke. Do not allow any solvent inside the yoke spindle sleeve (54, Fig. 7) or on the sleeve bearings (50).

Apply a thin film of light oil such as Superla watch oil on the spindle sleeve and pitch-bearing mounting holes, then mount the yoke in the bench fixture (1, Fig. 8).

Install the cam-bearing shims (12, Fig. 7) and the cam pitch bearing (8), using the two screws (9, Fig. 7) and the eccentric screw and locknut (10, 11) on the guide block side of the yoke. Similarly install the brush-block bearing shims (12), brush-block pitch bearing (8) and the three screws (9).

Using about 10X magnification, check the brushes on the brush block (3) for pitted or burned contact edges. Small defects can be removed by polishing paper, but very bad cases may require either repositioning of the brushes so as to shift their points of contact on the slip rings or complete brush-block replacement.

Install an acceptable brush block (3) on the yoke using two screws (4). Resolder the three leads such that white (phase A) goes to the wide, flat-end brush, black (phase B) to the center set of brushes, and yellow (phase C) to the remaining set of brushes (representing the innermost slip ring on the gyrostat slip-ring assembly).

<u>Static Balance</u>.—It is advantageous to have counterweight screws with locknuts in the three possible locations on the back of the yoke. Two

positions are pictured at 5, Fig. 11, along with an elastic stop nut on a separate screw (6). All static yoke balancing is accomplished by adjusting the positions of the counterweight screws with the aid of their locknuts. Additional stop nuts or locknuts may have to be added or removed from the screws, depending on the balance requirements.

The balancing procedure is quite simple. Nudge the yoke into slow, free rotation with a finger or tweezer and observe where it stops. The center of unbalanced mass is then directly below the roll axis except for the bearing frictional effects. Therefore, the adjustable weights must be moved so as to shift their resultant weight (and overall-system center of gravity) vertically or <u>diagonally</u> <u>opposite</u> the region of pendulosity. This procedure is repeated again and again. Balance will converge rapidly (especially when one is experienced) to a point where detection of unbalance is difficult.

To overcome the bearing friction, it is helpful to vibrate continuously the bench fixture in some fashion. Rotating the hexagonal head of a screwdriver against the fixture by hand is one way, but a more convenient and less-tiring method is to mount an eccentric flywheel on a small PM d-c motor, clamp the motor to the fixture and vary its speed to provide the desired amount of vibration.

Acceptable static balance will be achieved when for any arbitrary position of the yoke no motion occurs because of unbalance. Fixture vibration may cause the yoke to wander in a random fashion, but the point of unbalance is still indeterminate. This condition should exist of course after all the locknuts are tight. Therefore, it is advisable to keep all the locknuts tight as the point of indeterminacy is approached.*

In preparing the yoke for the gyro-yoke assembly, remove the two brush-block screws and lay the brush block back against the back side of the yoke, taping it temporarily in position to protect the brushes and three electrical connections. Remove the three retaining screws, brush-block pitch bearing and shims, storing all the parts including the two brush-block screws in the same dust-proof container.

Similarly, remove the cam pitch bearing and its associated parts. Check both pitch-bearing seats and bore holes in the yoke for foreign particles as detailed previously. If the bore holes are ever cleaned again with solvent, make certain that an oil film is applied to them before the pitch bearings are reinstalled. Dry steel on dry aluminum will result in seizure of the aluminum to the steel.

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*As the region of indeterminate unbalance is approached, the state of cleanliness of the spindle bearings will become quite evident. The effects of dirty bearings are manifested by uneven, jerky rotation for no fixture vibration and with very slow yoke rotation.

The yoke should be stored in a dust-free container such as a polyethylene freezer bag until used in the gyro-yoke assembly.

GYRO-YOKE ASSEMBLY

Outline of Procedure.—The preparation of parts for the assembly primarily involves the gyrostat and the pitch bearings. The pitch-bearing preparation will be discussed in detail.

After installing the gyro in the yoke, a preliminary setting of pitch-axis end play is made, followed by a rough pitch-axis balance using a dummy sphere weight. Next, the sphere is installed and pitch-axis balance completed. The final step is centering the gyrostat in the yoke and resetting of pitch-axis end play accompanied by balancing about the roll axis.

Gyrostat.—Check the gyrostat slip rings and if necessary polish them as outlined previously under yoke preparation, but mask off all openings into the rotor chamber beforehand. After slip-ring conditioning, thoroughly clean all parts and surfaces of the gyrostat using a bristle brush moistened with cleaning solvent.* As with the yoke, it would be unwise to allow solvent inside the rotor housing.

Clean the brass replacement weight (48-100-203) of the erection mechanism and mount on the spindle of the gear (32, Fig. 10) with the nut (11). Store the gyrostat in a dust-free container.

Pitch-Bearings.—Clean and check all the parts associated with each pitch bearing. The shims should be carefully checked for nicks, dents, and embedded particles. Remove the nicks and dents by burnishing on a lapped plate with a lapped rod (7, Fig. 5) or equivalent equipment. Measure the shims associated with the cam pitch bearing to an accuracy of plus or minus 0.0001 and record for later use; do likewise for the brush-block pitch-bearing shims. Store the parts associated with the pitch bearings in two separate, clean, dust-free containers.

Before discussing the cleaning and test of the pitch bearings, let us recall the precautions mentioned under "Disassembly of Gyro-Yoke Mechanism." Avoid direct contact of fingers with the bearings and use nonmagnetized tweezers. There are a few times when the bearings must be steadied, positioned, or rotated by hand, but direct contact can be avoided by using a lint-free cloth (18, Fig. 5). Rayon jersey is recommended by the manufacturer, and is quite satisfactory. It is advisable, however, to prevent contact of

*The brush pitch-bearing pivot and the doweled seat for the cam-bearing pivot assembly should be thoroughly cleaned.

the cloths with large amounts of the cleaning solvent. The portions so exposed become stiff and useless. The cloths can be any convenient size (such as 10 x 10 inches) and should be hemmed on the raw edges. When soiled, they can be hand-laundered in detergent solutions, rinsed under running water, allowed to dry under lint- and dust-free conditions, and then stored in polyethylene bags.

Extremely dirty bearings may first require immersion in cleaning solvent. After this operation, lightly press the bearing on a tweezer (6 or 9, Fig. 5) utilizing the tweezer as a temporary shaft mounting. Holding the tweezer vertically in the fingers, spin the outer race while directing a stream of cleaning solvent from the wash bottle (2) into the ball races and through the spring separators. Utilize both directions of rotation as well as inverting the bearing on the tweezer. If the bearing is cleaning out satisfactorily, you will notice a distinct improvement in the rotational characteristics. The vibrational "feel" of the rotating bearing transmitted through the tweezers should be less and the coast-down time increases. If repeated cleaning of a bearing does not improve any rough rotational characteristics, then the bearing must be replaced. The best way to dispose of excess solvent in a bearing is to blow it out with clean, dry nitrogen. When this is not available, then natural evaporation aided by bearing rotation must suffice.

The final test of a clean, usable pitch bearing depends somewhat on the experience of the person doing the testing, but this experience can be acquired by anyone having the patience and time to develop a keen sense of feel. Lightly holding the tweezer vertically in one hand while keeping that arm away from any solid object, briskly spin the bearing. If the bearing is clean, and has no internal rough spots, then rotational motion will hardly be detectable through the tweezer. For extremely good bearings, it is quite difficult to predict from the "feel" of the tweezer whether the bearing is rotating or not; and the coast-down time will be much longer than usual. When one has difficulty predicting bearing quality from the "feel" of the tweezer, then the coast-down time will provide an alternate criterion for judgment. The final check of the pitch bearing should be with the tweezer vertical and the flange side of the bearing on top. This combination of ball-race contact is that which exists in assembled gyro.

If there is doubt as to the operational acceptability of a bearing, then it is advisable to secure additional bearings from the gyro manufacturer.

When the dry performance of the bearing is satisfactory touch the precleaned capillary tube of a watch-type oiler (containing Pioneer No. 10 oil obtainable from the manufacturer) <u>just once</u> to one ball. Spin the bearing in both directions of rotation and in both positions on the tweezer to spread the oil over all the contacting surfaces. At the same time, repeat the acceptance test described above, for occasionally dirt is inadvertently introduced into the bearing during the oiling operation. The oil, despite its low viscosity produces a marked decrease in the coast-down time, thus the reason for applying only a very limited amount.

Installing Gyrostat in Yoke.—Remove the yoke assembly from its container and mount in the bench fixture (1, Fig. 8), Remove the cam pivot and pin assembly (49, Fig. 10) from its container and clean with solvent and brush. Rotate the yoke assembly so that the brush side is on top. Place the cam pivot and pin assembly, gear side down, in the lower or cam-bearing mounting hole of the yoke. Remove the gyrostat from its container and insert it into the yoke with the slip-ring pivot protruding up through the brush-bearing mounting hole. While carefully holding the gyrostat assembly from falling out of the yoke, invert the yoke and seat the cam pivot assembly on the gyrostat. Position and orientation is determined by a flange and dowel pin. Install and tighten the four screws (50).

Install the cam-bearing shims (12, Fig. 7), aligning the clearance holes in the shims with the tapped holes in the yoke. Install the cam pitch bearing (8), two screws (9), and eccentric screw (10). Assemble the special washer (10, Fig. 9), cam (8), and then the screw (9). Proper orientation of the cam is readily determined after observing the cam configuration described as follows. When the gear or splined section of the cam was originally formed, metal flow in a specific direction occurred. Therefore, the cam is installed as though the gear pivot assembly on the gyrostat were repeating the forming operation. Cam orientation about the gear is determined by facing the detent portion directly toward the rear when the gyrostat is in its caged position.

Rotate the yoke until the slip-ring end of the gyrostat is on top. Install the slip-ring bearing shims (12, Fig. 7), the flanged slip-ring bearing (8), the nut (7), and the three screws (9).

Pitch-Axis End Play.—The next step is to determine the amount of pitch-axis end play between the gyrostat and the yoke. A precision ten-thousandths indicator (2, Fig. 8) mounted on a holding fixture (3, 48-100-301) is attached to the gyrostat utilizing the tapped holes for the brush-block screws. The indicator is lowered on the fixture to make contact with the end button of the slip-ring assembly (pitch axis vertical, indicator on top). Note the indicator reading; invert the yoke assembly and take a second reading. Repeat this procedure a sufficient number of times to obtain consistent and reliable readings. For the immediate use of the gyro, an end play between 0.007 and 0.0020 inch is satisfactory. Increasing shim thicknesses will increase the end play and conversely for decreasing shim thicknesses. A more precise setting will be carried out after completion of centering. A general rule to follow when changing the shim thickness is to use the minimum number of shims per bearing and maintain about the same shim thickness under each bearing. This latter condition has a very important relation to the centering of the gyro rotor. Centering will be discussed in some detail after preliminary balance about the pitch axis.

Pitch-Axis Balance.—Make up a dummy weight for simulating the effect of the sphere (5, Fig. 9) on the gyrostat. The sphere weighs about 0.2 ounce so the weight added should be about 1/2 ounce to allow for the difference between moment arms of the sphere center of gravity and the actual attached weight. Mount this dummy weight on the cam side of the gyro assembly using the two screws (6, Fig. 9). Install the sphere counterweight block (1) on the slip-ring side of the gyro assembly using the two screws (2). Check the counterweight blocks (13, 19) for centering between their mounting screws and the counterweight nuts (16) having motion parallel to the pitch axis for symmetry on the blocks. Holding the yoke so that the pitch axis is horizontal, observe the pendulosity of the gyrostat assembly. More than likely any large unbalance will be due to the erection-system replacement weight since it is designed to be heavy initially. Consequently, the first step will be to reduce the size of the brass replacement weight until there is just a slight amount of pendulosity due to this component. As the pendulosity becomes less it may become evident that unbalance is not due to the brass weight alone. Counterweight screws and nuts having motion perpendicular to the pitch axis can be added, removed, substituted, or shifted on the counterweight blocks (13, 19) to achieve an approximate balance. In general, it is advisable at this stage to have slight pendulosity with block (13) downward. The reason for this recommendation is that this particular block (and associated weights) is not accessible when the sphere is in place.

Remove the sphere dummy weight and the sphere counterweight block. Assemble the specially prepared "block" sphere on the gyrostat assembly with the "dive" end of the sphere adjacent to the brass replacement weight. Add the counterweight block (1) and lightly tighten the screws (2). Install and lightly tighten the two screws (6). The screws should be tight enough to maintain the sphere in position but still permit some shifting by hand.

Before proceeding with the pitch-axis balance the spherical section must be properly located on the gyrostat. It is desired that the spherical section truly describe a spherical surface for rotation about either the pitch or the roll axes, and, that an imaginary extension of the roll axis should intersect the spherical section midway between its edges for any position of the gyrostat about the pitch axis.

The first condition may be experimentally realized by establishing a reference point approximately coincident with the roll axis and about 1/8 inch from the spherical surface, observing that 1/8-inch clearance throughout the complete range of pitch-axis rotation, then shifting the sphere to compensate for any change in that spacing. The second specification may be checked two ways. One is to fix the gyrostat at various positions about the pitch axis, rotate the yoke about the roll axis, and observe where the point of zero rotation occurs on the sphere. The second method is to fix the roll-axis position and rotate the gyrostat about the pitch axis observing whether the edges of the spherical section lie in planes perpendicular to the pitch axis. When an acceptable position of the sphere is achieved, tighten down the four retaining screws.

Pitch-axis balance may now be extended to a finer degree. The procedure is the same as before: observing the pendulosity or heavy point of the gyrostat, then adjusting the counter weights for proper compensation. By this time, vibration of the fixture may be necessary to overcome bearing friction. Eventually, this procedure will lead to a condition of indeterminate unbalance. Then it is time to proceed to roll-axis balance.

Roll-Axis Balance.—The initial step in making a balance about the roll axis is to center the rotor between the yoke supports. The rotor is said to be centered when its center of gravity lies at the intersection of the pitch and roll axes. By construction, the rotor is centered in its housing support within 0.060 inch. By use of optical methods, the manufacturer centers the rotor assembly in the yoke supports within 0.003 inch at the same time that the pitch-axis end play is being set. The primary reason for centering the rotor assembly is to permit balancing of the unit utilizing the existing counterweight adjustments. The assembly would not have to be very far off center to make it impossible to balance using the adjustments provided.

First untape the brush block (3, Fig. 7) from the yoke and carefully install it in position using the two screws (4). Exact positioning of the brushes on the slip ring is not essential at this time.

Off centering is experimentally evident if there is large unbalance about the roll axis. Thus, by trial and error, one may shift the gyrostat along the pitch axis increasing shim thickness on one end and decreasing the thickness on the other until moderately good roll-axis balance is obtained. At the same time, the pitch-axis end play should be adjusted to 0.0007- to 0.0008 inch. Experimental tests indicated that 0.0007-inch end play with the gyro at room temperature would leave about 0.0001-inch end play when the gyro(with dust cover installed) has been running approximately 15 to 20 minutes in an environment maintained at room temperature (68° to 75°F). The amount of decrease of the end play will undoubtedly vary somewhat from one gyro to the next depending largely on the electrical characteristics, rotor-bearing friction, windage, and variations in thermal properties of the materials. It is advisable to check each gyro individually while it is hot for proper end play.

The almost negligible amount of pitch-axis end play of the "hot" gyro emphasizes the necessity for maintaining clean pitch bearings. During the procedure of obtaining desired end play and centering, one must observe strict cleanliness of the yoke-bearing seats and the pitch bearings, and use only shims in acceptable nick-free condition and maintain clean tools. After centering has been completed, sufficient to permit final roll-axis balance using the available adjustments, it is desirable to check the relative positions of the brushes with respect to the slip rings making certain that no shorts occur and that the respective brushes are in their proper locations.

Brush force on the slip rings should be of the order of 3 to 5 grams. A pair of extra-fine-point jeweler's tweezers (8, Fig. 5) proves excellent for estimating the force by gently lifting each brush off the slip ring. Do not try to hold the brush clamped in the tweezers, but rather use the tweezers as a lever with the fingers providing both the fulcrum and the lifting force. A little practice in lifting a 3-gram weight with the tweezers will help one calibrate his "feel." Proper force can be set by bending the brushes slightly. All brushes should have about the same amount of force on the slip rings.

The points of contact of "common" brushes on one slip ring should be diagonally opposite each other so as to cancel out their contact forces and reduce the radial bearing load on the pitch bearings. In general, it is easier to start with too much brush force and reduce it by lifting the brush quite far away from the slip ring. However, one must observe caution so as not to unduly cold-work and break-off a brush.

The next step is to "finish-balance" the gyro-yoke assembly about the roll axis. The procedure is similar to that followed for pitch-axis balance. Index the yoke to various positions and upon release, note direction and extent of rotation. From these observations, one can determine the location of the unbalanced mass. Counterweights on the gyrostat having motion parallel to the pitch axis may be adjusted for compensating the unbalance, and if necessary, the counterweight screws and nuts on the yoke may also be used. Ideally, if all the previous balancing and centering has been nicely carried out then the latter yoke adjustments should not be required. Again the general rule to follow when making adjustments is to shift the counterweights so as to move their effective weight diagonally opposite the region of unbalance. As with the yoke- and pitch-axis balancing, fixture vibration will be necessary as critical balance is approached. When the unbalance becomes indeterminate then proceed to the next step.

GYRO-YOKE ASSEMBLY INTO FRAME

Before the "blank" spherical section can be engraved a reference point relative to a known rotor position must be established. The reference position chosen is when the rotor is perpendicular to the roll axis and occupying a known angular position about that axis with respect to the yoke spindle sleeve and the gyro frame. This condition hereafter will be called the "zero" position. Thus, the following procedure is carried out to establish a known reference point on the spherical section and to check out the operation of the caging mechanism.

Grasp the gyro-yoke assembly (62, Fig. 6) with thumb on the cam side of the yoke and second and third fingers straddling the brush-block assembly. If possible avoid direct contact of the fingers on the flanges of the pitch bearings. Index the yoke 45 degrees with respect to the gyro frame. To permit installation in the frame the pitch axis cannot lie in a diagonal plane passing through the caging guide rod corner but must be perpendicular to such a plane. Start the yoke spindle (54, Fig. 7) into the frame leaving the tapped screw holes in the spindle just visible. Now index the spindle until the two holes are aligned with the clearance holes in the frame spindle support. Complete insertion of the yoke assembly into the frame support until the tapped holes in the spindle are visible through the clearance holes in the frame.

Install the two bushings (48-100-110) in the clearance holes and install and tighten the two screws (63, Fig. 6). Stand the frame assembly face down on a circular supporting ring. The supporting ring is necessary because spherical section usually protrudes slightly from the front of the frame.

Install the laminated washer (46),the rear brush block (44), and the two screws (45). Follow the same instructions given for the yoke brush block for soldering of the color coded leads, brush force, and points of contact on the slip rings. Some axial adjustment of the brush block relative to the yoke slip rings may be required. Use of the two bushings around the screws (63) restricts axial adjustment to the laminated washer (46). The laminated washer thickness can be decreased by removing some of the laminations. The purpose of the bushings is to prevent shifting of the gyro-yoke assembly relative to the frame under high G-loading.

Assemble the gasket (13), receptacle gasket (11), cover plate (12), receptacle gasket (11), the cable port (48-100-201 and Figs. 2, 11), and two screws (10). Install two retaining screws (7, Fig. 11) and lock washers in the limit-switch bracket pads. Assemble the caging mechanism as described under frame modification but leave the gyrostat uncaged.

"Zero" Marking.—Mount the frame and gyro assembly in a right-angle fixture (3, Fig. 13). This mounting fixture is designed to maintain the frame in a known orientation with respect to the surface plate and to fix the yoke axis parallel to and a known fixed distance from its base. Place the fixture and gyro on a surface plate (1).* Set up a height gage with a sharp-edged tool so that the point of the tool is the same height above the plate as the yoke axis. Before continuing, strip the ends of the seven leads in the electrical cable at the rear of the gyro and attach them to a connector

*The surface plate need not be precision leveled for "zero" marking.

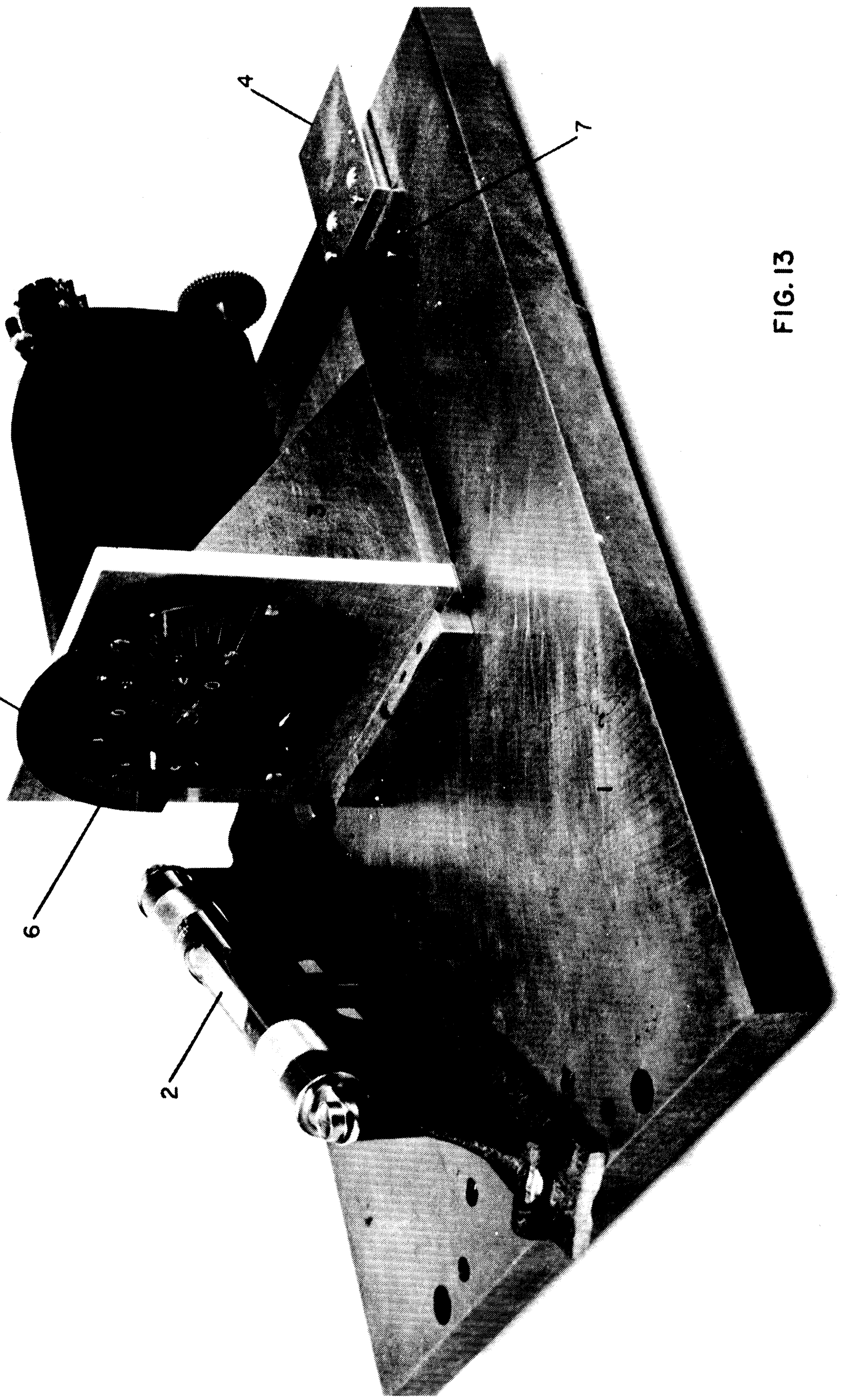


FIG. 13

block such as Jones barrier-type terminals. Make the appropriate connections for 3-phase 115-volt 400-cycle power to the gyro. Sequential phasing is A, B, and C to white, black, and yellow respectively.

Steady the gyrostat by hand to prevent tumbling during run up, apply power to the gyro and allow it to reach operating speed. The phase current may be monitored using the cabinet control panel (19, Fig. 5) to observe run-up time. The average starting time will be from 30 to 60 seconds for acceptable rotor-bearing friction.*

Check the direction of rotor rotation by pushing down on the cam side of the yoke and observing that the top end of the rotor tilts or precesses forward (gyro viewed from front). If a visual check can be made, the rotor rotation is clockwise when viewed from the end of the brass replacement weight of the gyrostat. Allow about ten minutes for the unit to warm up observing precession over one-minute intervals. To permit accurate "zero" line marking, precession about either the pitch or roll axis should not be greater than 0.5 degree during that interval. The reason is that about 40 seconds is required to scribe the "zero" line after the "zero" position is attained. If excessive precession occurs, then better static balancing is mandatory.

Set up a reference pointer (could be a wire) on the gyro frame or the frame fixture so that it is approximately in line with the rotor axis when the rotor axis is perpendicular to both the roll axis and the surface plate. A light pencil mark on the sphere beneath this pointer will aid one in establishing the desired reference position of the rotor. This condition may be tested by rotating the holding fixture on the surface plate and observing any motion of the sphere with respect to the reference pointer. Slight repositioning of the gyrostat followed by another fixture rotation is the simple trial-and-error method by which the "zero" reference position is attained. When this position is reached, there will be no sphere movement for any angular rotation of the fixture on the plate. Then, lightly scribe a short horizontal line near the center of the sphere with the height gage tool. Repetitive checks should produce essentially coincident "zero" lines.

Caging System Checkout.—The purpose of this section is to check the caging action, make necessary adjustments to prevent rotor position shift during uncaging, and to check the physical position and actuator operation of the limit switches.

Three adjustments are available for attaining proper caging system operation. One is positioning of the hub post on the centering bracket assembly (7, Fig. 12); another is the location of the guide block (32, Fig. 7) on the yoke; and the third is the angular location of the pivoted caging

*Refer to the Overhaul Handbook for more complete speed specifications, paragraph 2-39, p. 22; "See Acknowledgements."

bearing (14, Fig. 12). The exact positioning of the pivoted caging bearing is not necessary at this time since it may be adjusted after final assembly without affecting gyro balance. However, the exact location of the centering (guide) block on the yoke should be established. Since the location of the centering block and hub post is not independent in their effect on yoke orientation, then these are the major adjustments required during this procedure. Note that the hub post is a coarse positioning device for orienting the yoke relative to the gyro frame while the centering block provides fine positioning. Their proper relative locations must be established to prevent binding during caging or uncaging. Therefore, with gyro power off, loosen slightly the two screws (33, Fig. 7). Manually drive the centering bracket in until the hub post (11, Fig. 12) has just entered the slot in the yoke cam. Check the fixed reference pointer for any roll deviation from the pencil mark made during "zero" marking. To compensate for any variation, loosen the two screws (13) and shift the hub laterally, then tighten the screws. Continue manual caging until the centering bracket bearing (12) enters the centering block on the yoke, then tighten the two retaining screws (33, Fig. 7). Complete the caging operation and check the "zero" mark against the height gage. Adjust the pivoted centering bearing to reduce the pitch deviation. Uncage the unit and then recheck the above procedure.

The forward (caged position) limit switch should be actuated when the driving block has compressed the spring approximately two turns of the drive shaft. Thus, the actuating pawl (8) may now be trimmed to satisfy the above requirement. The uncaged limit switch should be actuated by the hub post when the driving block is about 1-1/2 threads from the retaining collar.

The next test will involve motor-driven caging and uncaging with the gyro running. Mount the 250-rpm drive motor (such as Delco Appliance Series 5069600, 27-volt, d-c) on the pad (4, Fig. 13). The 4/5 step-down gearing ratio from the motor to the caging drive shaft provides a caging or uncaging time of 8 to 10 seconds at rated motor voltage. Check the powered caging-uncaging cycle and limit-switch operation. When caged, the gyrostat should be in its "zero" position as checked with the fixed pointer and the height gage tool.

Apply power to the gyro (in caged position) and allow the unit to warm up for about five minutes. Initiate the uncaging cycle and observe closely any changes occurring in the pitch and roll angles due to uncaging. There may be a "kick" or precession produced about one or both of the axes. The cause of these effects will be the three caging positioners. Other contributing sources will be the play between the centering bracket assembly and guide shafts, and bending of the guide shafts. The effects of the latter conditions can be reduced by shifting the forward limit switch or its actuating pawl so as to reduce the spring compression in the caged position. If the "impulse" occurs about the pitch axis at instant or uncaging, then the cause is due to incorrect positioning of the centering guide block. By trial-and-error adjustment of the positioners, one can produce a smooth, "kick"-free uncaging action which will leave the gyrostat in its "zero" position as checked by the reference pointers and/or fixture rotation. Similarly, that "zero" position should also exist in the caged position. Several caging and uncaging trials should be made to insure consistency of operation.

Upon successful completion of the caging checkout, remove the reference pointer from the fixture. Remove the gyro frame from the right angle fixture and place it on its side for easy access to the caging assembly. Dismantle the caging system except for the drive shaft. Remove the two screws (7, Fig. 11) holding the switch bracket and shift the bracket toward the rear for access to the yoke spindle screws (3). Remove the gyro and yoke assembly per previous instructions. Place the yoke assembly in the bench fixture (1., Fig. 8). With a sharp scribe, outline the edges of the tabs securing the spherical section to the gyrostat. Remove the four retaining screws (6, 2, Fig. 9) and the counterweight block (1). Carefully remove the spherical section.

Engraving the Spherical Section.—This operation requires a dividing head, an engraving point, and a suitable machine for holding and driving the point. The engraving point is the same as that used to engrave the beta scale described in "Modifications of Parts and New Part Construction."

Occasional reference to Figs. 1, 3, and 8 may be helpful in clarifying the following discussion about the spherical section.

A Bridgeport vertical mill is used in our work. A dividing head with chuck is mounted on the table so that the axis of rotation of the chuck is parallel to the table and directed along the longitudinal motion of the carriage. The crossfeed position of the chuck axis is located so as to intersect the vertical spindle axis. The spherical section and its special fixture (3, Fig. 5) are mounted on an arbor and chucked in the dividing head. Next in the procedure is "indicating" the surface of the spherical section so that when rotated it will truly describe a sphere while maintaining its edges in parallel planes perpendicular to the axis of rotation. The latter "edge" requirement is not so stringent and can permit a variation of about 0.010 inch with rotation. However, the surface should describe a circle (indicator resting halfway between the two edges) to within 0.001 inch to avoid excessive trouble during the engraving operation. These requirements can be met if the spherical section has not been dented or excessively sprung out of shape. It can be shifted on the fixture and sprung to conform to the specification if necessary.

Next the longitudinal position of the carriage is determined such that the spindle axis is midway between the two edges. The engraving point is mounted in a holder which in turn is colleted in the locked spindle. A single midline is engraved on the sphere, "splitting" it parallel to the edges from one end to the other, a total of about 200 degrees rotation. To observe and monitor the line width, a 25-power microscope is mounted on the mill. Depth of cut, and hence line width, are controlled by the vertical carriage feed and all operations are carried out using the hand controls.

To engrave incremental degree lines the spindle and cutting needle are rotated 90 degrees. The dividing head is indexed until the "zero" mark is nearest the cutting needle. Some ambiguity may exist because of the hole plate on the dividing head, but the error is less than a half degree. Using the longitudinal carriage feed, several passes are made over the work with successive lowering of the needle until the proper line width and depth of cut are attained at the "midline." Having determined the "zero" line, lines are engraved in one-degree increments for plus and minus 20 degree, two-degree increments in the interval 20 to 42 degrees, and five-degree increments from 45 to 90 degrees.

To extend the five-degree intervals (and multiples thereof) for easier reading, the height gage with marking point is set on the carriage table with the marking point the same height above the table as the rotational axis of the dividing head. Using the microscope and properly indexing the dividing head, aforementioned interval lines are extended farther out on the spherical section. Accuracy of the angular division is already established by the machine at the midline (where angles are read during data reduction), so line extensions need not be perfect.

Remove the spherical section from the fixture, carefully smooth off any rough line edges by rubbing lightly with a lint-free cloth. Clean the engraved lines of foreign particles by brushing with a moderately stiff bristled brush (like a tooth brush) or wash under running water. Be careful not to scratch the enamel or cause it to peel away and flake off from the lines. Allow the surface to dry thoroughly. As with the beta scale, smear white printer's ink into the engraved lines, wipe off excess, and allow to dry.

Final Preparation of Spherical Section.—To prevent specular reflections during photographic data recording, the surface must be coated a dull black. This result can be achieved by masking the engraved lines with very narrow strips of masking tape. This technique is slow and tedious but will lead to an acceptable product. After masking, the surface is sprayed with architectural dull black using an airbrush. After the paint has dried, carefully peel off the masking tape. Using a rubber number stamp such as Justrite type BN2-6 and stamp pad containing white indelible ink, appropriate numbers are stamped on the sphere for the 20-degree increments. When viewed from the front in normal position of the gyro ("dive" end of sphere on top) negative angles will be below the zero line and positive angles above (2, Fig. 1; 4, Fig. 8).

FINAL ASSEMBLY AND TEST

OUTLINE

After recleaning the tools and unassembled components the spherical scale will be installed, a check made of pitch-bearing cleanliness, and measurement of end play taken. These steps will be followed by final static balancing about the two axes, reassembly of gyro into frame, check of the "zero" position of the sphere, installation of the beta scale, static balance with gyro running, dynamic balance and acceptance testing on the oscillating table, calibration of the two engraved scales, and finally, seal-up.

ASSEMBLE SPHERE ON GYROSTAT

When installing the spherical section in position, locate the supporting tabs with respect to the previously scribed tab outlines. Tighten the four screws slightly. The entire procedure previously outlined for positioning the sphere for "zero" marking must now be repeated. However, the scribed tab outlines should aid in reducing the work.

CHECK PITCH BEARING CLEANLINESS

Remove the brush block from the gyrostat slip rings and fold back. The pitch axis is then fixed in a vertical position and the gyrostat caused to rotate very slowly by a slight nudge with a tweezer or finger. Do not maintain contact with the gyrostat but let it rotate freely. It should turn smoothly and uniformly with no jerks or uneven rotation. It should not exhibit "stickiness" as though braking were being applied. If rough, uneven rotation is displayed, then the lower pitch bearing is quite likely to be dirty. The other pitch bearing can be tested in similar fashion. Sometimes if one bearing has a large "chunk" in it, then it will be hard to distinguish which bearing is dirty since the jerky motion is evident for each bearing tested.

If this clean bearing test is not satisfactory, then one might as well remove the faulty bearing, reclean, re-oil, check shims for nicks, check bearing pivots and supports for foreign particles, and reinstall the shims and bearing. Then the pitch-axis end play should be rechecked. If it is not within the 0.0007 to 0.0008 inch range, then add or decrease shim thicknesses as described under "Roll-Axis Balance."

STATIC BALANCE

Due to the balancing effort carried out for the "zero" marking operation, pitch-axis balance should be readily achieved by adjustment of the elastic stop nuts (10, Fig. 11) toward or away from the pitch axis. If necessary, some slight shifting of the center of gravity parallel to the rotor axis can be made by the two counterweights (8) on the counterweight block (13, Fig. 9) having motion parallel to the rotor axis. Vibration of the bench fixture will again be a necessity as the balance becomes critical.

If the rotor centering was undisturbed during readjustment of end play then roll-axis balance can be attained by adjusting the counterweight nuts (9, 6, Fig. 11) and screws (5) as outlined for the "zero" marking operation.

Reset the yoke brush block in position on the gyrostat slip rings and adjust for proper force and contact position.

GYRO-YOKE ASSEMBLY INTO FRAME

Assembly of the yoke into the frame has been previously described. Briefly, it proceeds as follows:

1. Remove screws from rear cover plate and shift cover plate to permit access to brush block.
2. Assemble yoke into frame being especially careful as the slip rings move into the rear brushes.
3. Install the two bushings (48-100-110) in the frame clearance holes.
4. Install and tighten the two yoke spindle screws.
5. Reposition switch mounting bracket; install and tighten screws.
6. Check and set proper brush pressure and location on the spindle slip rings.
7. Replace rear cover plate and a few retaining screws.
8. Install the caging mechanism and readjust switch bracket location for proper spring loading when gyrostat is caged.
9. Mount frame assembly in right-angle surface-plate fixture.

Zero Position Check.—Make setup of surface plate, gyro, and right-angle fixture; height gage with pointer coincident with roll axis; reference pointer above plus 90 degrees point of the spherical scale (hereafter called the "alpha" scale); mount caging drive motor on surface plate pad; provide power source for gyro and make appropriate connections; provide power source and caging-uncaging control for the drive motor.

With gyrostat caged, apply power to the gyro and allow it to warm up for ten minutes. Uncage the gyrostat noting any precessional effects due to uncaging. Rotate the fixture and manually adjust the gyrostat position until no change in either alpha or beta occurs for full 360-degree rotation of the fixture on the surface plate. Check location of the alpha zero line with respect to the height gage pointer. If they do not coincide within 1/4 degree, then stop the gyro and reposition the alpha scale on the gyrostat. Necessary readjustments are slight; therefore, the gyrostat is not thrown completely out of balance. A satisfactory scale location will have the following characteristics:

1. For the "zero" position of the rotor with respect to the surface plate, the zero line on the alpha scale will match the height gage pointer within 1/4 degree.

2. For the full range of rotation of the gyrostat about the pitch axis (gyro motor stopped); the midline will lie directly under the second (+90 degrees) reference marker.

3. The surface of the scale will describe a true circle during rotation about the pitch axis.

Caging System Check.—Cage the gyrostat and check the position of the alpha zero line with respect to the height gage pointer. Also check the coincidence of the alpha scale midline with the upper 90-degree reference pointer. If these checks vary from coincidence more than 1/4 degree, then the three caging positioners may have to be relocated as detailed under "Caging System Checkout." When they are adjusted to provide the tolerance specification above, then test the powered uncaging action with the gyro running. The change in pitch (alpha) or roll angles from the caged values to the uncaged values must be 1/4 degree or less.

Install Beta Scale.—Cage the gyrostat and shut off gyro power. Using four shortened retaining screws (25, Fig. 6) and washers (48-100-206) install the beta scale (5, Fig. 13) with gasket (37, Fig. 6). Test the installation of the cover plate (3, Fig. 2 and 48-100-205) for clearance of the four screws in the 0.161-diameter clearance holes. Tighten the cross-hair wire by means of the 0-80 screw. The desired position of the beta scale is for the horizontal cross hair to be straight out from the alpha zero line and about 1/32 to 1/16 inch from the scale. An extension of the alpha mid-line should intersect with the zero line of the beta scale. The tolerance of the beta-scale mounting holes is such that some position shifting is permitted. Tighten down the four retaining screws when the scale is in the desired position. Using a cement which will adhere to neoprene plexiglas and metal, cement the beta scale to the gyro frame. Doweling the scale in position is inadvisable for obvious reasons of dirt, dust, and inconvenience.

Final Static Balance.—Preliminary note: An ideal free gyro having no unbalance, no bearing friction, etc., should be able to reproduce the predicted effect of earth's rotation. In general then, final balancing is aimed at achieving this precessional effect and reproducing it consistently over short time intervals of the order of three minutes. Although one can only approach this idealized condition, it is possible to come sufficiently close to satisfy the experimental uses of the gyro for rocket aspect instrumentation.

In allowing for the precessional effect due to earth's rotation, one must know the angle between the spinning rotor and the earth's axis of rotation.

This requirement can be met if the test initially starts with the rotor perpendicular to the earth's surface and if the latitude is known.

The analysis of gyro precession due to earth's rotation can be simplified by aligning the roll and pitch axes with the major, true (not magnetic) compass directions of N-S and E-W. Note that by physical construction the pitch and roll axes are mutually perpendicular so if one axis is aligned N-S, the other is automatically aligned E-W (both axes tangent to the earth's surface). Assuming these conditions to be satisfied, then the variation due to earth's rotation of the angle (alpha) whose rotational axis is aligned N-S will be described by

$$\tan \alpha = \tan \theta \cos \lambda ,$$

while the angle (beta) whose rotational axis is aligned E-W will be described by

$$\tan (\lambda + \beta) = \frac{\tan \lambda}{\cos \theta}$$

where

θ = the earth's angular rate in siderial time ($2\pi/86164$ rad/sec) and

λ = the latitude angle.

For the latitude of Ann Arbor (42 degrees, 14 minutes), for example, the alpha angle will change 0.50 degrees in three minutes but there is a negligible change in the beta angle up to about 6 minutes. For these small time intervals and correspondingly small angles the rate of change in earth's effect can be assumed linear.

To insure perpendicularity of the rotor to the earth's surface the surface plate should be leveled with a precision level (2, Fig. 13) such as Starret Model No. 98. For convenience of leveling, mount the surface plate on three toolmaker's jacks. Disconnect the electrical cable from the terminal strip, slip on the dust cover (5, Fig. 6) (in a temporary fashion as it must be removed to adjust the balancing weights). The dust cover serves the purpose of allowing the gyro to reach and maintain operating temperature in balance with ambient cabinet conditions. Reconnect the cable leads to the terminal strip and apply power to the caged gyro. Allow a 20-minute warmup.

Align one of the axes, for example, the roll axis, with the E-W compass bearing. The beta scale is then lying in a N-S plane and the alpha scale in the E-W plane. Now earth's precessional effect will appear only in the alpha angle (considering only short time intervals, five minutes or less). Uncage the gyro; read and record alpha and beta angles at time intervals of 0, 60, 90, and 180 seconds. To reduce parallax error in reading the scales, it is advisable to set up reference conditions so that the eye is always in the same position for successive readings. Of course beta angle is determined by visually extending the alpha midline to intersect the beta scale. A line scribed on a clear plexiglas strip may facilitate this visual extension of the alpha midline. An alternative method for reading the beta angle is to rotate the fixture exactly 90 degrees and then read the value of beta off the alpha scale. This latter method should only be used at time 0 and 180 seconds.

After eliminating the earth's precession rate from the data, note the sign and amount of precession about each axis. The amount is indicative of the magnitude of the unbalance and the sign determines which side of an axis the unbalance is on. Keep in mind that precession in alpha is due to unbalance about the roll axis and that precession in beta is due to unbalance about the pitch axis. If in doubt these effects can be observed experimentally with the gyro. Thus, for correct rotor rotation, heaviness on the cam side of the yoke will cause the alpha angle to increase in a positive value while heaviness on the brush-block side of the yoke will cause the alpha angle to increase in negative value. Also, heaviness on the sphere side of the gyrostat will precess beta in a positive direction while that on the back side will cause beta to increase in a negative direction. From these facts and the experimental data, one can determine what counterweight adjustments to make and approximately how much they should be adjusted. By trial and error one can rapidly improve the balance to a point where the precession tests will have to include (1) an initial alpha setting at plus and minus 15 degrees with beta equal to zero, (2) realignment of the roll axis with the N-S compass bearing, and, (3) three more tests with alpha equal to zero but beta equal to 0 plus and minus 15 degrees. For this latter orientation the earth's effect will appear in the beta angle. From these five tests, very small amounts of unbalance may be detected and compensated. It should be noted that the gyro will cool down a little when the dust cover is slipped back for counterweight adjustment (assuming forced convection in the cabinet working space). Thus, sufficient time must be allowed for the gyro to return to operating temperature before continuing the precession tests.

As balance becomes much improved, other factors become increasingly important. Some of these limiting factors are: the existence of a finite amount of pitch-axis end play, bearing friction on both axes, and brush friction against the slip rings. Therefore, when the gyro begins to reproduce earth's effect within plus or minus 1 degree, it is time to proceed to dynamic testing on an oscillating stand.

OSCILLATING TABLE ACCEPTANCE TEST

It has been established that most Aerobee sounding rockets in flight develop a variation in the three Eulerian angles of rotation. In order to measure these variations, some type of acceptance test based on the anticipated environmental conditions is desired. A laboratory simulation of this environment is shown in Fig. 14. Although it is not an exact simulation it provides adequate information on the acceptability of an aspect gyro.

<u>Equipment</u>.—As pictured in Fig. 14, this device consists of a 110-volt 60-cycle motor driving a shaft through a worm gear. The output gear of the shaft drives a Veeder-Root counter directly and a crank arm by means of an eccentric pin. The crank arm drives a pivoted platform (7) to which is mounted a turntable (8) for holding the gyro. The gyro mounting plate (6) is part of the right-angle surface-plate fixture used in previous work. The total angle of oscillation is about 20 degrees.

By proper orientation of the turntable, one can select which set of bearings is to be activated during oscillation. An intermediate position would cause both pitch and roll bearings to be activated.

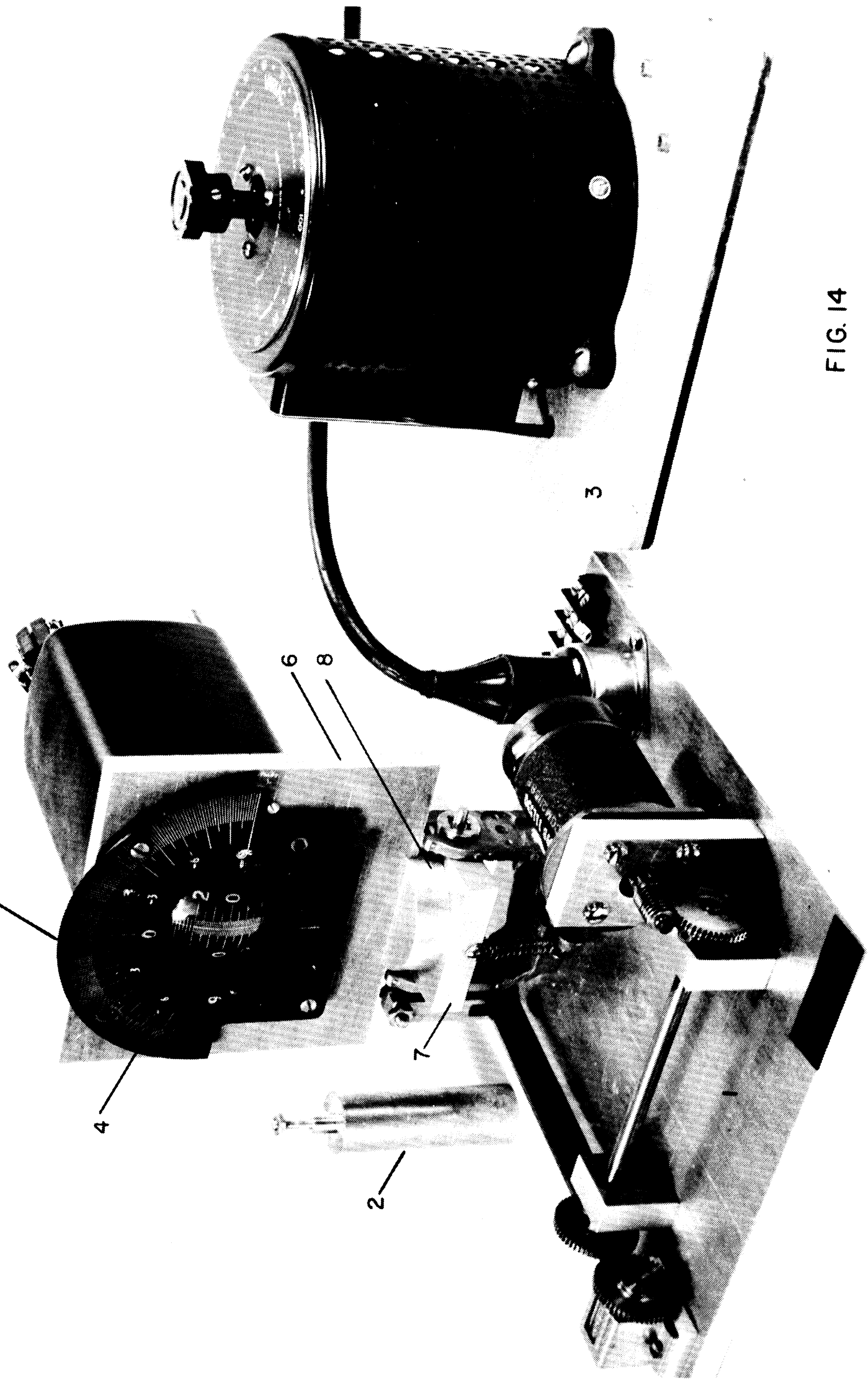


FIG. 14

Correlation of the counter reading with time provides cyclic rate information and the variac (3) allows control of that rate. Testing is done at a rate of 1 cps based on past Aerobee aspect experience.

Again one must establish reference points to avoid parallax reading error when making successive scale readings. In addition for the gyro position on the platform indicated in Fig. 14, the cantilevered mass of the gyro must be counterbalanced with a weight (2) to insure a uniform oscillatory rate.

Test Procedure.—Apply power to the gyro and uncage it after run up. Allow at least 15 minutes for warmup (dust cover in place). During warmup, position the turntable so that oscillation will be about the pitch axis activating the pitch bearings. Adjust variac speed control for about 1 cps rate of oscillation. Align roll axis with E-W compass direction. With pivoted platform located at the extreme end of travel, note and record counter reading. Adjust the gyrostat position so that beta is approximately zero and alpha about 10 degrees so that oscillating range of alpha will be plus and minus 10 degrees. At time equal zero, read both alpha and beta, initiate oscillation and record the readings. At the end of 180 seconds stop oscillation so that platform is again in the same extreme limit of travel as determined by the units digit of the counter; read and record both alpha and beta. Read counter digits and record. Repeat the test for an angular variational range in alpha of 0 to plus 20 degrees and 0 to minus 20 degrees. Eliminate earth's effect from the alpha data and interpret corrected data for location and extent of unbalanced masses based on the previously detailed behavior of a gyro having unbalance. Make corrective adjustments with the appropriate counterweights. Repeat the three alpha (or "live pitch axis") tests for recheck.

Rotate gyro 90 degrees on the turntable to align the pitch axis with the E-W compass bearing, with base of the test stand unchanged in position. Oscillation will now be about the roll axis. The testing procedure is the same as before except that alpha is adjusted to zero while beta swings through the ranges: plus and minus 10 degrees, 0 to plus 20 degrees, and 0 to minus 20 degrees during the prescribed 180-second test periods.

This trial-and-error testing and counterweight adjustment is continued until the gyro reproduces earth's effect to within plus or minus 0.3 degree during a three-minute interval and does so consistently. A gyro producing this result is considered acceptable. As this condition is approached, recent-history temperature becomes very important in its effect on consistent data. Some experimental testing on the relation of ambient temperature and elapsed running time to gyro functional behavior (gyro initially at ambient temperature) indicated a correlation and follows a somewhat predictable pattern. Consequently, time of operation and ambient temperature must be considered when comparing data taken several days or even hours apart.

If the data are not at all consistent and vary erratically trial after trial, then the faults might be one of the following: too much, or lack of, pitch-axis end play, dirty-pitch or roll-axis bearings, unbalanced brush forces on the slip rings, or loose parts such as nuts or screws. Dirt in the pitch bearings is the most common trouble and requires repetition of a large number of previously described procedures, including the final testing; thus, the maintenance of overall cleanliness has been stressed throughout this report.

CALIBRATION OF SCALES

Equipment needed for scale calibration includes: the surface plate with a reference bar (7, Fig. 13), sine plate, right-angle fixture, and a set of gage blocks with planer gage for setting known angles on the sine plate. Some means must also be devised for avoiding parallax error when reading the scales.

With the gyro mounted in the right-angle fixture on the surface plate, apply power and allow 15 to 20 minutes warmup. Set up gage blocks on the sine plate for a 5-degree angle. Manually, uncage gyrostat and adjust for alpha and beta equal to zero. Transfer the gyro fixture <u>laterally</u> on to the sine plate and read the alpha angle and record. Check to see that beta is still zero, read alpha, and transfer the fixture back to the plate and read alpha again. Record both readings. The difference between the alpha readings is the experimental angle which later will be plotted against the true angle for a calibration curve.

This procedure is carried out for alpha angles of plus and minus 5, 10, 15, 20, 30, and 40 degrees. One should make three or four trials for each particular setting and then later average the values. These various intervals are short so earth's precessional effect is negligible.

One must always make certain that the gyro fixture is shifted laterally or parallel to its original position. If not, then compound angles are present and alpha will be less than its real experimental value. The reference bar on the surface plate aids in this requirement. Both the gyro fixture and sine plate can be butted against the bar; then the fixture is assured of being moved laterally.

Calibrating the beta scale calls for a more refined scale reading if high accuracy is desired. Visual extension of the alpha midline is rather coarse, so photographic recording was utilized and then the data read from the film by means of a Recordak microfilm reader. If this technique is used, one must not overlook parallax effects when locating the camera.

The same ranges of calibration used on the alpha scale are also desired for the beta scale. After completion of calibration, neither the beta nor the alpha scale positions must be disturbed.

SEAL-UP

Install the "O" ring gasket (28, Fig. 6) and the clear plexiglas cover plate (3, Fig. 1 and 48-100-206) securing it with four screws (25, Fig. 6). Tighten the screws sufficiently to make a good dust seal, but not so much as to warp or bow the beta scale. Check minutely the whole front end of the gyro for possible dust leaks and seal off with cement.

Seal the dust cover (5, Fig. 6) firmly into place on the frame. Install the reinforcing ring (2) with two or three screws (3).

Mount two, Jones 8-terminal barrier-type terminal strips on the terminal strip bracket (48-100-207) as indicated by 1, Fig. 3. Install the terminal assembly on the rear of the gyro (5). Cut cable leads to length, attach solder lugs, and finish cabling (4). Seal off the cable port outlet with cement. Install 1N34 diode and 0.01-mf capacitor per 48-050-050 and Fig. 3. This concludes the preparation of the gyro.

RECOMMENDATIONS

The procedures outlined in this report have been established by experience. However, if any further modification work of this nature is to be carried out, then one should consider the following.

PITCH-BEARING SHIELDS

Physical construction of the pitch bearings is such that they are fully exposed and hence susceptible to foreign-particle contamination. Seeking a way to shield the bearings, thin discs were designed and installed, where the disc diameter was greater than the outer race diameter. The discs were not truly flat and therefore were apt to rub the outer race flange under pitch-axis rotation. A second design similar to a spring washer was not followed through because of lack of time. It would certainly be desirable to have some close-fitting shield which would protect the bearings from contamination and still not interfere with gyro operation.

PITCH-AXIS END PLAY

If more refined studies are to be made of pitch-axis end play and its correlation with physical phenomena, then another mounting should be designed to permit rapid installation and removal of the dial indicator, without disturbing the gyro assembly. At present the pitch-axis brush block must be removed and replaced each time an end-play measurement is made. This step not only produces undesired lags in measuring time but increases the possibility of damage to the slip rings or brushes.

DRYING THE PITCH BEARINGS

It is most desirable to have a source of dry, clean air or nitrogen available for blowing off bearings just after solvent cleaning. Slightly humid weather causes extensive trouble with moisture condensation on the bearings, thus running a risk of bearing corrosion with consequent loss of the bearing.

BENCH FIXTURE

The bench fixture used to support the yoke assembly when the yoke is out of the frame should be designed to (1) position the yoke axis parallel to and a fixed known distance from its base, (2) provide means of applying power through the slip rings of the rear spindle axis, and (3) provide a suitable reference pointer. If these conditions are met, then not only could static balance about both axes be accomplished in that fixture, but the complete "zero" marking operation on the sphere would be simplified as well as the final static balancing procedure.

SPHERE ENGRAVING

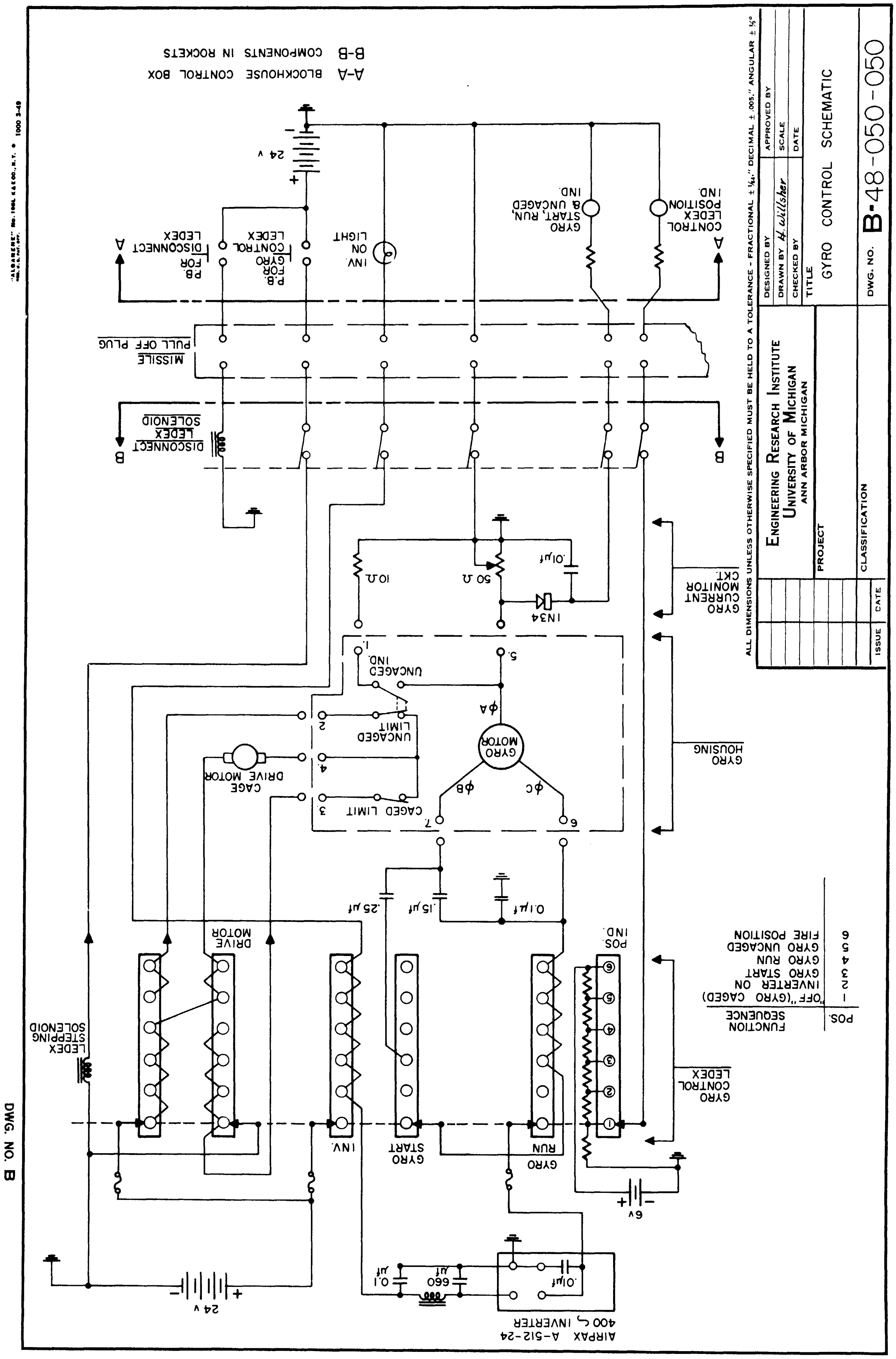
The techniques described in the report for engraving the sphere are time-consuming and tedious. There certainly exists a need for an easier and speedier method of achieving the desired scale. One suggestion has been to discard the sphere entirely and design a more convenient physical form which could be readily engraved and prepared for photographic recording.

ACKNOWLEDGEMENTS

The project is indebted to the Pioneer Central Division of Bendix Aviation Corporation, Davenport, Iowa, for generously supplying parts, and in particular to Messrs. Norman Hosford, Byron Allison, Robert Berg, and Keith Hullinger for their most helpful suggestions and technical advice on certain aspects of the work described in this report.

The exploded views used in this report are from the AN 05-20GF-1 *Handbook of Overhaul Instructions for the Type J-8 Attitude Horizon Indicator* (Eclipse-Pioneer). This publication was most useful on many phases of the aspect gyro work.

APPENDIX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CONTROL LEDEX POSITION IND.
MISSILE PULL OFF PLUG
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GYRO CURRENT MONITOR CKT.
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50 Ω
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φB
φC
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0.1μf
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DRIVE MOTOR
INV.
GYRO START
GYRO RUN
GYRO CONTROL LEDEX
6 v
24 v
0.1 μf
660 μf
.01μf
AIRPAX A-512-24
400 ∿ INVERTER
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2 INVERTER ON
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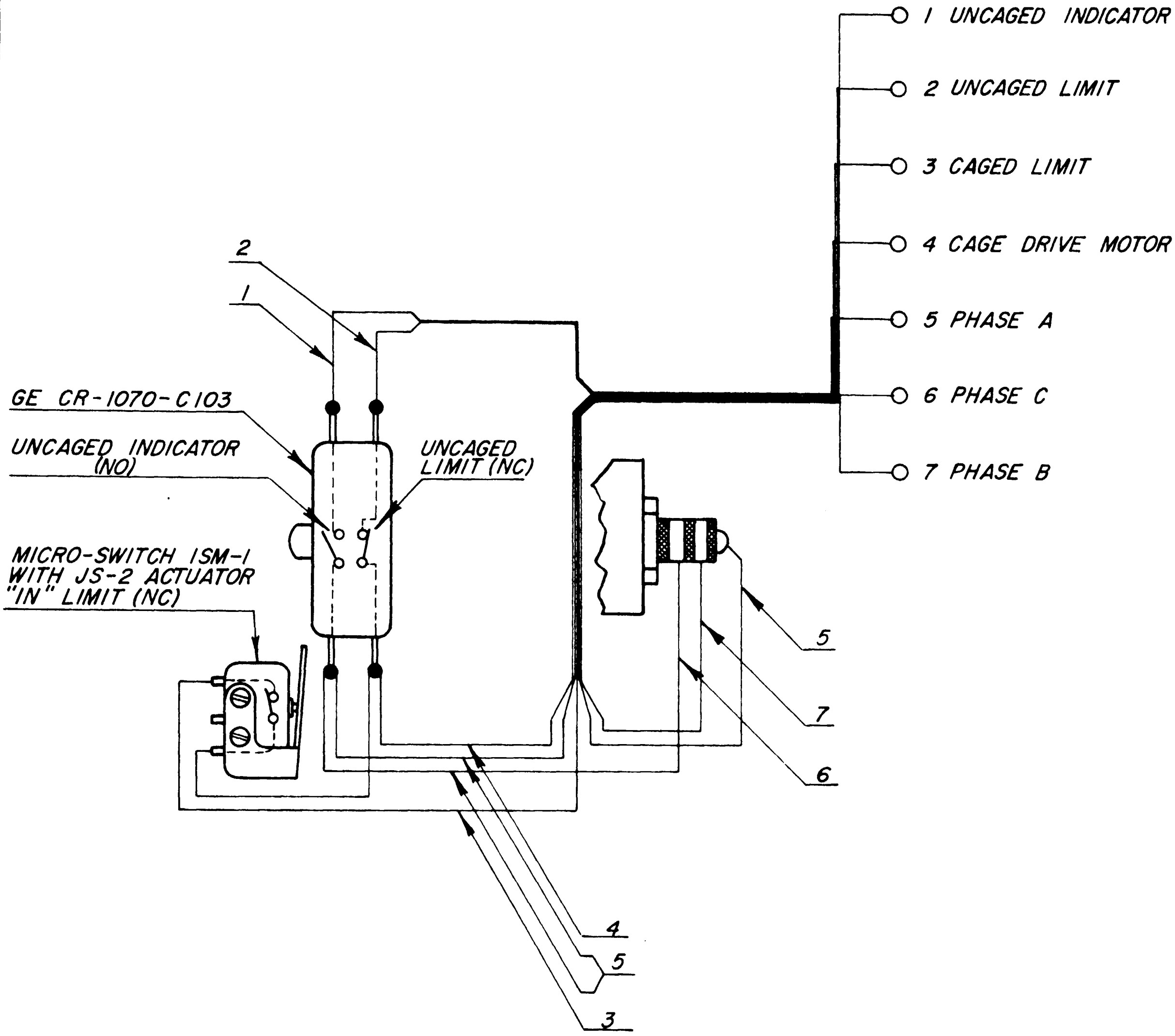

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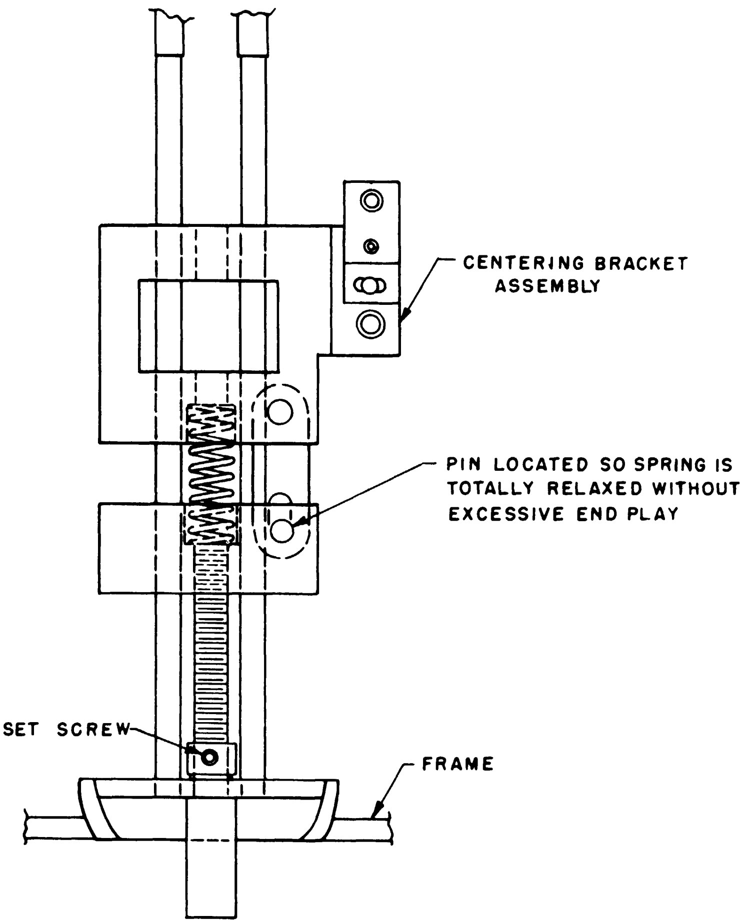

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64" DECIMAL ± .005" ANGULAR ± 1/2°

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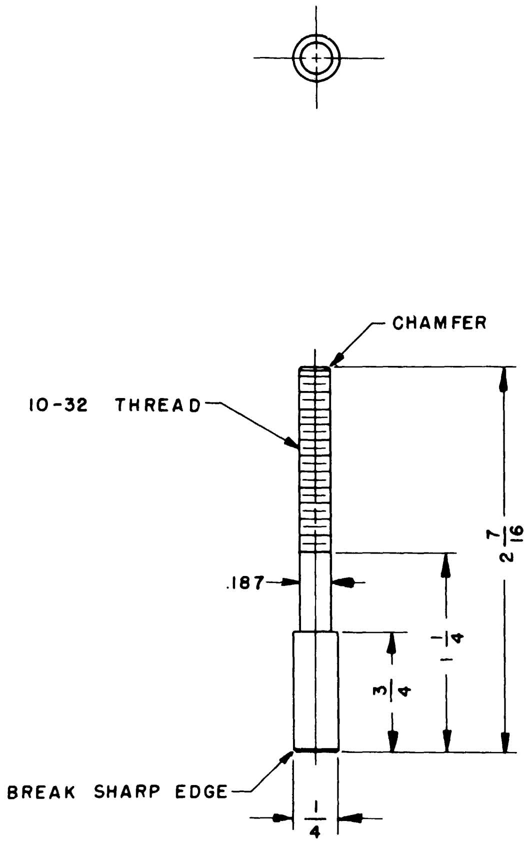
PROJECT	TITLE CAGING SYSTEM ASSEMBLY	
CLASSIFICATION	DWG. NO. A-48-100-100	
ISSUE / DATE		

DWG. NO. A



SAE 1015 OR APPROV. EQUIV.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR MICHIGAN

DESIGNED BY J.F.	APPROVED BY
DRAWN BY P.L.W.	SCALE
CHECKED BY	DATE 5-19-53

PROJECT

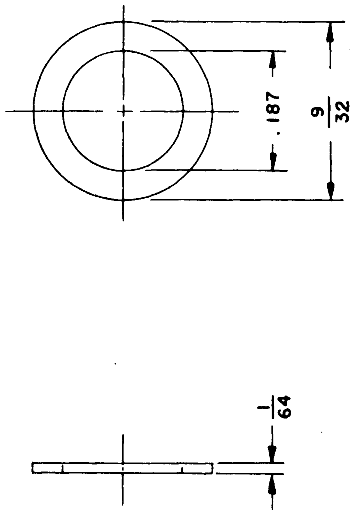
TITLE
CAGING SYSTEM DRIVE SHAFT

CLASSIFICATION

DWG. NO. A- 48-100-101

ISSUE | DATE

DWG. NO. A



STEEL SHIM STOCK OR APPROV. EQUIV.— 1 REQ'D.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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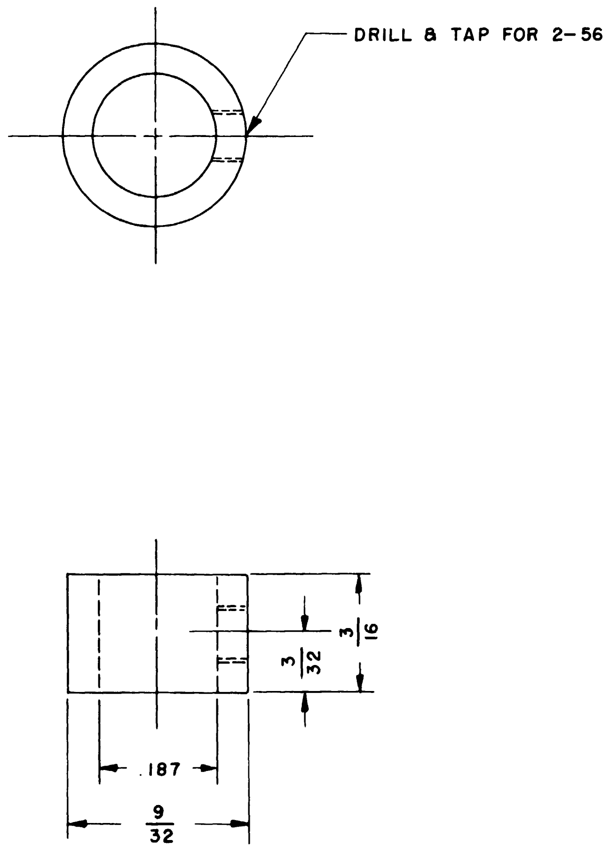
	DRAWN BY P. L. W.
	CHECKED BY
	APPROVED BY
	SCALE
	DATE 5 - 27-54
PROJECT	TITLE DRIVE SHAFT WASHER
CLASSIFICATION	DWG. NO. A- 48-100-102
ISSUE / DATE	

DWG. NO. A

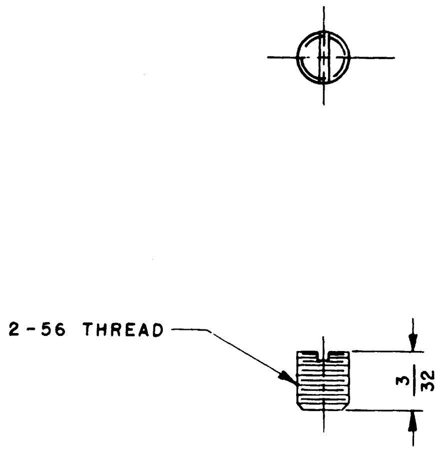


S.A.E 1015 OR EQUIV. — 1 REQ'D.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ISSUE / DATE	ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J.F.	APPROVED BY
		DRAWN BY P.L.W.	SCALE
		CHECKED BY	DATE 5-27-53
	PROJECT	TITLE DRIVE SHAFT RETAINING COLLAR	
	CLASSIFICATION	DWG. NO. A- 48-100-103	

DWG. NO. A



MAT. - SCREW STOCK OR EQUIV. - I REQ'D.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64." DECIMAL ± .005," ANGULAR ± 1/2°

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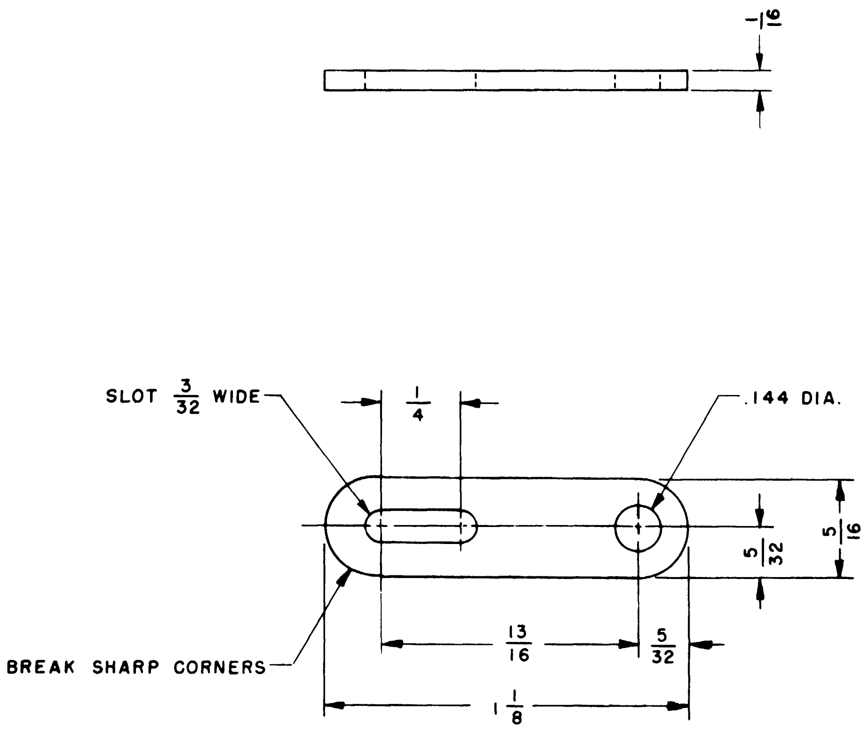
	CHECKED BY	DATE 5-27-53
PROJECT	TITLE RETAINING COLLAR SET SCREW	
CLASSIFICATION	DWG. NO. A- 48-100-104	

ISSUE	DATE

DWG. NO. A



24S OR APPROV. EQUIV. — 1 REQ'D.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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PROJECT

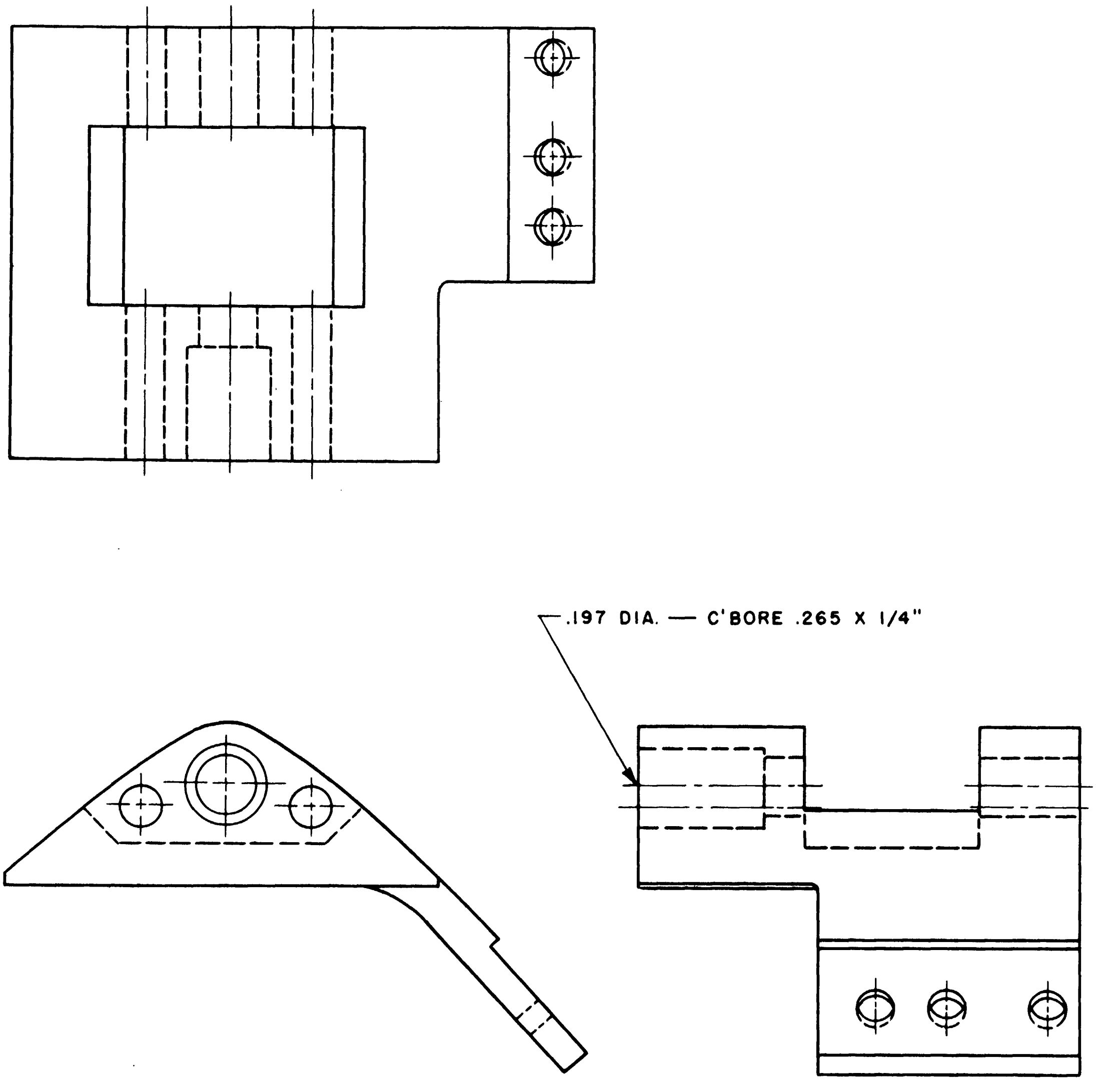
TITLE
UNCAGING DRAG LINK

CLASSIFICATION

DWG. NO. A- 48-100-105

ISSUE | DATE

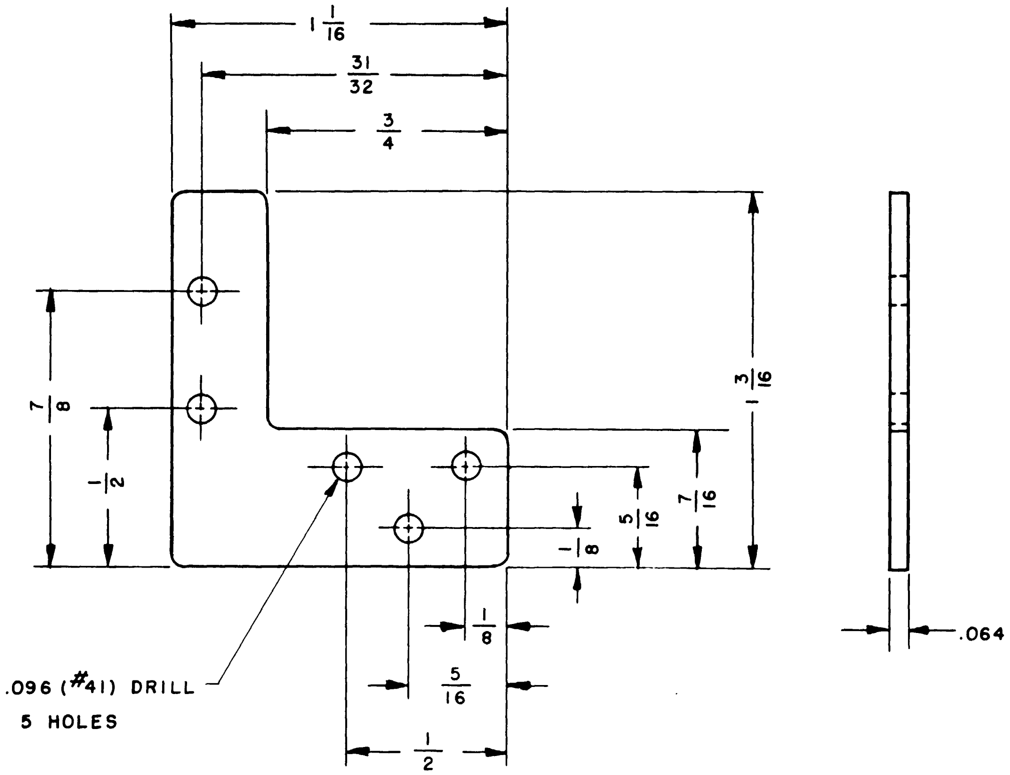
DWG. NO. A



ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J. F.	APPROVED BY	
	DRAWN BY P. L. W.	SCALE	
	CHECKED BY	DATE 5-19-53	
PROJECT	TITLE CAGING BRACKET MODIFICATION		
CLASSIFICATION	DWG. NO. A- 48-100-106		
ISSUE	DATE		

DWG. NO. A

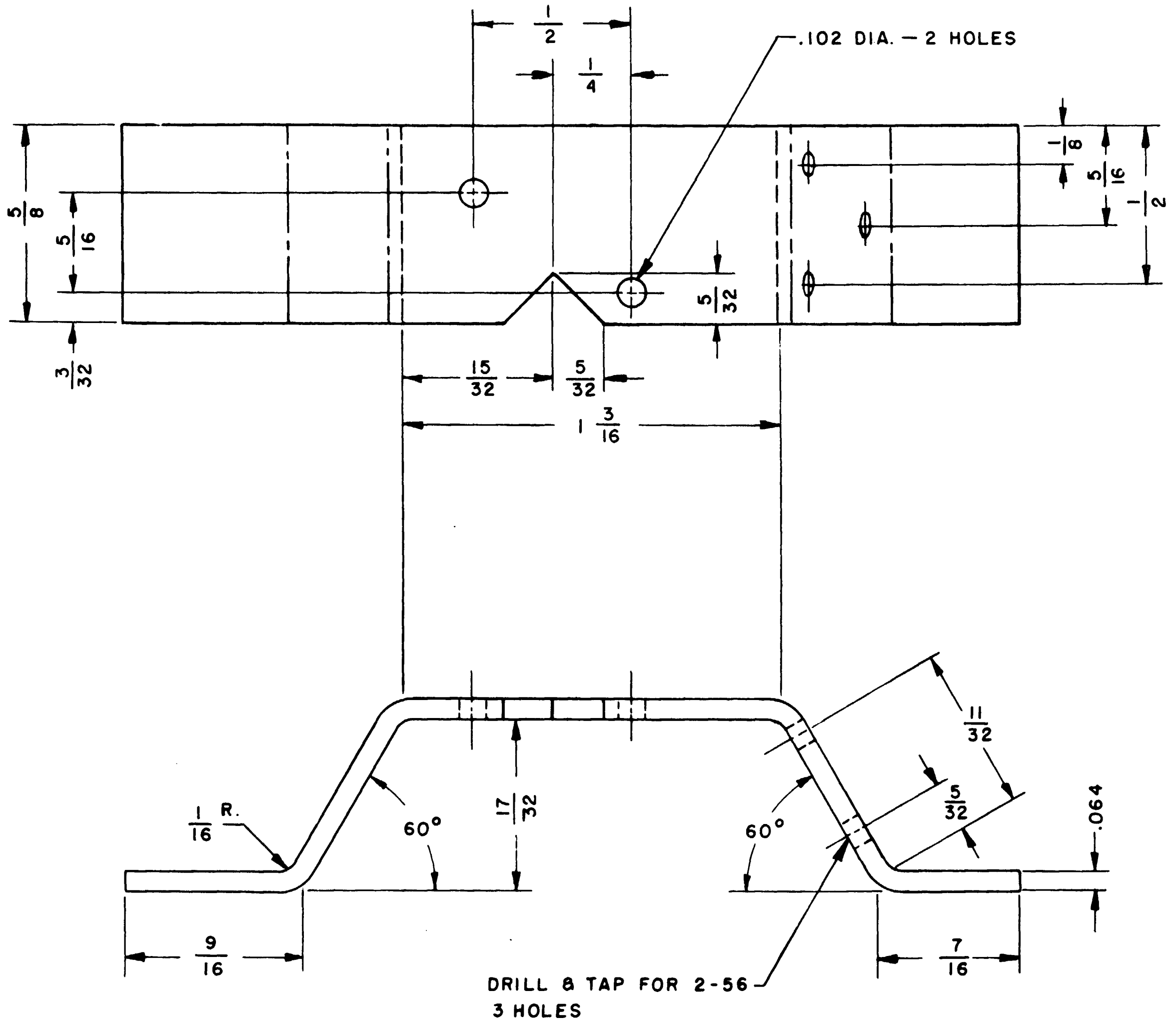


MAT: 24S OR EQUIVALENT

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J. FOSTER · APPROVED BY DRAWN BY P.L.W. · SCALE CHECKED BY · DATE 8-8-55
PROJECT	TITLE ISMI MICRO-SWITCH SUPPORT
CLASSIFICATION	DWG. NO. A- 48-100-107
ISSUE / DATE	

DWG. NO. A



MAT: 24 S OR APP'D. EQUIV.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

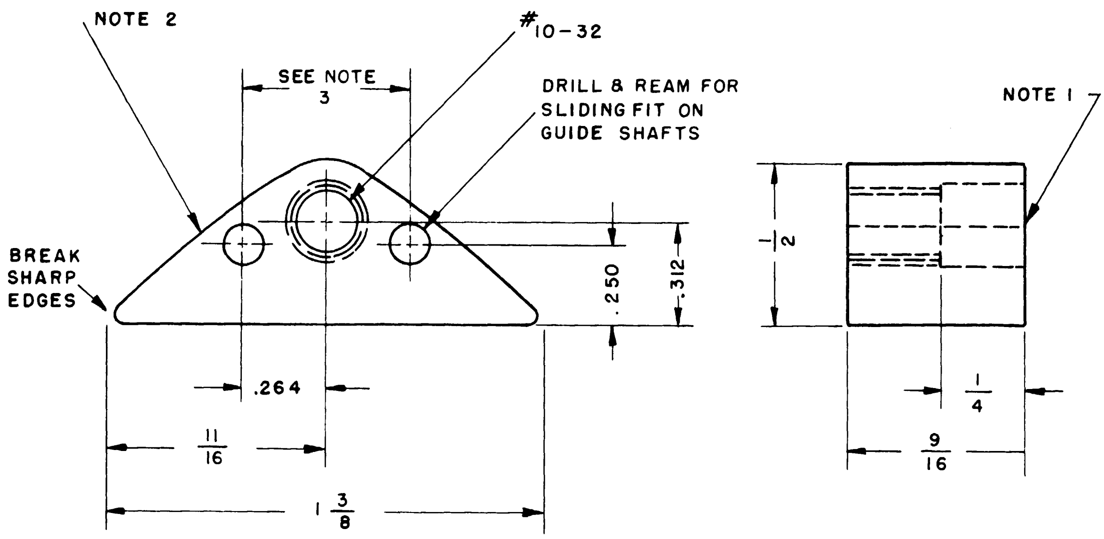
ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J.F.	APPROVED BY	
	DRAWN BY P. L.W.	SCALE	
	CHECKED BY	DATE 5-28-53	
PROJECT	TITLE SWITCH SUPPORT BRACKET		
CLASSIFICATION	DWG. NO. A- 48-100-108		
ISSUE	DATE		

DWG. NO. 12

NOTE 1 : COUNTERBORE .265 X 1/4" FOR SPRING

NOTE 2: MACHINE THIS SURFACE TO CLEAR GYRO DUST COVER

NOTE 3: THIS DISTANCE NOMINALLY IS 0.529 BUT IT MAY VARY FROM UNIT TO UNIT.



MAT: YELLOW BRASS OR APP'D. EQUIV.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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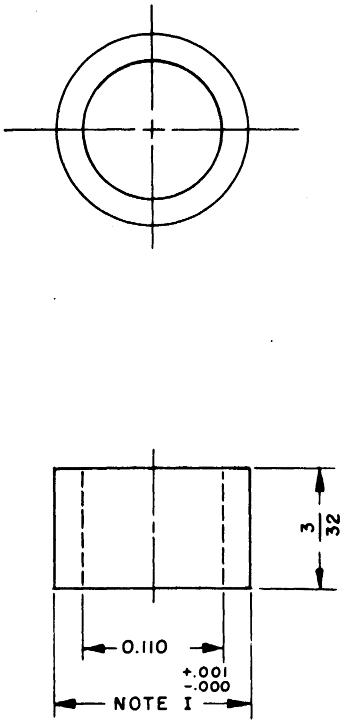
PROJECT	TITLE DRIVE BLOCK; GYRO CAGE MECHANISM	
CLASSIFICATION	DWG. NO. A- 48-100-109	
ISSUE / DATE		

DWG. NO. A



NOTE I:
VALUE IS ABOUT 0.152 BUT SHOULD BE FITTED FOR .001 - .002 CLEARANCE WITH THE TWO FRAME SPINDLE HOLES OF A PARTICULAR GYRO.

MAT.: YELLOW BRASS

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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DESIGNED BY A. K.
APPROVED BY
DRAWN BY P. L. W.
SCALE
CHECKED BY
DATE 5-4-55
TITLE
BUSHING

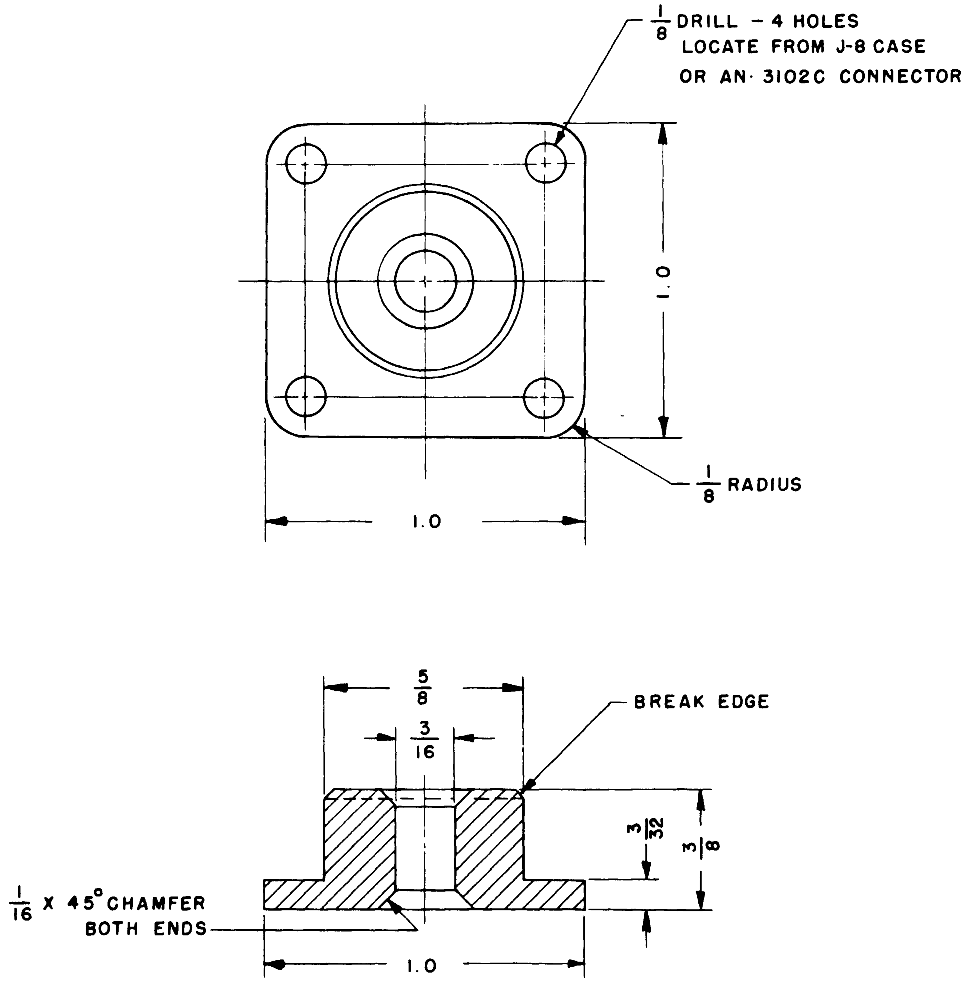
PROJECT

CLASSIFICATION

DWG. NO. A- 48-100-110

ISSUE | DATE

DWG. NO. A



MAT. - 24S OR APPROVED EQUIV. - 1 REQ'D.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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PROJECT

TITLE
J-8 CABLE PORT

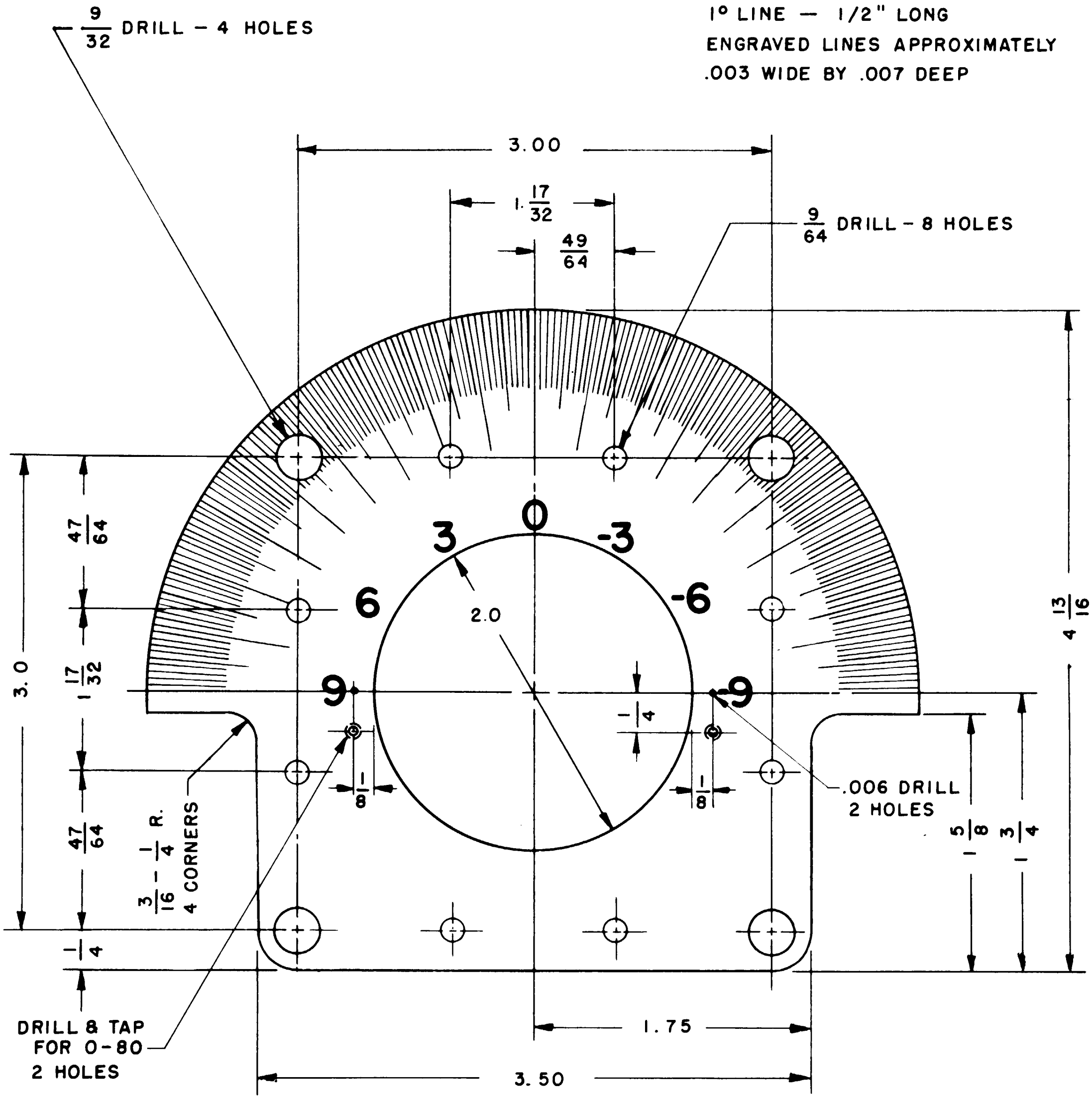
CLASSIFICATION

DWG. NO. A- 48-100-201

ISSUE | DATE

DWG. NO. A

0° LINE — 1 1/8" LONG
90° LINE — 1" LONG
10° LINE — 7/8" LONG
5° LINE — 5/8" LONG
1° LINE — 1/2" LONG
ENGRAVED LINES APPROXIMATELY .003 WIDE BY .007 DEEP



1/16" BLACK PLEXIGLAS — 1 REQ'D.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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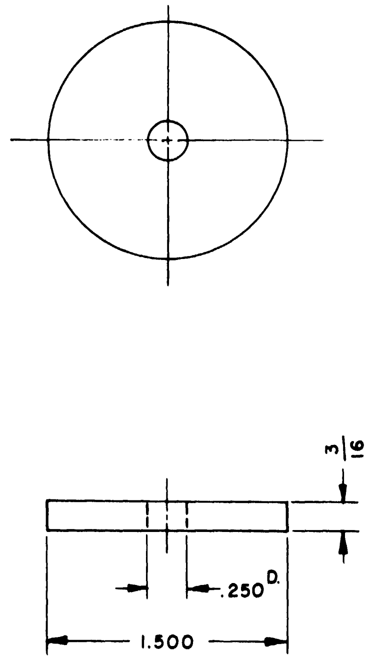
PROJECT	TITLE β - SCALE ; J - 8 GYRO
CLASSIFICATION	DWG. NO. A- 48 - 100-202
ISSUE · DATE	



YELLOW BRASS - 1 REQ'D.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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ANN ARBOR MICHIGAN

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APPROVED BY
DRAWN BY P.L.W.
SCALE
CHECKED BY
DATE 11-1-54

PROJECT

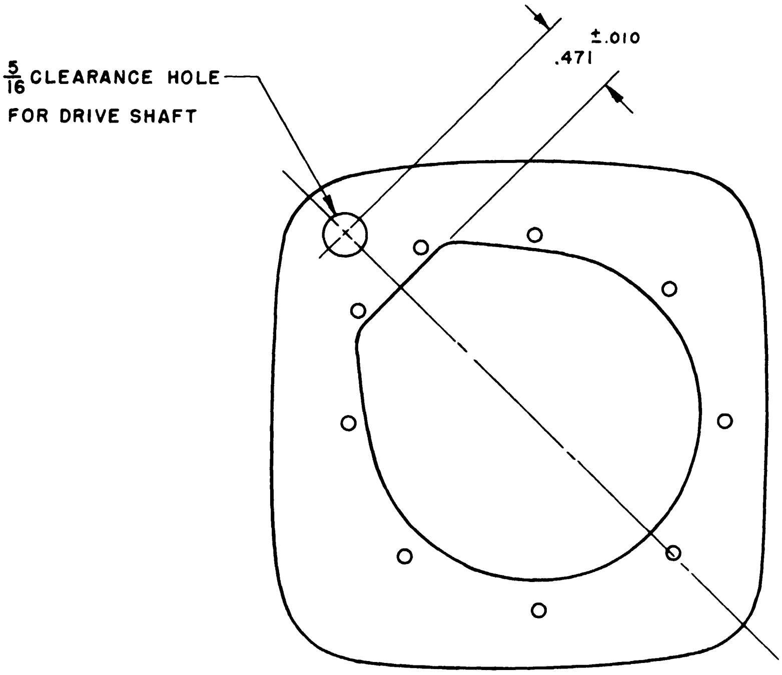
TITLE
ERECTING MECHANISM
REPLACEMENT WEIGHT

CLASSIFICATION

DWG. NO. A- 48-100-203

ISSUE | DATE

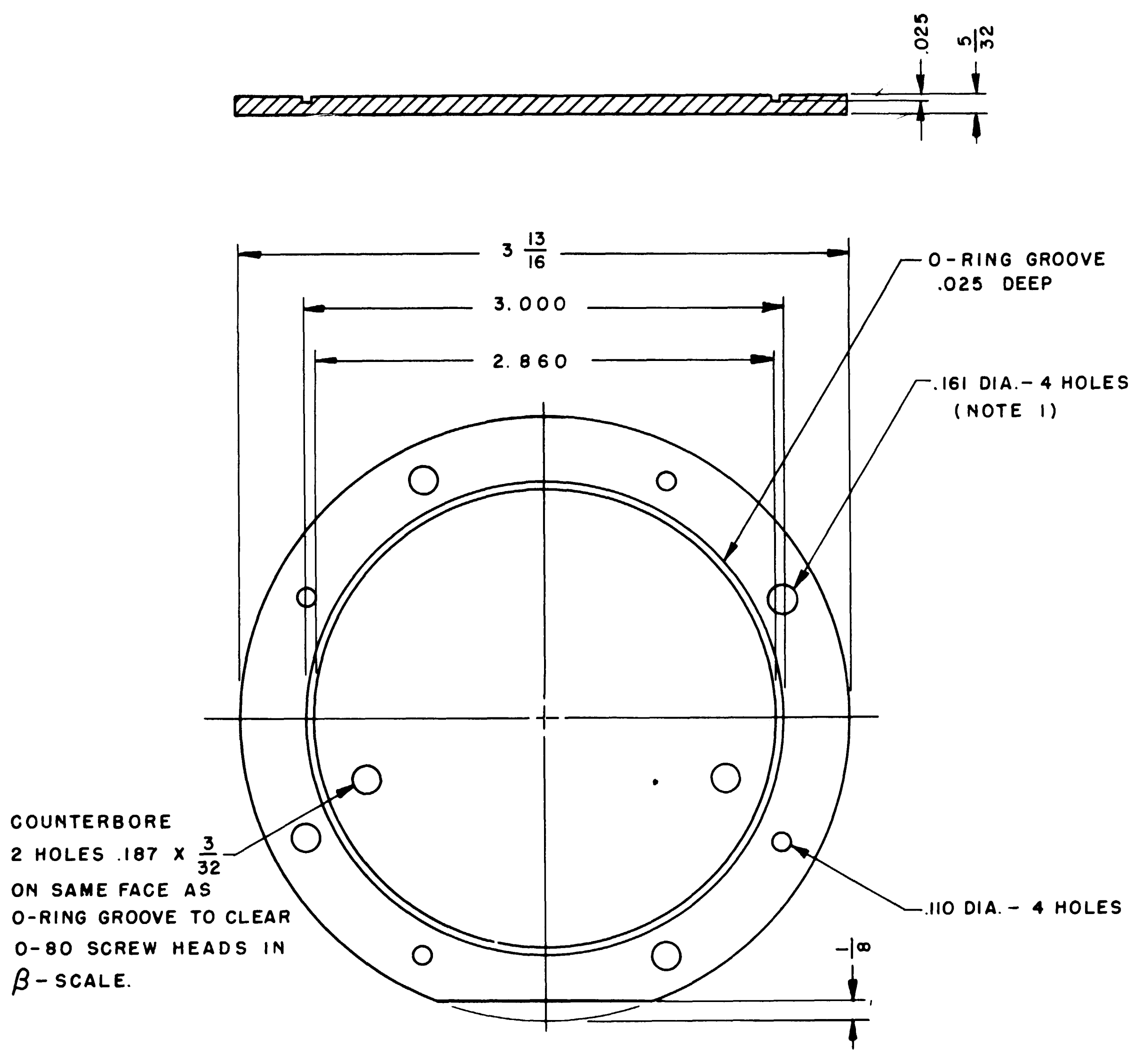
DWG. NO. A



ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J.F.	APPROVED BY
	DRAWN BY P.L.W.	SCALE
	CHECKED BY	DATE 1-25-54
PROJECT	TITLE J-8 COVER MODIFICATION	
CLASSIFICATION	DWG. NO. A- 48-100-204	
ISSUE / DATE		

DWG. NO. A



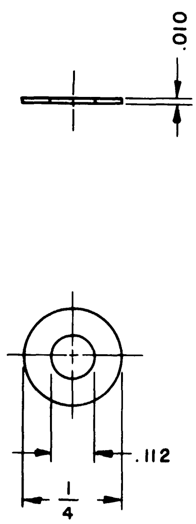
NOTE 1: LOCATE HOLES FROM β-SCALE

MATERIAL: CLEAR PLEXIGLAS (5/32 DEEP)

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J.F. / APPROVED BY DRAWN BY P.L.W. / SCALE CHECKED BY / DATE 10-1-53
PROJECT 2096	TITLE β-SCALE COVER PLATE
CLASSIFICATION	DWG. NO. A-48-100-205
ISSUE / DATE	

DWG. NO. A

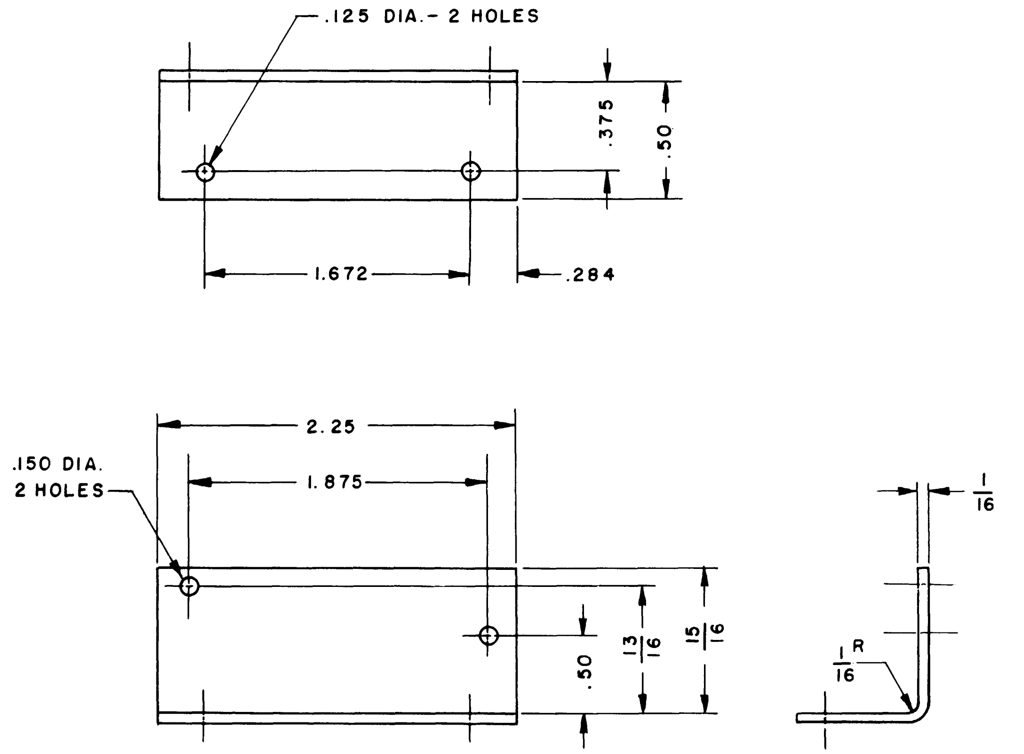


MATERIAL: STEEL SHIM STOCK OR APP'D. EQUIV.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J.F. DRAWN BY PLW CHECKED BY	APPROVED BY SCALE DATE 10-1-53	
PROJECT 2096	TITLE WASHER FOR β-SCALE RETAINING SCREW		
CLASSIFICATION	DWG. NO. A- 48 - 100 - 206		
ISSUE	DATE		

DWG. NO. A



MAT. - 24 S OR APP'D. EQUIV.

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

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DRAWN BY P. L. W.	SCALE
CHECKED BY	DATE 7-6-53

PROJECT 2096

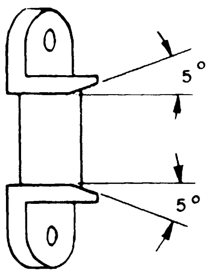
TITLE TERMINAL STRIP BRACKET

CLASSIFICATION

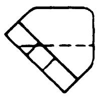
DWG. NO. A- 48-100-207

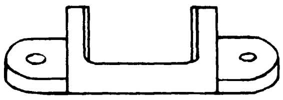
ISSUE | DATE

DWG. NO. A



RELIEF GRIND TO LAST POINT
OF BEARING CONTACT

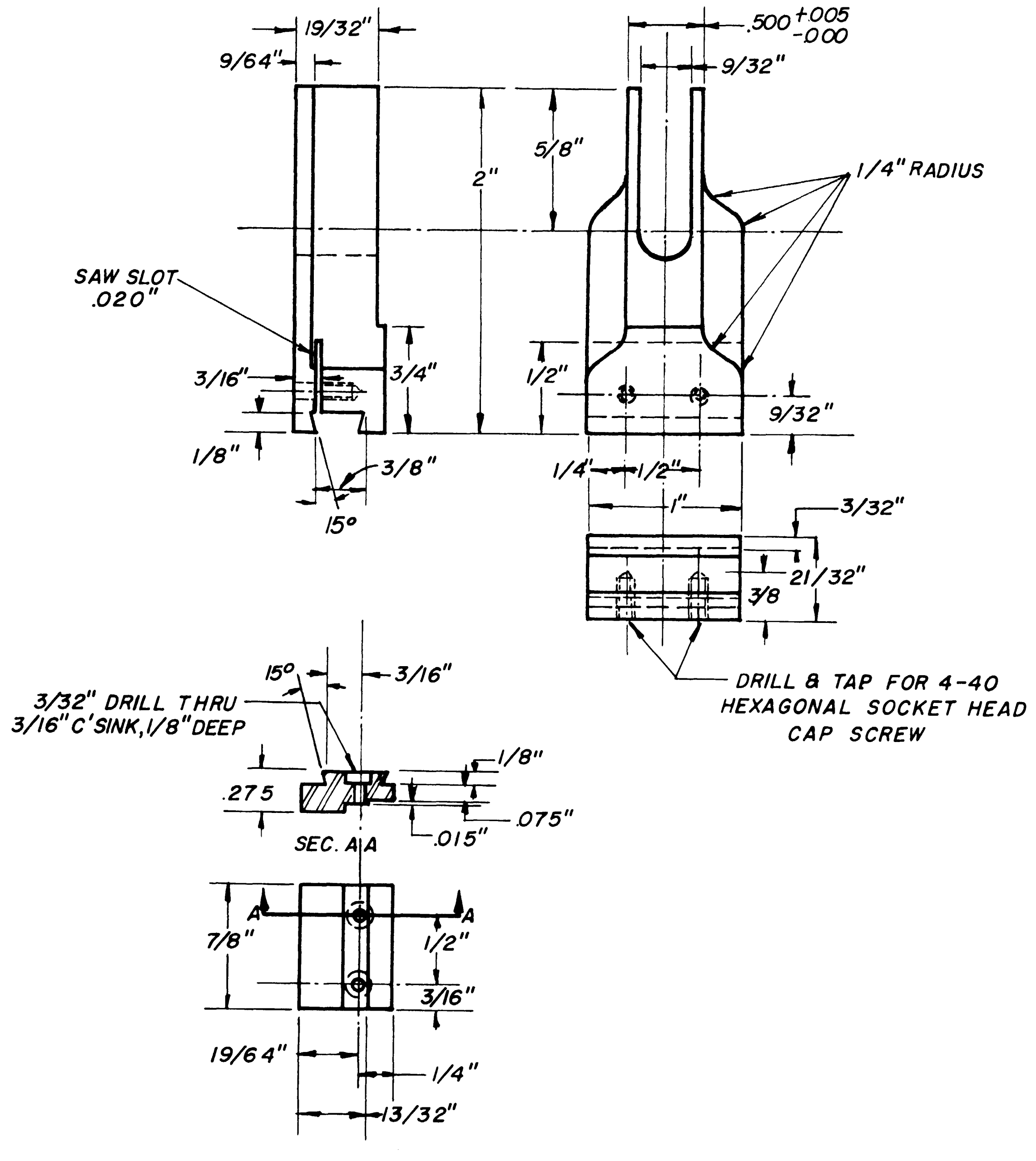




ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64," DECIMAL ± .005," ANGULAR ± 1/2°

ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY J. F. DRAWN BY P.L.W. CHECKED BY	APPROVED BY SCALE DATE 10-1-53
PROJECT 2096	TITLE GUIDE BLOCK MODIFICATION	
CLASSIFICATION	DWG. NO. A- 48 – 100–210	
ISSUE / DATE		

DWG. NO. A



ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64." DECIMAL ± .005." ANGULAR ± 1/2°

ISSUE	DATE	ENGINEERING RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN ANN ARBOR MICHIGAN	DESIGNED BY	APPROVED BY
			DRAWN BY W.O. DAVIS	SCALE —
		PROJECT 2069	CHECKED BY	DATE 2-7-55
			TITLE END PLAY INDICATOR MOUNTING POST	
		CLASSIFICATION	DWG. NO. A- 48-100-301	