

**HANDBOOK**  
on the  
**ASSEMBLY and TESTING**  
of the  
**M.I.T. 201G**  
**INTEGRATING**  
**GYRO UNIT**

**INSTRUMENTATION  
LABORATORY •**

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**

**CAMBRIDGE 39, MASS.**

**DECEMBER 1956**

Report R-101

# HANDBOOK on the ASSEMBLY and TESTING of the M.I.T. 201G INTEGRATING GYRO UNIT

by

Lester R. Grohe, Jacque A. Hogg, and Andrew C. Lattanzi  
of the Instrumentation Laboratory, M.I.T.

and

A. Leonard Anderson, Elliot L. Croft, Gardner W. Pope, and James W. Williams  
of Jackson & Moreland, Inc.

December 1956

INSTRUMENTATION LABORATORY  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
*Prepared for Publication by Jackson & Moreland, Inc.*

Approved for publication



Assistant Director for Miniature Components

## ACKNOWLEDGMENT

The authors acknowledge gratefully the assistance and cooperation given by many people throughout the Instrumentation Laboratory, M.I.T., during the preparation of Report R-101. We especially wish to thank Mr. Richard Coffey, Mr. Ervin Lewis, and Mr. Hugh McArdle - all of the Laboratory's Miniature Components Group - and Mr. Warren C. Brimblecom and his associates in the production group of the Jackson & Moreland, Inc., Technical Publications Division.

Particular thanks are due also to Mr. David Hoag, Assistant Director for Naval Fire Control at the Instrumentation Laboratory, for his permission to use in Section VIII some of the information and material already appearing in Instrumentation Laboratory Report R-91, of which he is the author. In particular, Table 8-2 and Fig. 8-25 of Section VIII are incorporated without change from Table I and Fig. 19 of Report R-91.

Much of the credit for the background and development of the 20IG Integrating Gyro Unit and associated test equipment covered in Report R-101 belongs to the Weapons Guidance Laboratory, United States Air Force, for support given under Contracts W33-038ac-13969 and AF33(616)-2039, and to the Bureau of Ordnance, United States Navy, for support given under Contract NOrd 10796.

This report was prepared under the auspices of D.S.R. Project 52-115, sponsored by the Weapons Guidance Laboratory of the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, through USAF Contract No. AF 33(616)-2039, Task IV, E. O. No. R-554-311-SR-1Z.

The publication of this report does not constitute approval by the Air Force of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

# TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
I	INTRODUCTION . . . . .	1
	1-1. Purpose . . . . .	1
	1-3. Contents . . . . .	1
	1-5. Applicable Publications . . . . .	1
II	DESCRIPTION . . . . .	2
	2-1. Over-all Physical Description . . . . .	2
	2-4. Mounting . . . . .	2
	2-7. Salient Physical Features . . . . .	2
	2-12. Detailed Physical Description . . . . .	3
III	SPECIAL TOOLS, EQUIPMENT, AND FACILITIES FOR ASSEMBLY AND TESTING . . . . .	15
	3-1. Introduction . . . . .	15
	3-4. Special Tools and Test Equipment . . . . .	15
	3-6. Special Facilities for Assembly and Testing . . . . .	15
IV	COMPONENT ASSEMBLY . . . . .	28
	4-1. Introduction . . . . .	28
	4-5. Motor Assembly . . . . .	28
	4-41. Microsyn Units . . . . .	42
	4-51. Floated Units Assembly . . . . .	47
	4-74. Housing Assemblies and Associated Components . . . . .	68
V	OVER-ALL ASSEMBLY. . . . .	81
	5-1. Introduction . . . . .	81
	5-5. Mounting the Signal Generator End Housing Assembly on the Special Assembly Test Stand. . . . .	81
	5-8. Assembling the Main Housing Assembly and the Floated Units Assembly onto the Signal Generator End Housing Assembly . . . . .	82
	5-10. Assembling the Torque Motor End Housing Sleeve and Associated Components onto the Main Housing Assembly . . . . .	85
	5-12. Adjusting the End Shake . . . . .	86
	5-22. Adding the Power Lead Baffle Assembly and the Associated Flex Leads . . . . .	89
	5-25. Securing the Torque Motor End Housing Cap Assembly . . . . .	91
VI	MICROSYN CENTERING . . . . .	92
	6-1. General. . . . .	92
	6-10. Equipment Required . . . . .	96
	6-12. Procedure for Placing Gyro Unit in Centering Fixture . . . . .	96
	6-14. Signal Generator Centering Procedure . . . . .	99
	6-17. Torque Motor Centering Procedure . . . . .	103
	6-20. Flex-Lead Null . . . . .	105
	6-22. Gyro Unit Friction Level . . . . .	105

TABLE OF CONTENTS (Cont.)

<u>Section</u>		<u>Page</u>
VII	FILLING AND FINAL ELECTRICAL CHECK. . . . .	107
	7-1. Introduction . . . . .	107
	7-6. Attaching the Outer Case Assembly . . . . .	107
	7-8. Testing the Gyro Unit for Leakage . . . . .	107
	7-10. Description of the Filling Equipment . . . . .	109
	7-13. Filling the Gyro Unit . . . . .	110
	7-15. Making the Final Electrical Check. . . . .	112
VIII	TESTING PROCEDURE . . . . .	113
	8-1. Introduction . . . . .	113
	8-4. Tests to be Performed. . . . .	113
	8-6. Minimum Performance Standards . . . . .	113
	8-8. Basic Test Setup. . . . .	114
	8-16. Circuit Arrangement of the Basic Test Setup . . . . .	121
	8-20. Preliminary Conditions . . . . .	121
	8-28. Selection of the Signal Generator Quadrature Resistor . . . . .	124
	8-33. Alignment of the Input Axis . . . . .	125
	8-38. Application of Compensation to the Torque Generator Prior to Making Mass Unbalance Adjustments . . . . .	126
	8-44. Mass Unbalance Adjustments without Earth-Rate Effect. . . . .	128
	8-49. Mass Unbalance Adjustments with Earth-Rate Effect. . . . .	128
	8-55. Determination of the Excitation Current Squared - Reaction Torque Sensitivity of the Signal Generator . . . . .	129
	8-61. Determination of the Excitation Current Squared - Reaction Torque Sensitivity of the Torque Generator . . . . .	130
	8-68. Determination of the Angle - Torque Sensitivity of the Elastic Restraint-Producing Components . . . . .	132
	8-76. Determination of the Angular Velocity - Voltage Rate Sensitivity of the Gyro Unit . . . . .	134
	8-84. Determination of the Current Squared - Voltage Rate Sensitivity of the Gyro Unit . . . . .	136
	8-92. Determination of the Current Squared - Angular Velocity Sensitivity Ratio of the Gyro Unit . . . . .	138
	8-98. Determination of the Base Angular Velocity - Controlled Member Angular Velocity Sensitivity Ratio of the Gyro Unit . . . . .	139
	8-105. Determination of the Gravity-Sensitive Drift Rate, Compensated and Uncompensated. . . . .	141
	8-110. Determination of the Nongravity-Sensitive Drift Rate, Com- pensated and Uncompensated. . . . .	142
	8-115. Final Balance Trim . . . . .	142
	8-119. Determination of Characteristic Time . . . . .	142

TABLE OF CONTENTS (Cont.)

<u>Appendix</u>		<u>Page</u>
A	20IG ASSEMBLY RECORD BOOK . . . . .	145
B	A STATISTICAL ANALYSIS OF THE 20 SERIES OF FLOATED INSTRUMENTS . . . . .	161
C	PARTS LIST FOR THE 20IG INTEGRATING GYRO UNIT. . . . .	165
D	TAP SIZES REQUIRED FOR THE 20IG INTEGRATING GYRO UNIT .	167
E	SCREW SPECIFICATIONS FOR THE 20IG INTEGRATING GYRO UNIT	168

# LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-1	Actual-size photograph of the M. I. T. 20IG Integrating Gyro Unit . . .	xviii
2-1	Simplified pictorial diagram of the 20IG gyro unit . . . . .	3
2-2	Cutaway views of the 20IG unit . . . . .	4
2-3	Photograph of the 20IG unit showing major components prior to final assembly. . . . .	5
2-4	Photograph of the outer case assembly. . . . .	6
2-5	Photograph of the diaphragm assembly. . . . .	6
2-6	Photographs of the torque motor end housing cap assembly . . . . .	7
2-7	Photograph of the jewel ball and jewel ball retainer . . . . .	7
2-8	Cross-section view of the torque motor end housing cap assembly . . . . .	7
2-9	Photograph of the power lead baffle assembly . . . . .	8
2-10	Photograph of the Microsyn torque motor assembly . . . . .	9
2-11	Main housing assembly (viewed from the signal generator end of the gyro unit) . . . . .	9
2-12	Photograph of the assembled floated units assembly . . . . .	10
2-13	Photograph showing the location of the Microsyn torque motor rotor with respect to the stator core . . . . .	10
2-14	Cross-section view of the power lead-in body . . . . .	11
2-15	Pictorial view of the pivot assembly . . . . .	11
2-16	Cross-section view of the motor assembly . . . . .	11
2-17	Cross-section view of the signal generator end housing assembly. . . . .	13
2-18	Schematic wiring diagram for the M. I. T. 20IG Integrating Gyro Unit.	14
3-1	Plastic-covered boxes . . . . .	18
3-2	Assembly fixture - hysteresis ring into bushing . . . . .	18
3-3	Assembly fixture - bushing-and-ring assembly into rotor . . . . .	18
3-4	Annis Dynograph Balancer. . . . .	18
3-5	Air gauge . . . . .	18
3-6	Electronic indicating gauge . . . . .	19
3-7	Honing machine . . . . .	19
3-8	Assembly fixture - spin axis bearings and preload spacers into rotor	19
3-9	Jeweler's loupe . . . . .	19
3-10	Simpson Multimeter . . . . .	19

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
3-11	Analytical balance . . . . .	20
3-12	Surgical shears . . . . .	20
3-13	Centrifuge . . . . .	20
3-14	Small hole gauge . . . . .	20
3-15	Micrometer. . . . .	20
3-16	Microscope and light. . . . .	20
3-17	Insulation resistance meter . . . . .	20
3-18	Induction soldering machine (including soldering coils) . . . . .	20
3-19	Induction soldering setup . . . . .	21
3-20	Pivot wrench . . . . .	21
3-21	Test fixture for measuring float runout . . . . .	21
3-22	Dial indicator and support . . . . .	21
3-23	Special poising arbor . . . . .	21
3-24	Watch-balance-wheel poising tool . . . . .	21
3-25	Torque wrench. . . . .	21
3-26	Telescoping gauge . . . . .	21
3-27	Jeweler's lathe and associated equipment. . . . .	22
3-28	Torque wrench. . . . .	22
3-29	Vibrator . . . . .	22
3-30	Temperature-controlled oven. . . . .	23
3-31	Test console . . . . .	23
3-32	Stethoscope. . . . .	23
3-33	Gimbal shell evacuation and pressurization equipment . . . . .	23
3-34	Mass spectrometer . . . . .	23
3-35	Thermally controlled aluminum tank . . . . .	24
3-36	Pair of analytical balances. . . . .	24
3-37	Hypodermic needle . . . . .	24
3-38	Industrial washing machine . . . . .	25
3-39	Winding fixture . . . . .	25
3-40	Wheatstone bridge . . . . .	25
3-41	Two-part potting mold . . . . .	25
3-42	Assembly test stand . . . . .	25
3-43	End-shake measuring equipment. . . . .	25
3-44	Annealing fixture . . . . .	25



LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
3-45	Removing tool . . . . .	25
3-46	Microsyn centering fixture. . . . .	25
3-47	Test console and associated equipment. . . . .	26
3-48	Filling equipment. . . . .	26
3-49	Basic test setup . . . . .	27
4-1	Exploded view of the motor assembly . . . . .	29
4-2	Cross-section view of a typical rotor . . . . .	29
4-3	Cross-section view of a typical bushing . . . . .	30
4-4	Cross-section view of the hysteresis ring. . . . .	30
4-5	Exploded view showing the method for inserting the hysteresis ring inside the bushing. . . . .	30
4-6	Exploded view showing the method for inserting the bushing-and-ring assembly inside the rotor . . . . .	31
4-7	Characteristic feature of unbalance in the rotor assembly . . . . .	32
4-8	Pictorial view of the Annis Dynograph Balancer, set up to obtain the dynamic balancing of the rotor assembly . . . . .	33
4-9	Pictorial view showing the special balancing arbor inserted in the rotor assembly . . . . .	34
4-10	Typical features of the spin-axis bearings and the associated preload spacers . . . . .	35
4-11	Dimensional details of the motor shaft. . . . .	36
4-12	Pictorial view of the honing machine . . . . .	37
4-13	Construction of the honing tool . . . . .	38
4-14	Exploded view showing the method for assembling the bearings and the preload spacers inside the rotor bore. . . . .	40
4-15	Exploded view showing the method for assembling the bearing retainer . . . . .	40
4-16	Pictorial view of a typical motor stator . . . . .	41
4-17	Motor assembly components ready to be packaged for further use. . . . .	42
4-18	Exploded view showing the method for securing the stator mount to each Microsyn stator core. . . . .	45
4-19	Top view of the Microsyn torque motor stator assembly, with the mounting feet upward . . . . .	47
4-20	Top view of the Microsyn signal generator stator assembly, with the mounting feet upward . . . . .	47
4-21	Exploded view of the floated units assembly . . . . .	48
4-22	Cutaway view of the power lead-in body . . . . .	48

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
4-23	Exploded view showing the procedure for inserting the power lead-in body in the gimbal fork . . . . .	49
4-24	Pictorial view showing the procedure for soldering the power lead-in body in the gimbal fork . . . . .	50
4-25	End view of the gimbal fork shaft showing the positive direction of the spin axis. . . . .	50
4-26	End view of the gimbal shell shaft showing the positive direction of the spin axis . . . . .	51
4-27	Pictorial diagram showing the procedure for aligning the gimbal fork and the gimbal shell . . . . .	51
4-28	Pictorial view showing how the pivot assembly is mounted in the pivot wrench . . . . .	51
4-29	Pictorial view showing the test setup for measuring the float runout .	52
4-30	Exploded and assembled views showing the procedure for inserting the power lead-in clamp . . . . .	53
4-31	End view of the gimbal fork shaft identifying the three power lead-ins of the power lead-in body . . . . .	54
4-32	Pictorial view showing the four balance nuts mounted on the balance assembly . . . . .	54
4-33	Pictorial view showing how the poising tool is used for statically balancing the balance nuts . . . . .	54
4-34	Exploded view showing the method for assembling the motor assembly in the gimbal fork. . . . .	56
4-35	Pictorial view showing the test setup for checking the pendulosity of the floated units assembly . . . . .	57
4-36	Side view of the gimbal fork - motor assembly combination as modified for checking coast-down time . . . . .	60
4-37	Pictorial view showing how the gimbal fork - motor assembly combination is mounted in the temperature-controlled oven when checking coast-down time . . . . .	61
4-38	Pictorial view of the vacuum-pump arrangement used in the gimbal-shell evacuation-pressurization procedure . . . . .	63
4-39	Schematic view of the vacuum-pump arrangement used in the gimbal shell evacuation-pressurization procedure . . . . .	64
4-40	Pictorial view of the Fluorolube-filled tank used for obtaining end-for-end and rotational balancing of the floated units assembly . . .	65
4-41	Pair of analytical balances used for the balancing procedur� in Fluorolube . . . . .	67

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
4-42	Wiring diagram identifying the terminal pins of the 20-pin connector and showing the manner in which the power and signal leads are threaded through the signal generator end housing . . . . .	70
4-43	Pictorial views showing the procedure for soldering the power and signal leads to the 20-pin connector. . . . .	71
4-44	Pictorial view showing the procedure for soldering the filter screen to the signal generator end housing . . . . .	72
4-45	Cross-sectional view showing the signal generator end jewel assembly inserted in the jewel holder extractor and the signal generator end housing . . . . .	74
4-46	Cutaway view of the signal generator end housing showing how the balance forks are secured in position . . . . .	75
4-47	Pictorial view of the industrial washing machine . . . . .	76
4-48	Cutaway view of the main housing showing the stop pin . . . . .	77
4-49	Pictorial view showing the procedure used to wind the sensing coil assembly . . . . .	78
4-50	Pictorial view of the power lead baffle assembly showing how the terminals are secured to the baffle plate . . . . .	80
5-1	Buildup of the 20IG gyro unit by the over-all assembly procedure covered in Section V. . . . .	82
5-2	Pictorial view of the assembly stand used for assembling the 20IG gyro unit . . . . .	83
5-3	Pictorial view showing the signal generator end housing assembly mounted on the assembly stand . . . . .	83
5-4	Pictorial view showing the main housing assembly and the floated units assembly assembled on top of the signal generator end housing assembly . . . . .	83
5-5	Pictorial view showing the location of the Microsyn signal generator leads in the cutouts of the lips that project from the main housing assembly . . . . .	84
5-6	Pictorial view showing the torque motor end housing sleeve with its associated components assembled onto the main housing assembly .	85
5-7	Cross-section view showing the end shake in an assembled gyro unit mounted on an assembly stand . . . . .	86
5-8	Cross-section view showing the special equipment used for determining the actual amount of end shake in a gyro unit . . . . .	87
5-9	Cross-section view showing the special end-shake equipment mounted on the torque motor end housing sleeve . . . . .	87
5-10	Cross-section view showing the special end-shake equipment mounted on the torque motor end housing cap . . . . .	88

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
5-11	Pictorial view showing the power lead baffle assembly, together with three gyro motor flex leads, added to the torque motor end housing sleeve . . . . .	90
5-12	Top view of the power lead baffle assembly, identifying the end connections of the three gyro motor flex leads . . . . .	90
5-13	Pictorial view showing the torque motor end housing cap assembly secured to the torque motor end housing sleeve . . . . .	91
6-1	Signal generator performance plot; voltage output signal as a function of rotor angular displacement. . . . .	92
6-2	Wiring diagrams for the Microsyn centering procedure of the 20IG gyro unit . . . . .	93
6-3	Pictorial views of the Microsyn centering fixture . . . . .	97
6-4	Pictorial view of the Microsyn centering test equipment . . . . .	98
6-5	Functional block diagram of test equipment when used during signal generator rotational centering and radial centering along rotor long axis . . . . .	100
6-6	Patch-cord connections required on impedance matching panel of test console when signal generator primary winding is excited and torque motor is connected so as to drive rotor . . . . .	100
6-7	Functional block diagram of test equipment when used during signal generator radial centering along rotor short axis . . . . .	102
6-8	Patch-cord connections required on impedance matching panel of test console when signal generator secondary winding is excited and torque motor is connected so as to drive rotor . . . . .	103
6-9	Functional block diagram of test equipment when used during torque motor rotational centering and radial centering along rotor short axis . . . . .	104
6-10	Patch-cord connections required on impedance matching panel of test console when torque motor primary winding is excited and signal generator is connected so as to drive rotor . . . . .	104
6-11	Functional block diagram of test equipment when used during torque motor radial centering along rotor long axis . . . . .	105
6-12	Patch-cord connections required on impedance matching panel of test console when torque motor secondary winding is excited and signal generator is connected so as to drive rotor . . . . .	106
7-1	Pictorial view of the filling equipment . . . . .	108
7-2	Schematic diagram of the filling equipment . . . . .	109
7-3	Pictorial cutaway view of the filling valve assembly . . . . .	110
8-1	Pictorial view of the basic test setup . . . . .	115

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
8-2	Schematic diagram of the interconnections between components in the basic test setup . . . . .	116
8-3	Pictorial view of the servo-controlled turntable assembly and the gyro mounting package . . . . .	117
8-4	Pictorial view of the test console . . . . .	118
8-5	Schematic diagram of a simple hysteresis erasing circuit . . . . .	122
8-6	Schematic diagram of the arrangement used for controlling the temperature in the test block . . . . .	122
8-7	Calibration curve giving the variation of the resistance of the sensing-coil wire with changes in the gap temperature . . . . .	123
8-8	Schematic diagram showing the details of the Wheatstone bridge arrangement . . . . .	123
8-9	Schematic diagram of the multivibrator circuit used for "yozzling." . . . .	124
8-10	Method of connecting the quadrature resistor, the oscilloscope and the voltmeter to the signal generator windings . . . . .	125
8-11	Indication of the negative direction of the input axis by means of a dowel pin . . . . .	126
8-12	Method of connecting the compensating resistor to the torque generator windings . . . . .	127
8-13	View taken through the turntable microscope. . . . .	127
8-14	Typical plot of average drift rate versus signal generator excitation current squared . . . . .	130
8-15	Typical plot of average drift rate versus torque generator excitation current squared . . . . .	132
8-16	Series winding connections of the dummy signal generator and the gyro signal generator . . . . .	132
8-17	Dummy signal generator circuit . . . . .	132
8-18	Typical plot of drift rate due to flex lead reaction torque versus the output voltage of the Dummy Director signal generator . . . . .	135
8-19	Typical plot of voltage rate output versus angular velocity input . . . . .	136
8-20	Enlargement of the low-voltage-rate region of the plot given in Fig. 8-19 . . . . .	136
8-21	External connections to the torque generator windings . . . . .	137
8-22	Typical plot of current squared - angular velocity sensitivity ratio versus torque generator input current squared . . . . .	140
8-23	Typical plot of base angular velocity - controlled member angular velocity sensitivity ratio versus base angular velocity . . . . .	141

LIST OF ILLUSTRATIONS (Cont.)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
8-24	Schematic diagram of the test setup for measuring characteristic time . . . . .	143
8-25	Typical oscilloscope record of the characteristic time measurement for the 20IG gyro . . . . .	144
B-1	Assembly drawing of a typical 20IG integrating gyro unit. . . . .	163
B-2	Scatter chart of the various incidents during the production program for the 20 series of floated instruments . . . . .	164

# LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
3-1	Special tools and equipment used in the assembly and test procedures of Sections IV through VIII . . . . .	16-17
4-1	Explanation of code letters and numerals in bearing code designations having either the form C-AB or the form C-1B . . . . .	35
4-2	Gyro motor stator-winding resistance check list . . . . .	42
4-3	Microsyn resistance check sheet. . . . .	46
4-4	Types of rotor clamping screws . . . . .	66
8-1	Tabulation of test conditions . . . . .	114
8-2	Typical performance specifications for a 20IG gyro unit . . . . .	119-120
B-1	The various instruments of the 20 series that have been considered in the analysis . . . . .	162
B-2	A summation of the incidents that have occurred in the various instruments of the 20 series noted in Table B-1 . . . . .	162
B-3	A summary of incidents for gyroscopic instruments of the 20 series. . .	163
B-4	A summary of incidents for nongyroscopic instruments of the 20 series. .	163
B-5	A summary of incidents for Microsyn units used in the 20 series . . . .	163

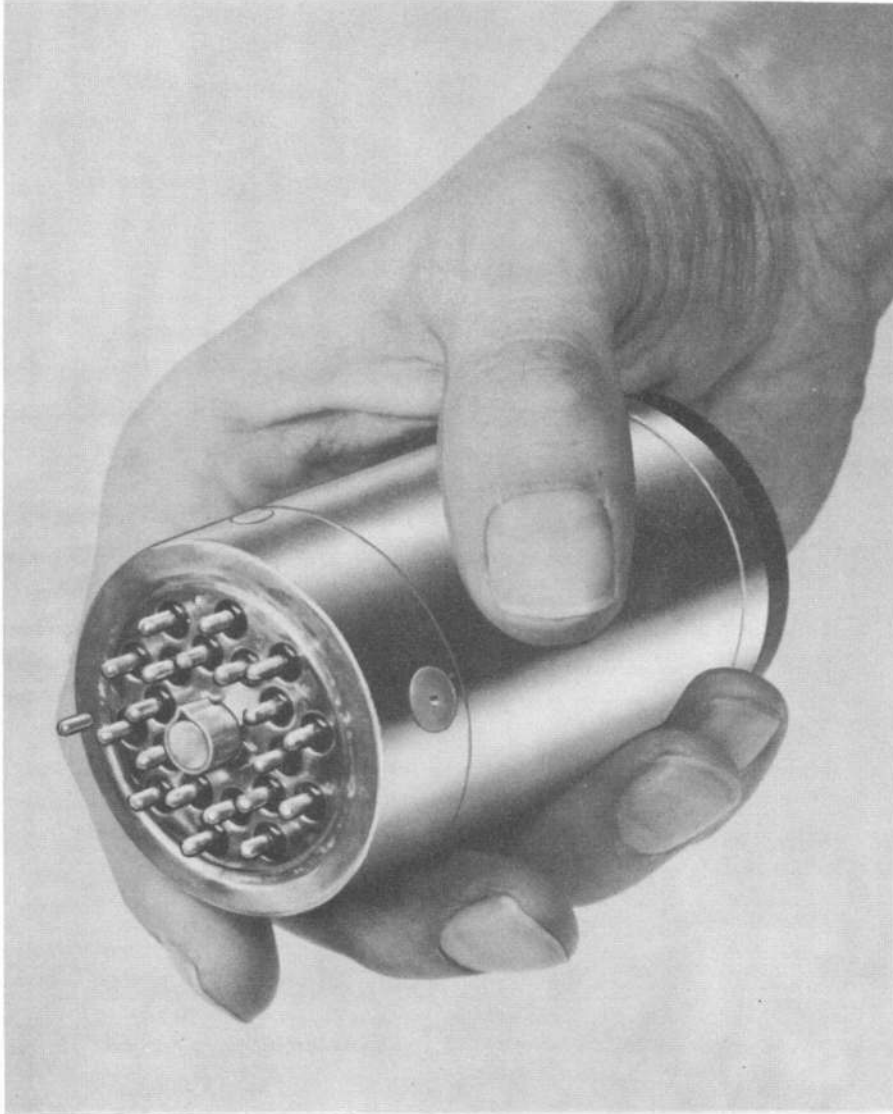


Fig. 1-1. Actual-size photograph of the M.I.T. 20IG Integrating Gyro Unit.



# SECTION I

## INTRODUCTION

### 1-1. PURPOSE.

1-2. This handbook provides information on the assembly and testing of the M. I. T. 20IG Integrating Gyro Unit (see Fig. 1-1). The handbook is written specifically for those who are engaged in the assembly and test procedures associated with the 20IG unit, but it should also prove informative to engineers, designers and others who are interested in these operations. For information on other aspects of the 20IG unit, such as its use and the theory of its operation, refer to the publications described in paragraph 1-6.

### 1-3. CONTENTS.

1-4. The remaining sections of the handbook cover the assembly and test procedures for the 20IG unit as follows. Section II briefly describes the physical characteristics of the 20IG unit. With its cut-away and exploded views of the over-all gyro unit, the section also serves as a useful reference for the reader when using those parts of the handbook that deal with individual components of the gyro unit. Section III lists and illustrates the test equipment and tools normally employed in the assembly and test of the 20IG unit. Common types of tools such as screw drivers, pliers, soldering irons and drills, are not listed; however, common types of test equipment, such as voltmeters, are tabulated. References to the items listed in Section III are made as required in subsequent sections. Section IV describes the procedure for assembling the individual components of the 20IG unit. Section V gives the procedure for assembling these components to form the complete unit. Section VI covers the procedure for centering the two Microsyn electromagnetic units. Section VII describes the filling of the unit

and the final electrical check. Section VIII gives a detailed description of the complete test procedure to be made on the assembled unit. Additional information on the 20IG gyro unit is given in the Appendices.

### 1-5. APPLICABLE PUBLICATIONS.

1-6. Information on aspects of the integrating gyro unit other than those covered in this handbook may be found in reports written by members of the Instrumentation Laboratory, M. I. T., particularly in "The Floating Integrating Gyro and Its Application to Geometrical Stabilization Problems on Moving Bases" by C. S. Draper, W. Wrigley and L. R. Grohe, Published as Sherman M. Fairchild Fund Paper No. FF-13 by the Institute of the Aeronautical Sciences, New York City (1955). A condensed version appears under the same title in the Aeronautical Engineering Review, Vol. 15, No. 6 (June 1956). This paper gives a complete physical description and mathematical analysis of the 20IG Integrating Gyro Unit, including detailed performance data obtained from typical 20IG units, and describes the application of the units to geometrical stabilization and rate measurement problems. The paper also includes an extensive bibliography on the various types of publications relating to integrating gyro units. Also relevant is "Suggested Specifications for the BuOrd Standard Integrating Gyro 20IG," (Report R-91, Instrumentation Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts, December 1955), written by David G. Hoag for the Bureau of Ordnance, U. S. Navy. This report gives a suggested set of detailed specifications and test procedures for commercial manufacture of the 20IG Integrating Gyro Unit.

### Note

*Occasionally, throughout this handbook, references are made to specific items of commercial products such as equipment and materials. This is done for convenience. It is not meant to imply (a) that the products noted are necessarily the best for the particular purposes used or (b) that any other commercial products would necessarily be unsatisfactory. The products noted are simply those used at the Instrumentation Laboratory, M.I.T., in connection with the 20IG unit and found to be satisfactory for the purposes used.*

## SECTION II

### DESCRIPTION

#### 2-1. OVER-ALL PHYSICAL DESCRIPTION.

2-2. Figure 1-1 is an actual-size photograph of the M. I. T. 20IG unit. The complete unit weighs 1-1/8 pounds and is 4 inches long by 2 inches in diameter. The numeral 20 in the designation 20IG stands for the outside diameter of the case in tenths of an inch. The letters IG signify that the unit belongs to the family of instruments called *integrating gyro units*.

2-3. The outside of the unit is comprised of a case that encloses the component parts of the unit and threads onto an endhousing. A component part of this end housing is a 20-pin connector that is induction soldered to one end of the housing. Through the pins of this connector, the electrical power necessary to operate the gyro unit is supplied and intelligence in the form of electrical signals is introduced and extracted. On the opposite end of the unit is an end cap that carries the identification for the gyro unit.

#### 2-4. MOUNTING.

2-5. In operation, the 20IG gyro unit is usually used as a component in a control system. As such, it is mounted (either alone or in sets, and with its 20-pin connector exposed) in a thermally-controlled block that is also a part of the control system. The block maintains the temperature of the gyro unit at a constant level. Besides providing a thermally-controlled heatwell, this arrangement also furnishes a rigid support for the gyro unit. In addition, the gyro unit can be inserted and removed without disturbing the heater and the associated thermostat.

2-6. Proper alignment of the gyro unit with respect to the block, and hence with respect to the control system, can be obtained by any one of several procedures. Since the procedures are properly associated with the particular control system used, rather than the individual gyro unit, they are not discussed in this report. A matching female connector, with leads connecting to other parts of the

control system, is attached to the exposed 20-pin connector of the gyro unit.

#### 2-7. SALIENT PHYSICAL FEATURES.

2-8. Figure 2-1 is a simplified pictorial diagram that shows the important physical features of the 20IG gyro unit. These are the case, the gyro rotor (a constant-speed, electrically driven wheel that is the rotor of a 2-phase electrical motor), the gyro motor stator, the gimbal, the gimbal float shell, the pivots, the Microsyn torque motor (or torque generator, as it is often called), the Microsyn signal generator, and the components used for adjusting the balance of the gyro unit. Also shown are the three mutually perpendicular axes associated with the operation of the gyro unit (positive senses indicated by the directions of the arrowheads):

a. The *output axis*, OA, coincides with the longitudinal centerline of the unit. This is the axis about which the gimbal and gimbal float shell rotate as a unit. Its positive sense is outward from the end of the unit that carries the identification.

b. The *spin reference axis*, SRA, coincides with the spin axis, SA, of the gyro rotor when the gimbal is in its reference position (the position of zero rotation). The key at the center of the 20-pin connector (ref. Fig. 1-1) is assembled so as to be in approximate alignment with the positive sense of the spin reference axis.

c. The *input axis*, IA, is at right angles to both the output axis and the spin reference axis. The location of the input axis is accurately indicated by a dowel pin set into the outer edge of the end surface of the housing that contains the 20-pin connector (ref. Fig. 1-1). The positive sense of the input axis is 180 degrees from the dowel pin.

2-9. The gimbal and the gyro motor assembly, surrounded by helium, are hermetically sealed in the gimbal float shell. Helium is used because it is a dry, inert gas that provides a nonoxidizing atmosphere for the motor bearings. It also has a

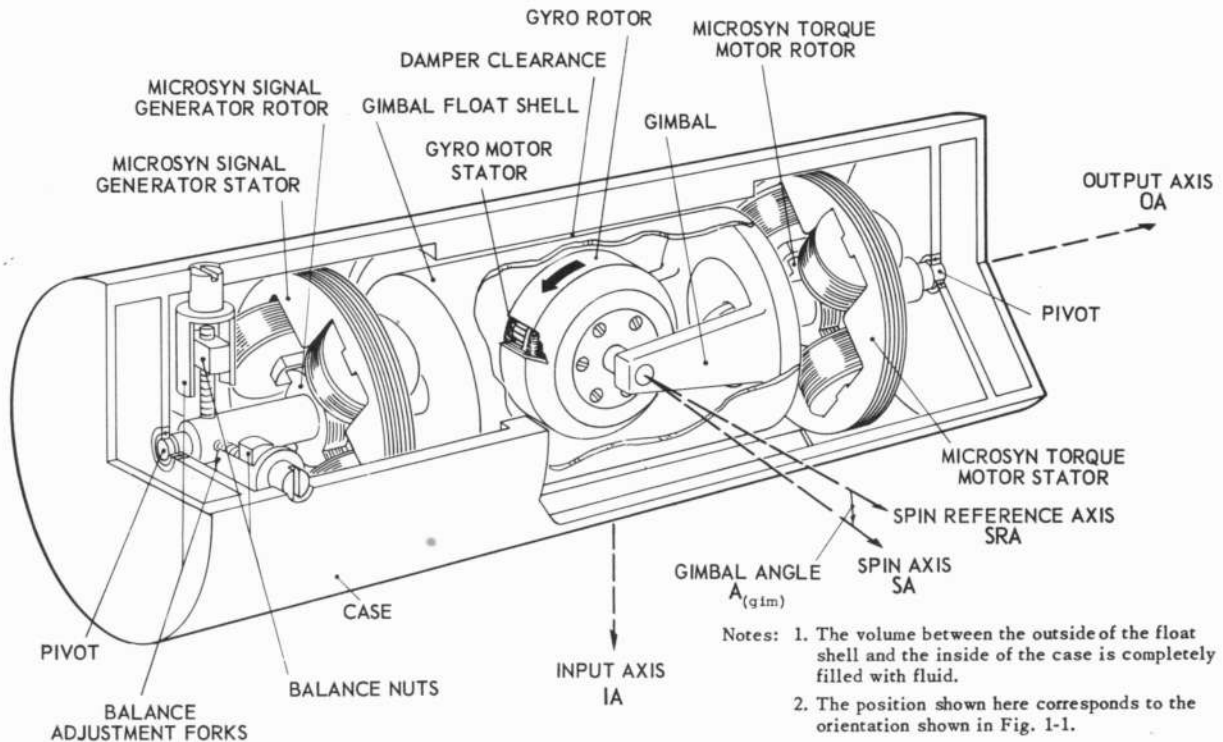


Fig. 2-1. Simplified pictorial diagram of the 20IG gyro unit.

high thermal conductivity, which aids in the transfer of heat from the motor to the float shell. The clearance space between this cylindrical shell and the case, also hermetically sealed, is completely filled by a high-density fluid. The shell and the components attached to it float in the fluid, so that the loads supported by the pivots are much smaller than they would otherwise be. The fluid also provides the required integrating damping action when the shell rotates with respect to the case.

2-10. Protruding from both ends of the gimbal float shell are integral shafts that terminate in the pivots. Each shaft carries the rotor of an electromagnetic device called a Microsyn. The corresponding stators, which are fixed to the case, have four poles. Each pole carries two coil windings. The coil windings of the Microsyn torque motor are connected so that when an input current signal is received, a rotational torque, or twist, is applied to the shaft upon which the torque motor rotor is mounted. The coil windings of the Microsyn signal generator, on the other hand, are connected so that, when the shaft rotates, an output voltage signal proportional to the angular displacement of the gimbal from its reference position is produced.

2-11. Also evident in Fig. 2-1 are two balance nuts, threaded at right angles to one another on studs that are attached to one of the gimbal float shafts. In addition to the two stud-and-nut combinations that are visible, there are two more hidden by the case. The balance nuts are used for preliminary balancing adjustments before the float is put in the case, to bring the center of gravity of the float assembly essentially on the output axis. Two balance adjustment forks are provided for refining the balance of the float. These forks make it possible to carry out final adjustments of the balance nuts with the gyro unit sealed.

#### 2-12. DETAILED PHYSICAL DESCRIPTION.

2-13. The actual 20IG unit has a number of features that are omitted from Fig. 2-1 in the interests of simplicity. For example, the electrical connections from the external pin terminals to the signal generator and the torque motor are not shown. Such details are described in the remainder of this section. The gyro unit is first discussed in terms of its major component parts and assemblies; then each component is described in turn and its function in the gyro unit is noted.

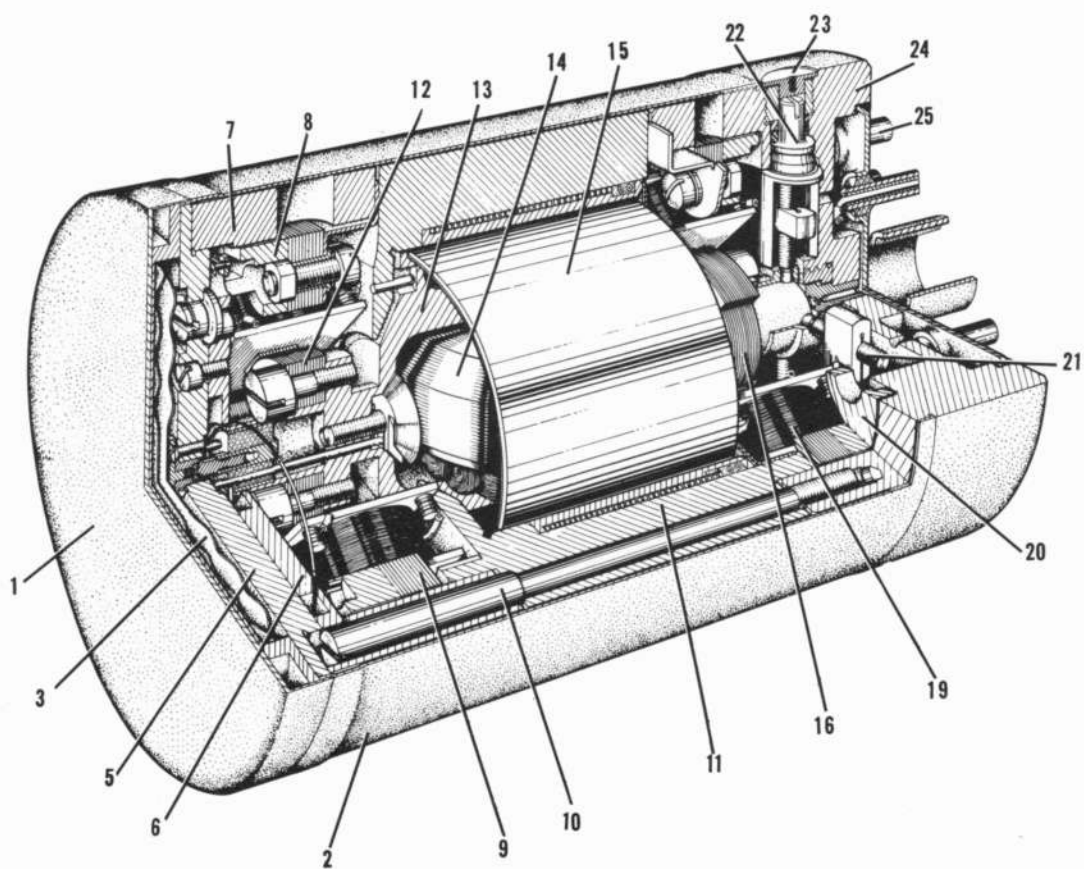
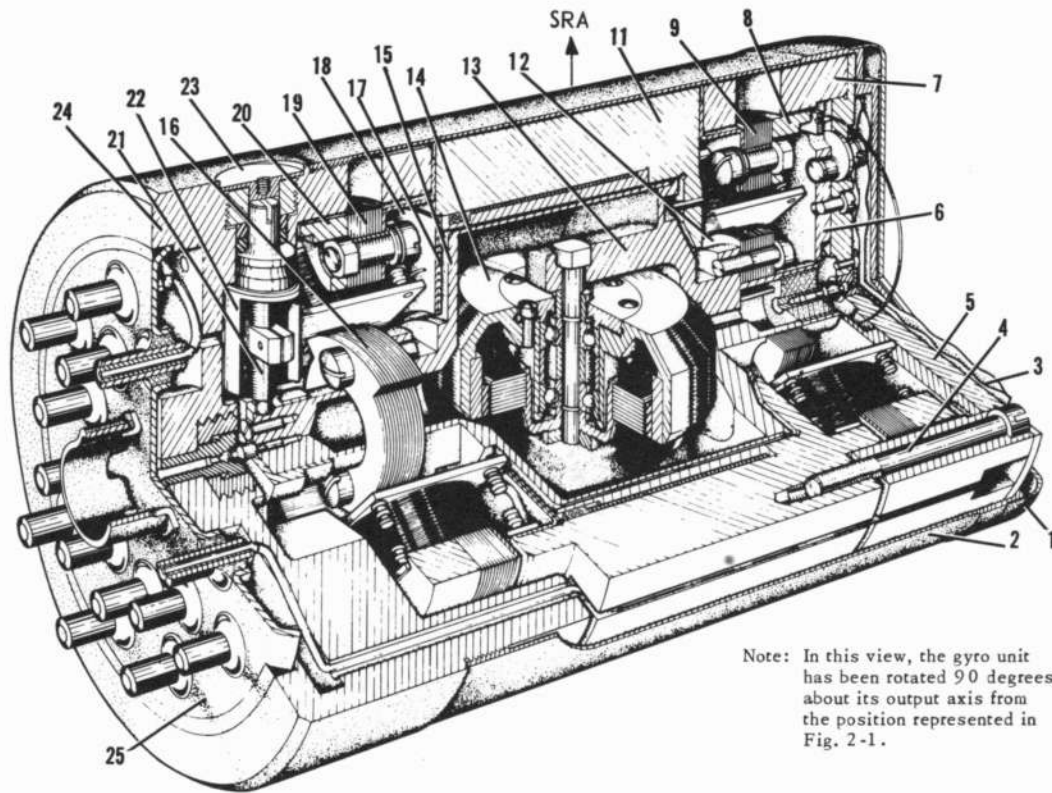


Fig. 2-2. Cutaway views of the 20IG unit.

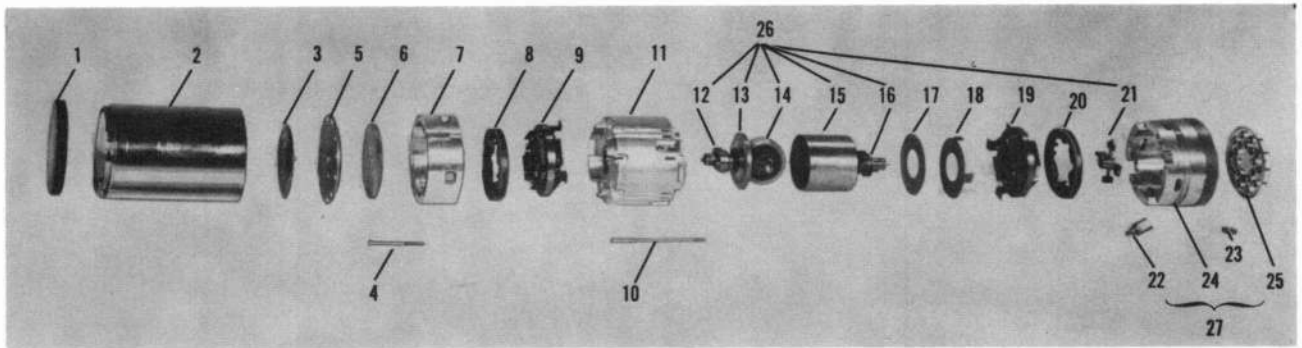


Fig. 2-3. Photograph of the 20IG unit showing major components prior to final assembly.

- |  |  |   |  |
|--|--|---|--|
| 1. Outer case cap                        | 8. Microsyn filler block                 | 16. Microsyn signal generator rotor           | 22. Balance adjustment fork                |
| 2. Outer case assembly                   | 9. Microsyn torque motor stator assembly | 17. Shield No. 1                              | 23. Balance fork plug                      |
| 3. Diaphragm assembly                    | 10. Signal generator tie rods            | 18. Shield No. 2                              | 24. Signal generator end housing           |
| 4. Torque motor tie rods                 | 11. Main housing assembly                | 19. Microsyn signal generator stator assembly | 25. 20-pin connector                       |
| 5. Torque motor end housing cap assembly | 12. Microsyn torque motor rotor          | 20. Microsyn filler block                     | 26. Floated units assembly                 |
| 6. Power lead baffle assembly            | 13. Gimbal fork                          | 21. Balance assembly and balance nuts         | 27. Signal generator end housing assembly. |
| 7. Torque motor end housing sleeve       | 14. Motor assembly                       |   |  |
|  | 15. Gimbal shell                         |   |  |

*Nomenclature for Figs. 2-2 and 2-3*

2-14. **COMPONENTS.** The 20IG unit consists of the assemblies and parts shown and named on the cutaway views of Fig. 2-2 and the photograph of the unassembled unit in Fig. 2-3. Figures 2-2 and 2-3 show the construction of the individual components and the way they fit together to form the assembled gyro unit. From a comparison of Figs. 2-2 and 2-3 with Fig. 2-1, an identification can be made between the actual components and the features shown in the simplified pictorial view. The major components (ref. Fig. 2-3) are identified by the numbers 1 through 25. The Microsyn torque motor rotor (12), the gimbal fork (13), the motor assembly (14), the gimbal shell (15), and the Microsyn signal generator rotor (16), together with the balance assembly and balance nuts (21), are all components of the rotating portion of the gyro unit, and are supported jointly by the flotation action of the fluid in which they are immersed and the pivot bearings. This floated portion is called the floated units assembly (26). The balance adjustment fork (22), the signal generator end housing (24), and the 20-pin connector (25), together with other small related parts not visible in Fig. 2-3, make up the signal generator end housing assembly (27).

2-15. **OUTER CASE CAP (1, Fig. 2-3).** This end cap, which fits snugly over the end of the outer

case assembly (2), serves to protect the copper tubing of that assembly from being tampered with. It is constructed of aluminum and has a black anodized finish. On its end surface is the gyro unit identification, printed on a nameplate decal. The identifying information includes name, model number, serial number, manufacturer (M. I. T. Instrumentation Laboratory), and a diagram that indicates the positive directions of the input, output, and spin reference axes (ref. paragraph 2-8). For the axis diagram to be meaningful, the end cap must be oriented so that the direction of the input axis indicated on the decal is 180 degrees away from the dowel pin on the opposite end of the gyro unit (ref. paragraph 2-8c).

2-16. **OUTER CASE ASSEMBLY (2, Fig. 2-3).** In conjunction with the signal generator end housing assembly (27), the outer case assembly provides a hermetic seal for the gyro unit. The outer case assembly comprises a case (1, Fig. 2-4), a tubing connector (2), and an approximately 3-inch length of soft copper tubing (3). The case and connector are made of brass and have a nickel-plate protective finish. The copper tubing is employed in the procedure for filling the gyro unit with the flotation fluid (ref. paragraph 2-9). This operation is described in Section VII.



1. Outer case    2. Tubing connector  
3. Copper tubing

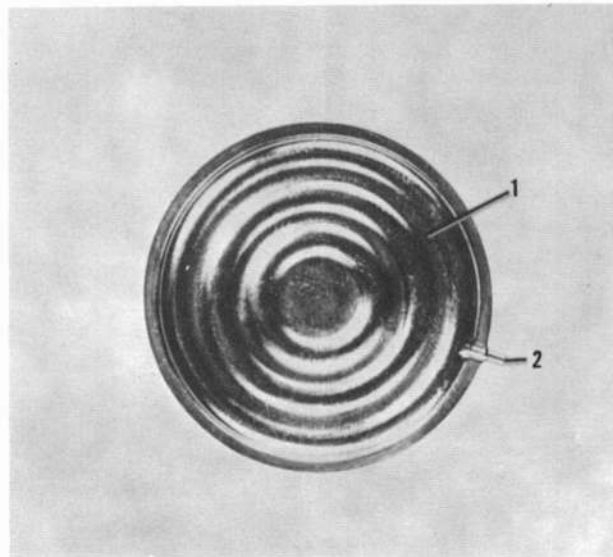
Fig. 2-4. Photograph of the outer case assembly.

2-17. DIAPHRAGM ASSEMBLY (3, Fig. 2-3). The diaphragm assembly, which is located inside the case at its closed end (ref. Fig. 2-2), absorbs the expansion and contraction of the flotation fluid with changes in temperature, and thus maintains the internal pressure nearly constant. Since the temperature of the gyro units is kept as constant as possible in operation (ref. paragraph 2-5), any changes in the volume of the fluid are small. The diaphragm assembly is made of two circular pieces of corrugated beryllium copper (1, Fig. 2-5) that are soldered together around their edges. Included in the assembly is a small copper tube (2), inserted at the edge of the assembly between the inner faces at the time of soldering. After the assembly is cooled to room temperature, the tube is sealed, so that the assembly is vacuum tight. The entire assembly is given a nickel plate finish to provide corrosion protection.

2-18. TORQUE MOTOR TIE RODS (4, Fig. 2-3). These four stainless-steel rods thread into the

main housing assembly (11), securing the torque motor end housing sleeve (7) and the Microsyn torque motor stator assembly (9) to the main housing assembly.

2-19. TORQUE MOTOR END HOUSING CAP ASSEMBLY (5, Fig. 2-3). The torque motor end housing cap assembly provides for both radial and axial bearing support of the floated portion of the gyro unit at the Microsyn torque motor end. This assembly comprises the torque motor end housing cap (1, Fig. 2-6), the torque motor end jewel assembly (2), the power lead baffle cam (3), a Tru-arc retaining ring (4), which holds the cam in place, the jewel ball (5, Fig. 2-7), the jewel ball retainer (6), and three fillister-head machine screws that hold the jewel ball retainer in place on the end housing cap. Figure 2-8 is a cross-section view that shows how these parts fit together. The torque motor end housing cap, machined from aluminum, is secured to the torque motor end housing sleeve by three screws. The torque motor end jewel assembly is shown by Fig. 2-8 to comprise the jewel holder (7) and the float-axis jewel (8). The jewel is a small doughnut-shaped sapphire. The corner of the aluminum jewel holder next to the jewel is spun over onto the jewel, thereby holding it tightly in place. The power lead baffle cam,



1. Two corrugated pieces of copper  
2. Copper tube

Fig. 2-5. Photograph of the diaphragm assembly.

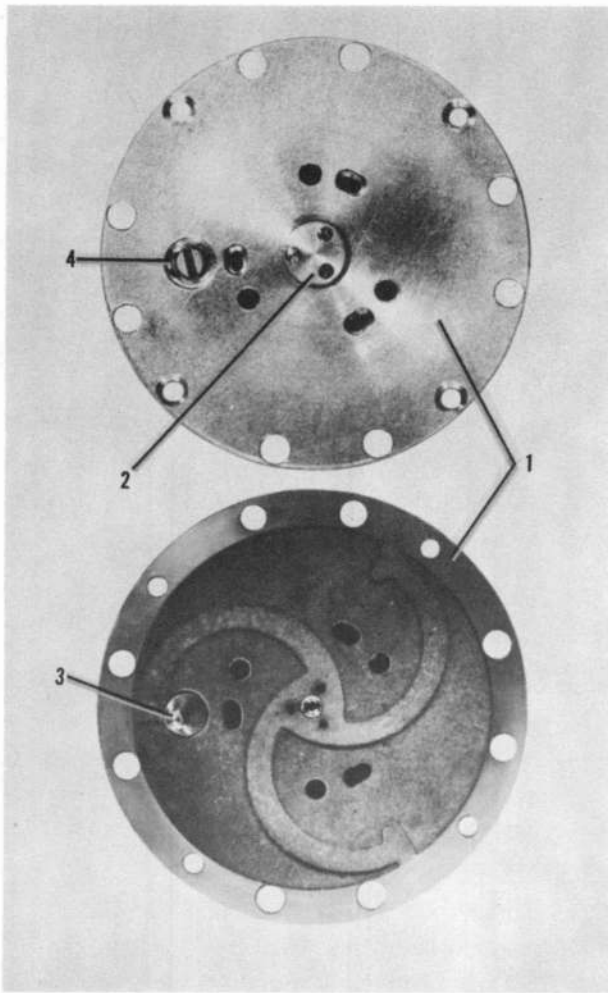


Fig. 2-6. Photographs of the torque motor end housing cap assembly.

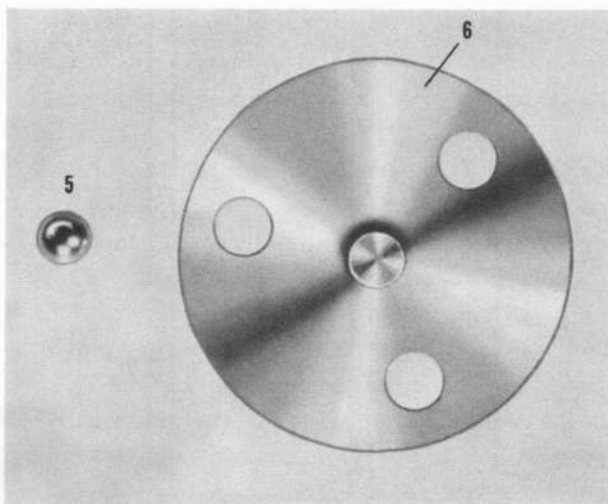


Fig. 2-7. Photograph of the jewel ball and jewel ball retainer.

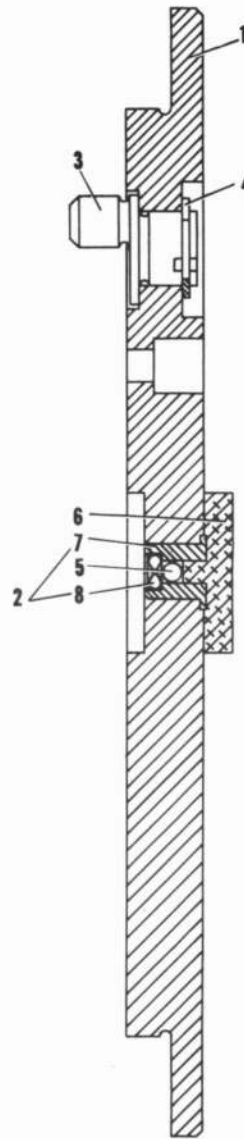


Fig. 2-8. Cross-section view of the torque motor end housing cap assembly.

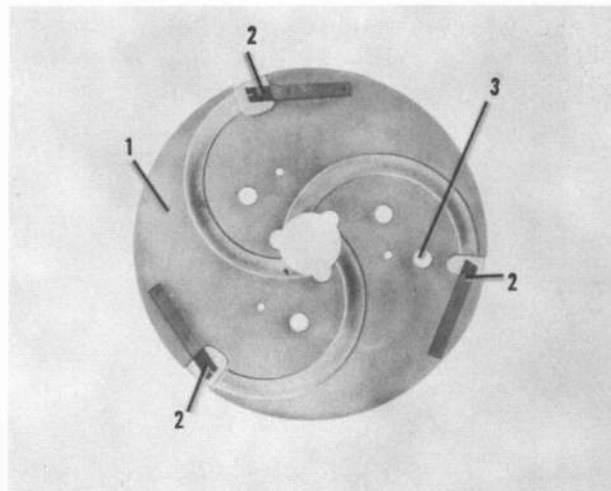
1. Torque motor end housing cap
2. Torque motor end jewel assembly
3. Power lead baffle cam
4. Tru-arc retaining ring
5. Jewel ball
6. Jewel ball retainer
7. Jewel holder
8. Float-axis jewel

Nomenclature for Figs. 2-6, 2-7 and 2-8

made of stainless steel, is used to adjust the tension or compression of the flex leads mounted in the power lead baffle assembly (6, Fig. 2-3). The eccentric cam engages a slot in the baffle assembly, so that rotating the cam moves the baffle plate with respect to the end housing cap. The jewel ball, made of tungsten carbide, is 1 millimeter in diameter. The jewel ball retainer is machined of aluminum.

2-20. POWER LEAD BAFFLE ASSEMBLY (6, Fig. 2-3). The power lead baffle assembly is designed to protect the three flex leads that supply power to the gyro motor assembly located in the floated portion of the gyro unit. The flex leads are thin flat ribbons, approximately 1-1/4 inches long and 0.001 inch by 0.009 inch in cross section, made of an 85-percent-silver, 15-percent-copper alloy. They are immersed in the flotation fluid. Temperatures below the freezing point of this fluid can be expected during the normal shelf life of many gyro units. Since the flotation fluid cracks when it freezes, the flex leads are subject to fracturing during extremely cold weather. This unfortunate situation is remedied by placing the flex leads in slots in the power lead baffle assembly. In the slots, the cracks of the flotation fluid resulting from freezing are small and weak, so that the fracturing effect can be withstood by the flex leads. (Further information on this subject is contained in Instrumentation Laboratory Engineering Note E-115, "Flex-Lead Tests," by J. J. Jarosh and J. A. Hogg, dated November, 1951). The power lead baffle assembly comprises the power lead baffle plate (1, Fig. 2-9) and three brass power lead terminals (2) bonded to it. The baffle plate, which contains three spiral-shaped slots for housing the three gyro motor flex leads, is made of a plastic resin that is a good electrical insulator. The baffle assembly is held in its proper position relative to the torque motor end housing cap assembly (ref. paragraph 2-19) by three fillister-head machine screws.

2-21. TORQUE MOTOR END HOUSING SLEEVE (7, Fig. 2-3). The torque motor end housing sleeve is a cylindrical piece of machined aluminum that surrounds the Microsyn torque motor stator assembly (9) and supports the torque motor end



1. Power lead baffle plate    2. Power lead terminals  
3. Slot for eccentric cam

Fig. 2-9. Photograph of the power lead baffle assembly.

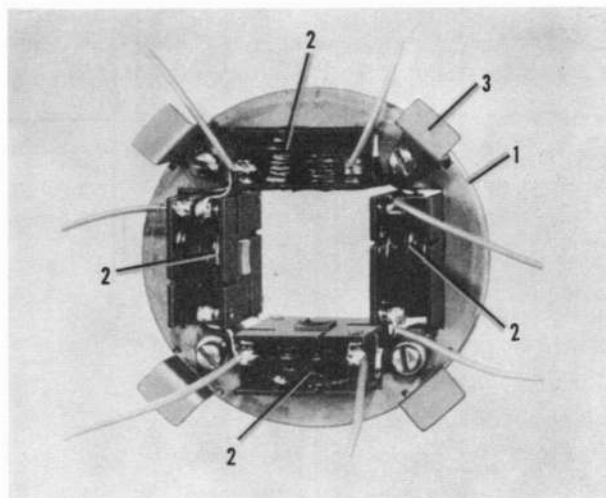
housing cap assembly (5). It also acts as a spacer to achieve coarse end shake adjustment (ref. Section V). Slots are provided in the sleeve, through which final radial and rotational adjustments can be made to the position of the Microsyn torque motor stator assembly.

2-22. MICROSYN FILLER BLOCK (8, Fig. 2-3). The Microsyn filler block, which is a cylindrical piece of machined aluminum with a protective hard-coat anodized finish, butts up against the Microsyn torque motor stator assembly. It serves to take up space that would otherwise be occupied by the filling fluid.

2-23. MICROSYN TORQUE MOTOR STATOR ASSEMBLY (9, Fig. 2-3). In conjunction with the Microsyn torque motor rotor, the Microsyn torque motor stator assembly is used to apply torques to the floated units assembly in accordance with an applied input signal. This assembly consists of a stator core (1, Fig. 2-10) made from insulated laminations of high-permeability iron-nickel alloy called Hypernik, four identical coil assemblies (2), a stainless-steel stator mount (3), and the wire jumpers required to complete the electrical circuit of the Microsyn torque motor. The stator core has four symmetrically spaced poles whose inner cylindrical surfaces are machined to a common radius. These surfaces are concentric with the



outer cylindrical surfaces of the Microsyn torque motor rotor (12, Fig. 2-3). The four coil assemblies are mounted on the four stator poles in the manner shown in Fig. 2-10. Each coil assembly contains two separate, electrically isolated windings; all windings are physically identical, with the same wire size and number of turns. Each winding on each pole has a mate on each of the other poles. The mating windings are connected in series to form an input circuit and an excitation circuit (ref. Section VI for the details of these connections).



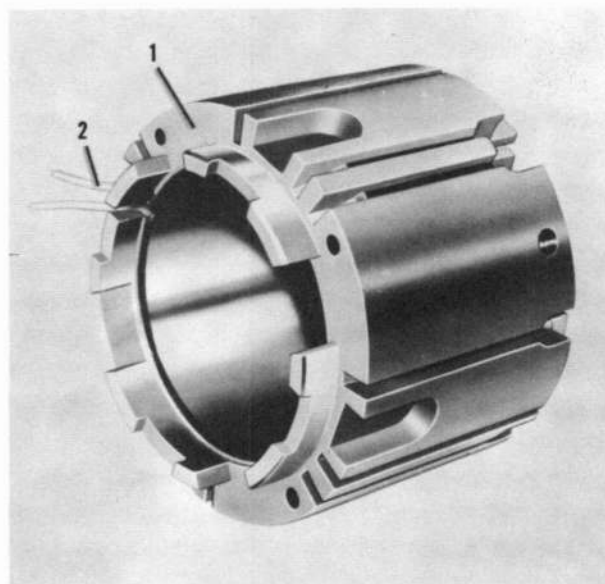
1. Stator core                      2. Coil assembly  
3. Stator mount

Fig. 2-10. Photograph of the Microsyn torque motor assembly.

One of two torque-motor designs is used: one operating on direct current, the other on 400-cps alternating current. In either instance, the excitation circuit is supplied with a constant input. The magnitude and sense of the input signal applied to the input circuit controls the torque applied by the Microsyn unit to the shaft upon which the rotor is mounted. The stator mount, bonded to the stator core laminations and secured there by four nuts and screws, has four spring feet located between the main housing assembly (11, Fig. 2-3) and the torque motor end housing sleeve (7). The spring feet are secured there by tightening the torque motor tie rods (4). The spring feet act as a strain relief by reducing strains in the Hypernik laminations that result from temperature changes.

2-24. SIGNAL GENERATOR TIE RODS (10, Fig. 2-3). These four stainless-steel rods thread into the signal generator end housing (24) and secure the main housing assembly (11) to it.

2-25. MAIN HOUSING ASSEMBLY (11, Fig. 2-3). In conjunction with the gimbal shell (15), the main housing assembly provides the damping gap used to obtain the required integrating damping action described in paragraph 2-9. The main housing assembly consists of the main housing (1, Fig. 2-11), and a sensing coil assembly (2) that fits inside it. This sensing coil assembly, which comprises about 27 feet of wire around a coil form, wound noninductively in a single layer, is used in the test procedure (ref. Section VIII) to determine the temperature of the damping fluid. It may also be used in a control circuit to maintain the desired temperature in a specific application of the gyro unit. The main housing itself is machined from aluminum bar stock. A small pin projecting from the inside of its end surface serves as a stop pin that engages a slot in the gimbal fork (13, Fig. 2-3) and limits the rotation of the floated units assembly (26) to



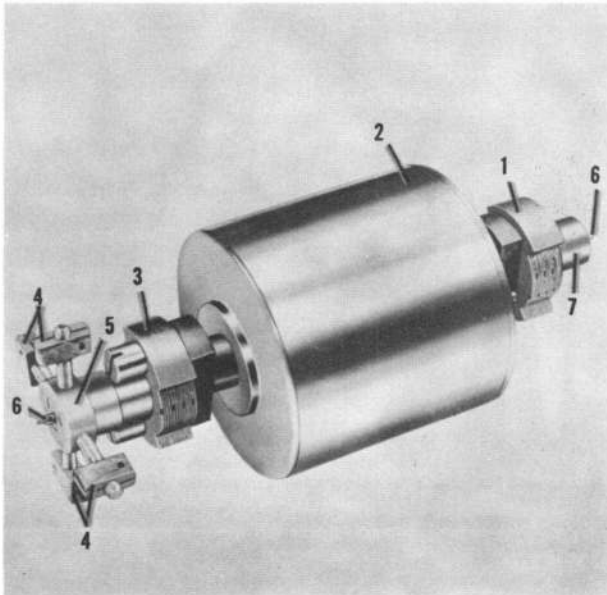
1. Main housing                      2. Sensing coil assembly

Fig. 2-11. Main housing assembly (viewed from the signal generator end of the gyro unit).

about 6 degrees on either side of the zero-rotation position. Four recesses on the outer surface of the main housing, near the signal generator end,

house four wire clips to which the leads from the Microsyn signal generator and sensing coil are attached.

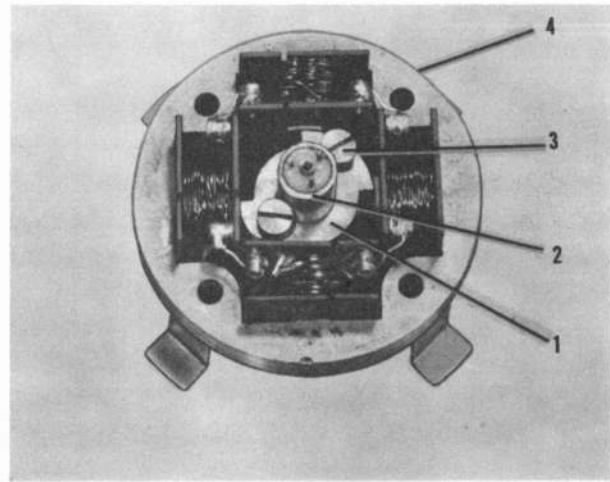
**2-26. FLOATED UNITS ASSEMBLY (26, Fig. 2-3).** The floated units assembly rotates about the output axis of the gyro unit in response to torques resulting from (a) gyroscopic action of the spinning rotor whenever the gyro unit is rotating about its input axis and (b) input signals applied to the Microsyn torque motor. The rotation of the floated units assembly from its zero reference position is the essential output of the gyro unit. The floated units assembly is essentially comprised of the Microsyn torque motor rotor (12), the gimbal fork (13), the motor assembly (14), the gimbal shell (15), and the Microsyn signal generator rotor (16), together with the balance assembly and balance nuts (21). These components are described in the following paragraphs. Figure 2-12 is a photograph of the assembled floated units assembly. Each of the two shafts contains a pivot assembly (6). In addition, the shaft on which the Microsyn torque motor rotor (1) is mounted contains a power lead-in body (7) through which power is supplied to the motor assembly.



- |                                    |                       |
|------------------------------------|-----------------------|
| 1. Microsyn torque motor rotor     | 4. Balance nuts       |
| 2. Gimbal shell                    | 5. Balance assembly   |
| 3. Microsyn signal generator rotor | 6. Pivot assembly     |
|                                    | 7. Power lead-in body |

Fig. 2-12. Photograph of the assembled floated units assembly

**2-27. MICROSYN TORQUE MOTOR ROTOR (12, Fig. 2-3).** Like the Microsyn torque motor stator core (ref. paragraph 2-23), the Microsyn torque motor rotor is made from insulated laminations of Hypernik. The outer faces of the symmetrical rotor are located with respect to the four stator poles as shown in Fig. 2-13. The rotor (1, Fig. 2-13) is secured in position on the gimbal fork shaft (2) of the floated units assembly by two clamp screws (3).



- |  |
|--|
| 1. Microsyn torque motor rotor                     |
| 2. Gimbal-fork shaft of the floated units assembly |
| 3. Clamp screw                                     |
| 4. Microsyn torque motor stator core               |

Fig. 2-13. Photograph showing the location of the Microsyn torque motor rotor with respect to the stator core.

**2-28. GIMBAL FORK (13, Fig. 2-3).** The gimbal fork, made of machined aluminum with a copper plating, includes a cylindrical shaft extending from the closed end of the fork. This is the shaft that carries the Microsyn torque motor rotor (12). The motor assembly (14) is supported inside the fork, and the gimbal shell (15) encloses the fork. Mounted inside the end of the shaft are the power lead-in body and the pivot assembly. The construction of the power lead-in body is indicated in Fig. 2-14. Through the length of a cylindrically shaped piece of Kovar tubing (1) run three symmetrically spaced Kovar wires (2) and a Kovar rod (3), of larger diameter, that is located along the centerline of the outside tubing. The wires and the rod are imbedded in a glass-to-metal seal (4) that insulates them from one another. At the exposed end of the Kovar rod, along its centerline,

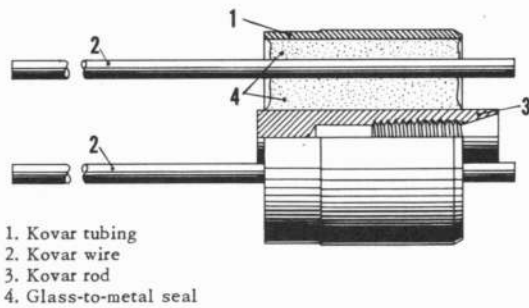


Fig. 2-14. Cross-section view of the power lead-in body.

is a tapped hole. The pivot assembly, which comprises a pivot (1, Fig. 2-15) and a pivot holder (2), threads into this tapped hole. The taper on the pivot holder mates with the taper in the Kovar rod to insure that the pivot and the outer diameter of the float will be concentric. The pivot is a polished tungsten carbide rod that is supported in the assembled gyro unit by the torque motor end jewel assembly (ref. paragraph 2-19). The bearing end of the pivot is spherical in shape, except that the extreme end is a 0.005-inch diameter flat. This flat contacts the jewel ball in the torque motor end housing cap assembly (ref. paragraph 2-19).

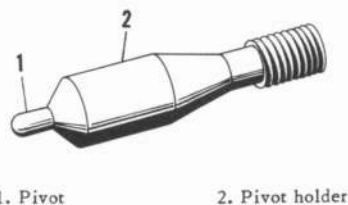


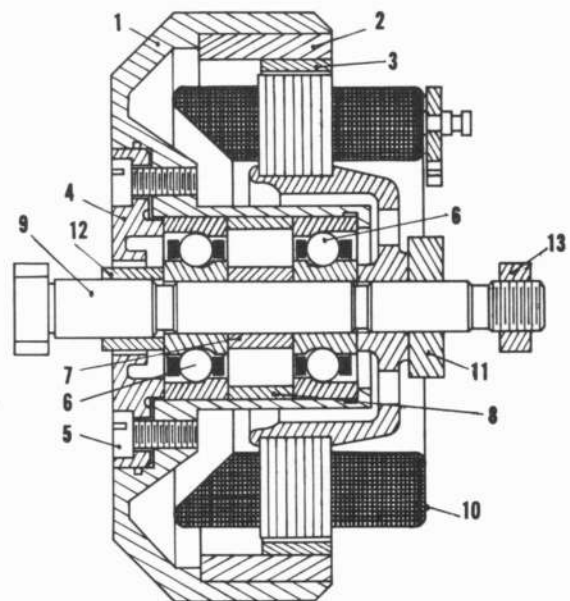
Fig. 2-15. Pictorial view of the pivot assembly.

2-29. **MOTOR ASSEMBLY** (14, Fig. 2-3). The motor assembly, which is supported inside the gimbal fork (13), is a 400-cps, two-phase, synchronous hysteresis motor. The spinning rotor is the essential gyroscopic element of the gyro unit. The motor belongs to the class of radial-air-gap motors, so called because the air gap between the rotor and stator is concentric with the spin axis (see Fig. 2-16). The motor assembly is comprised of three main groups of parts:

- a. The parts that rotate with respect to the gimbal fork.
- b. The parts that are fixed with respect to the gimbal fork.

c. The bearings, and associated spacers, that support the moving assembly with respect to the fixed assembly.

2-30. The moving assembly comprises the rotor (1, Fig. 2-16), the bushing (2), the hysteresis ring (3), the bearing retainer (4), and six screws (5). The rotor is a cylindrical piece machined from aluminum stock. The bushing, made of stainless steel, is inserted in the rotor in order to increase the mass concentration near the rim. With this arrangement, a maximum angular momentum per unit weight is obtained for a given rotor diameter. (Angular momentum is aptly described by one authority on gyros as "flywheel-osity," that is, the ability of a spinning body to act like a flywheel and - by its inertia - oppose and moderate any change in the speed of rotation.) The hysteresis ring is shrink-fitted inside the bushing. In conjunction with the motor stator, the ring causes the gyro wheel to spin. A magnetic flux from the stator windings passes into the hysteresis ring, producing a torque that spins the rotor in synchronism with the 400-cps frequency



- |                         |                         |
|-------------------------|-------------------------|
| 1. Rotor                | 8. Outer preload spacer |
| 2. Bushing              | 9. Motor shaft          |
| 3. Hysteresis ring      | 10. Stator              |
| 4. Bearing retainer     | 11. Motor lower spacer  |
| 5. Screws               | 12. Motor upper spacer  |
| 6. Bearing              | 13. Motor shaft nut     |
| 7. Inner preload spacer |                         |

Fig. 2-16. Cross-section view of the motor assembly.

of the alternating-current excitation. The hysteresis ring is made from a material that has a high hysteresis loss. The aluminum bearing retainer, which is secured to the rotor by six screws (5), holds the two bearings (6) in place. These bearings are separated by the inner and outer preload spacers (7 and 8).

2-31. The fixed assembly comprises the motor shaft (9), the stator (10), the motor spacers (11 and 12), and the motor shaft nut (13). The motor shaft is a stepped piece machined from aluminum. The stator has six poles; this design causes the gyro wheel to spin at 8000 revolutions per minute. There are two coils for each pole of these stators, one coil for each of the two phases. Each coil is wound with high-temperature, insulated wire. The coils are series-connected in such a way as to give clockwise rotation as seen from the terminal side. (See Fig. 2-18 at the end of this section for a schematic wiring diagram of the gyro unit.) The entire motor assembly is properly located and secured to the gimbal fork by means of the motor shaft (9), the motor spacers (11 and 12), and the motor shaft nut (13).

2-32. GIMBAL SHELL (15, Fig. 2-3). The gimbal shell is a thin-walled, copper-plated aluminum cylinder with an open end. The gimbal fork, containing the motor assembly, is inserted in the open end and induction-soldered to the gimbal shell. The copper plating on the gimbal fork and gimbal shell helps form a good soldered joint. Before the soldering takes place, the enclosed volume is first evacuated of air and then filled with helium. This inert gas provides a nonoxidizing atmosphere for the motor bearings, a low-viscosity medium that offers little resistance to the spinning rotor, and a medium with high thermal conductivity to aid in the transfer of heat from the motor assembly to the gimbal shell. The gimbal shell has a cylindrical shaft extending from the closed end of the cylinder. Mounted on this shaft are:

- a. The Microsyn signal generator rotor (16).
- b. The balance assembly and balance nuts (21), (ref. paragraph 2-37).

Contained in the end of the shaft, and protruding through the balance assembly, is a pivot assembly that is identical with the one described in paragraph 2-28.

2-33. MICROSYN SIGNAL GENERATOR ROTOR (16, Fig. 2-3). In conjunction with the Microsyn signal generator stator assembly, the Microsyn signal generator rotor produces a 400-cps electrical signal that is proportional to the rotation of the floated units assembly from its zero reference position. This rotor is identical in construction detail with the Microsyn torque motor rotor (ref. paragraph 2-27). The Microsyn signal generator rotor is mounted on the gimbal-shell shaft of the floated units assembly (26). The outer faces of the signal generator rotor are located with respect to the four associated stator poles in the same way as the faces of the torque motor rotor shown in Fig. 2-13. The signal generator rotor is secured to its shaft with two clamp screws in the same way that the torque motor rotor is secured to its shaft.

2-34. SHIELDS (17 and 18, Fig. 2-3). Shields No. 1 and No. 2 are used to prevent magnetic noise from the motor assembly (14) from interfering with the operation of the Microsyn signal generator. They are stamped from Mumetal, which is a high-permeability alloy.

2-35. MICROSYN SIGNAL GENERATOR STATOR ASSEMBLY (19, Fig. 2-3). The Microsyn signal generator stator assembly is identical in appearance with the Microsyn torque motor stator assembly (ref. paragraph 2-23). The essential difference is in the coil assemblies. As in the Microsyn torque motor, each coil assembly contains two separate, electrically isolated windings, and each winding on each pole has a physically identical mate on each of the other poles. However, in the Microsyn signal generator, the two windings of any one coil assembly differ in wire size and in the number of turns. As in the Microsyn torque motor stator assembly, there are two separate series circuits (ref. Section VI for the details of these connections). In the Microsyn signal generator, these are called the excitation circuit and the output circuit. The excitation circuit, whose coil windings contain relatively fewer turns, is supplied with a constant 400-cps, a-c input. The output circuit furnishes a 400-cps, a-c output signal whose magnitude is proportional to the angular displacement of the floated units assembly from its reference position. The phase of the output signal with respect to the input excitation indicates whether

the rotation is clockwise or counterclockwise from the reference position. The four spring feet of the stator mount are located between the main housing assembly (11) and the signal generator end housing (24), and are secured there by tightening the signal generator tie rods (10). The spring feet act as a strain relief by reducing strains in the Hypernik laminations that result from temperature changes.

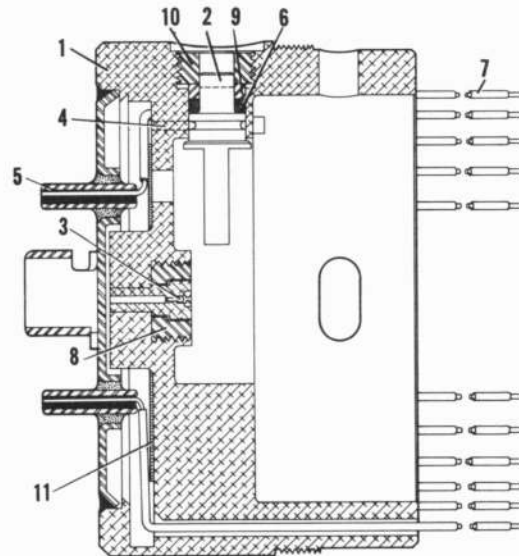
2-36. **MICROSYN FILLER BLOCK (20, Fig. 2-3).** This block is identical with the other Microsyn filler block (8), described in paragraph 2-22. It, too, serves to take up space that would otherwise be occupied by the filling fluid.

2-37. **BALANCE ASSEMBLY AND BALANCE NUTS (21, Fig. 2-3).** The balance assembly (5, Fig. 2-12) consists of a balance hub and four threaded balance studs spaced 90 degrees apart. The studs, made of stainless steel, are silver soldered at the hub. The balance of the floated units assembly about the output axis (the axis of the pivots) is adjusted by the four balance nuts (4) that are carried by the balance studs. The hub is secured with three screws to the end of the gimbal-shell shaft of the floated units assembly. The pivot assembly in the end of the shaft protrudes through a hole drilled in the hub.

2-38. **SIGNAL GENERATOR END HOUSING ASSEMBLY (27, Fig. 2-3).** The signal generator end housing assembly (see cross-section view of Fig. 2-17) comprises the following components:

- Signal generator end housing (1).
- Two balance adjustment forks (2).
- Signal generator end jewel assembly (3).
- Four fork retaining pins (4).
- 20-pin connector (5).
- Two O-rings (6).
- Wire leads (7).
- Jewel holder extractor (8).
- Two O-ring pressure washers (9).
- Two O-ring pressure screws (10).
- Wire-mesh strainer (11).

2-39. **SIGNAL GENERATOR END HOUSING (1, Fig. 2-17).** The signal generator end housing is a cylindrical piece of machined aluminum that houses the other components listed in the preceding paragraph and, in addition, the Microsyn signal generator stator assembly (19, Fig. 2-3), the



- |  |                           |
|--|---------------------------|
| 1. Signal generator end housing        | 6. O-ring                 |
| 2. Balance adjustment fork             | 7. Wire leads             |
| 3. Signal generator end jewel assembly | 8. Jewel holder extractor |
| 4. Fork retaining pin                  | 9. O-ring pressure washer |
| 5. 20-pin connector                    | 10. O-ring pressure screw |
|  | 11. Wire-mesh strainer    |

Fig. 2-17. Cross-section view of the signal generator end housing assembly.

Microsyn filler block (20), and the balance assembly and balance nuts (21). Four holes in the outer surface of the cylinder are used in the Microsyn centering procedure.

2-40. **BALANCE ADJUSTMENT FORKS (2, Fig. 2-17).** The two stainless-steel balance adjustment forks allow final balancing of the floated units assembly to be made after the gyro unit is assembled. Each fork is held in radial position in the signal generator end housing by two fork retaining pins (4). The O-ring (6), O-ring pressure washer (9), and O-ring pressure screw (10) associated with each fork form a seal that prevents leakage of the fluid through the end housing past the fork. The balance fork plug (23, Fig. 2-3), which is sealed in with adhesive, protects the fork adjustment setting. This plug has a small tapped hole in the center by means of which it can be lifted out should further adjustment be necessary.

2-41. **SIGNAL GENERATOR END JEWEL ASSEMBLY (3, Fig. 2-17).** The signal generator end jewel assembly provides both radial and axial support for the floated portion of the gyro unit at the

Microsyn signal generator end. It is similar in construction to the torque motor end jewel assembly (ref. paragraph 2-19). There are two basic differences, however. First, the jewel holder of the signal generator end jewel assembly is approximately three times longer than the jewel holder of the other assembly and, second, the tungsten carbide ball is permanently secured inside the jewel holder, so that no jewel ball retainer is required. The signal generator end jewel assembly is inserted into the signal generator end housing (1) with a light press fit. The jewel holder extractor (8), which has a slotted head, enables the jewel assembly to be withdrawn from the end housing without removing the 20-pin connector (5).

2-42. 20-PIN CONNECTOR (5, Fig. 2-17). The 20-pin connector, which is induction soldered to the signal generator end housing (1), is comprised

of a disc, 20 electrode pins, and a key. These components are made of cold-rolled steel with a fused electro-tin plate. The electrode pins are insulated from the disc by fused glass. Through these pins and the associated wire leads (7), the electrical power necessary to operate the gyro unit is supplied, and intelligence in the form of electrical signals is introduced and extracted. One pin, which is not connected to a wire lead, is tapped to receive a screw. It is through this pin that the unit is filled with the flotation fluid. The various pins are identified in Fig. 2-18, which is a schematic wiring diagram showing the internal connections of the gyro unit electrical circuits.

2-43. WIRE-MESH STRAINER (11, Fig. 2-17). The wire-mesh strainer filters out dirt or other foreign matter that would otherwise enter the gyro unit during the fluid-filling operation (ref. Section VII) and possibly interfere with its operation.

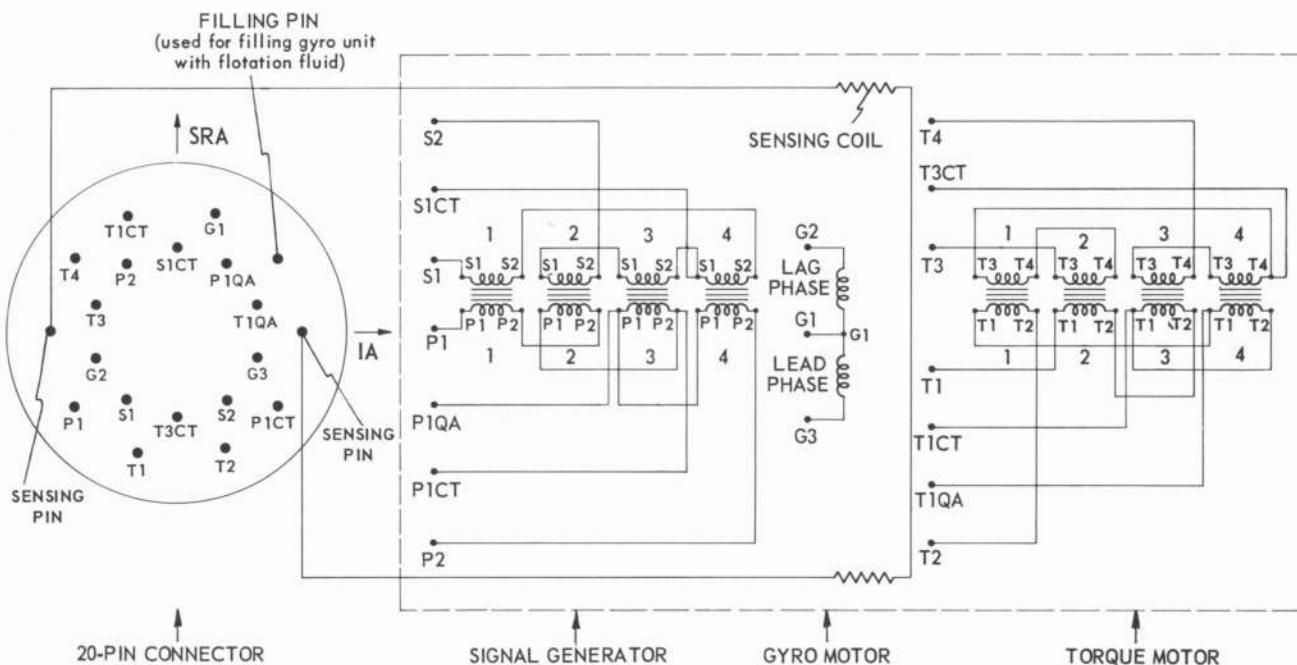


Fig. 2-18. Schematic wiring diagram for the M.I.T. 20IG Integrating Gyro Unit.

## SECTION III

# SPECIAL TOOLS, EQUIPMENT, AND FACILITIES FOR ASSEMBLY AND TESTING

### 3-1. INTRODUCTION.

3-2. This section illustrates and describes briefly the special tools, equipment, and facilities for assembly and testing that are utilized in connection with the 20IG gyro unit. It serves two prime functions:

a. It provides a convenient reference source on special tools, etc., for the remainder of the handbook, and allows the subject matter there to flow much more smoothly than would otherwise be possible.

b. It compiles in one place pertinent information relating to special tools, etc. so that anyone interested solely in this particular aspect need not comb through the other sections of the handbook.

3-3. For convenience, the material is presented under two main headings:

a. Special tools and equipment used in the assembly and test procedures of Sections IV through VIII (ref. paragraphs 3-4 and 3-5).

b. Special facilities for assembling and testing (ref. paragraphs 3-6 through 3-8).

### 3-4. SPECIAL TOOLS AND TEST EQUIPMENT.

3-5. Table 3-1 identifies in turn the special tools and equipment used in assembling and testing the 20IG gyro unit. The left-hand column specifies the figure in which the special tool or equipment is illustrated. These figures appear in sequence immediately following the table. They serve as identification only; where detail is required to clarify subsequent assembly and test procedures, separate illustrations are provided there as required. The next column gives the name of the special tool or equipment, together with the manufacturer when

applicable. The next column of Table 3-1 gives a brief description of the item's function. The right-hand column notes the paragraph in which reference to the special tool or equipment appears.

### 3-6. SPECIAL FACILITIES FOR ASSEMBLY AND TESTING.

3-7. Special, separate quarters, known as the assembly room, are provided for assembling the gyro units. Extraordinary precautions are taken to obtain and maintain a clear atmosphere in this assembly room. To this end, the room is served by air conditioning equipment that not only maintains the assembly area at an even, moderate temperature conducive to comfortable, perspiration-free working conditions, but also continuously filters the air to remove suspended dust or dirt particles. Entrance to the room is gained by passing through two glass-windowed doors between which is a small area that is used to don laboratory coats, head covering, or any other special clothing that is deemed necessary for cleanliness. Both doors are equipped with door checks that close the doors when released. An electronic communication system to outside areas is available, thereby minimizing traffic to and from the assembly room. The need for such painstaking precautionary measures becomes apparent from subsequent descriptions of the various assembly procedures - particularly those involving balancing operations.

3-8. A special area is also set aside for testing the assembled gyro units. This area, too, is air conditioned, to provide for the comfort of the test personnel and the proper functioning of the test equipment.

Table 3-1. Special tools and equipment used in the assembly and test procedures of Sections IV through VIII.

Fig. No.	Name (and source)	Use	Paragraph Reference
3-1	Plastic-covered boxes (standard commercial item)	Store parts required in assembly of gyro unit	4-1
3-2	Assembly fixture - hysteresis ring into bushing (Instrumentation Laboratory design)	Comprises arbor press, collet, heating pad, and heat-retaining block for assembly of hysteresis ring into bushing	4-10
3-3	Assembly fixture - bushing-and-ring assembly into rotor (Instrumentation Laboratory design)	Comprises arbor press, collet, heating pad, and heat-retaining block for assembly of bushing-and-ring assembly into rotor (arbor press, collet and heat-retaining block are the same as those of Fig. 3-2)	4-11
3-4	Annis Dynograph Balancer (R. B. Annis Co., Indianapolis, Ind.)	Dynamically balance rotor assembly of gyro motor	4-14
3-5	Air gauge (Federal Products Corp., Providence, R. I.)	Measure diameter of rotor bore Measure inside diameter of sensing coil	4-21a, 4-58c 4-99c
3-6	Electronic indicating gauge (Cleveland Instrument Co., Cleveland, O.)	Measure gyro motor rotor shaft at bearing surface.	4-21c
3-7	Honing machine (Sunden Products Co., St. Louis, Mo.)	Hone rotor bore Hone sensing coil	4-23 4-99c
3-8	Assembly fixture - spin axis bearings and preload spacers into rotor (Instrumentation Laboratory design)	Comprises arbor press, two arbor extensions, bearing-pad spacer, collet, heating pad, and heat-retaining block for assembly of bearings and preload spacers into gyro motor rotor (arbor press and heat-retaining block are the same as shown in Fig. 3-2)	4-32
3-9	Jeweler's loupe (Bausch & Lomb Optical Co., Rochester, N. Y.)	Inspect small components	4-36a
3-10	Simpson Multimeter (Simpson Electric Co., Chicago, Ill.)	Check winding resistances in the gyro motor and in the Microsyn units	4-38, 4-48 5-6, 5-9w 5-11j
3-11	Analytical balance (Christian Becker Torsion Balance Co., Clifton, N. J.)	Weigh Microsyn rotors	4-45d
3-12	Surgical shears (standard commercial medical item)	Trim wire booting	4-49c
3-13	Centrifuge (Instrumentation Laboratory design)	Remove excess oil from spin-axis bearings	4-21e
3-14	Small hole gauges (L. S. Starrett Co., Athol, Mass.)	Measure inside diameters	4-54a
3-15	Micrometer (L. S. Starrett Co., Athol, Mass.)	Measure diameter of power lead-in body Measure over-all stud lengths on balance assembly Measure thickness of motor spacers	4-54b 4-58c 4-63c
3-16	Microscope and light (Carl Zeiss, Germany)	Inspect parts	4-55a
3-17	Insulation resistance meter (General Electric Co., Schenectady, N. Y.)	Make ground check between gyro motor leads	4-55b, 4-59f
3-18	Induction soldering machine (including soldering coils) (Lepel Laboratories Inc., New York, N. Y.)	Solder power lead-in body in gimbal fork shaft Solder gimbal shell to gimbal fork	4-56i 4-69e, 4-84b
3-19	Induction soldering setup (Instrumentation Laboratory design)	Comprises soldering fixture, bench block, and positioning device for use with the induction soldering machine shown in Fig. 3-18	4-56h 4-69c 4-84a
3-20	Pivot wrench (standard commercial item)	Assemble pivot assemblies	4-58d
3-21	Test fixture for measuring float runout (Instrumentation Laboratory design)	Hold floated units assembly during float run-out check Hold floated units assembly while minimizing pendulosity	4-58g 4-65
3-22	Dial indicator and support (Federal Products Corp., Providence, R. I.)	Measure runout of floated units assembly	4-58h
3-23	Special poising arbor (Instrumentation Laboratory design)	Statically balance small balance nuts	4-60



Table 3-1. Special tools and equipment used in the assembly and test procedures of Sections IV through VIII. (cont.)

Fig. No.	Name (and source)	Use	Paragraph Reference
3-24	Watch-balance-wheel poising tool (Levin & Son, Inc., Los Angeles, Calif.)	Statically balance small balance nuts	4-60
3-25	Torque wrench (standard commercial item)	Measure turning torque of balance nuts	4-61g
3-26	Telescoping gauge (Lufkin Rule Co., Saginaw, Mich.)	Measure opening between prongs of gimbal fork	4-63a
3-27	Jeweler's lathe and associated equipment (F. W. Derbyshire, Inc., Waltham, Mass.)	Grind surfaces of motor spacers Coat gimbal shell with soldering flux	4-63c 4-69b
3-28	Torque wrench (P. A. Sturtevant Co., Addison, Ill.)	Tighten motor shaft nut	4-64c 4-68g
3-29	Vibrator (Syntron Company, Homer City, Pa.)	Overcome pivot friction in the procedure for minimizing pendulosity of floated units assembly	4-65
3-30	Temperature-controlled oven (Instrumentation Laboratory design)	Check coast-down time	4-68b
3-31	Test console (Instrumentation Laboratory design)	Check coast-down time	4-68c
3-32	Stethoscope (standard commercial medical item)	Listen to gyro motor operation	4-68h
3-33	Gimbal shell evacuation and pressurization equipment (Instrumentation Laboratory design)	Apply helium to inside of gimbal shell Evacuate the Fluorolube-filled test tank	4-70 4-73g
3-34	Mass spectrometer (General Electric Co., Schenectady, N. Y.)	Check floated units assembly for leakage	4-70k
3-35	Thermally controlled aluminum tank (Instrumentation Laboratory design)	Obtain correct weight and balance of floated units assembly	4-72 4-73
3-36	Pair of analytical balances (Seederer-Kohlbusch, Inc., Englewood, N. J.)	Obtain correct weight and balance of floated units assembly	4-73i
3-37	Hypodermic needle	Clean inside of jewel assembly	4-88d
3-38	Industrial washing machine (L & R Mfg. Co., Arlington, N. J.)	Clean signal generator end housing assembly	4-92
3-39	Winding fixture (Instrumentation Laboratory design)	Wind sensing coil	4-97
3-40	Wheatstone bridge (Rubicon Company, Philadelphia, Pa.)	Measure resistance of sensing-coil winding	4-98m
3-41	Two-part potting mold (Instrumentation Laboratory design)	Bond sensing-coil winding to coil form	4-98w
3-42	Assembly test stand (Instrumentation Laboratory design)	Assemble gyro unit	5-3
3-43	End-shake measuring equipment (Instrumentation Laboratory design)	Comprises adapter ring, surface plate, and special type micrometer gauge for determining gyro unit end shake	5-16
3-44	Annealing fixture (Instrumentation Laboratory design)	Anneal flex leads	5-24d
3-45	Removing tool (Hammel Riglander & Co., Germany)	Remove torque motor end housing cap assembly from torque motor end housing sleeve	5-27d
3-46	Microsyn centering fixture (Instrumentation Laboratory design)	Hold gyro unit and permit easy adjustment of each stator with respect to its rotor	6-11
3-47	Test console and associated equipment (Instrumentation Laboratory design)	Carry out Microsyn centering procedure	6-11
3-48	Filling equipment (Instrumentation Laboratory design)	Fill the assembled gyro unit Includes a filling fixture, vacuum pumps, vacuum gauges, thermometers, control valves, etc.	7-11
3-49	Basic test setup (Instrumentation Laboratory design)	Carry out complete testing procedure	8-9

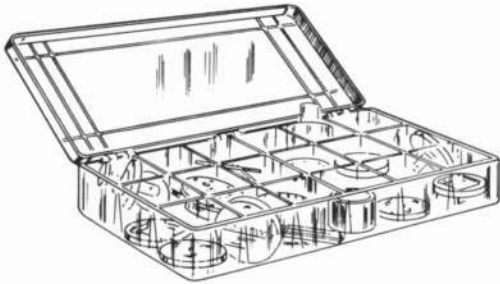


Fig. 3-1. Plastic-covered boxes.

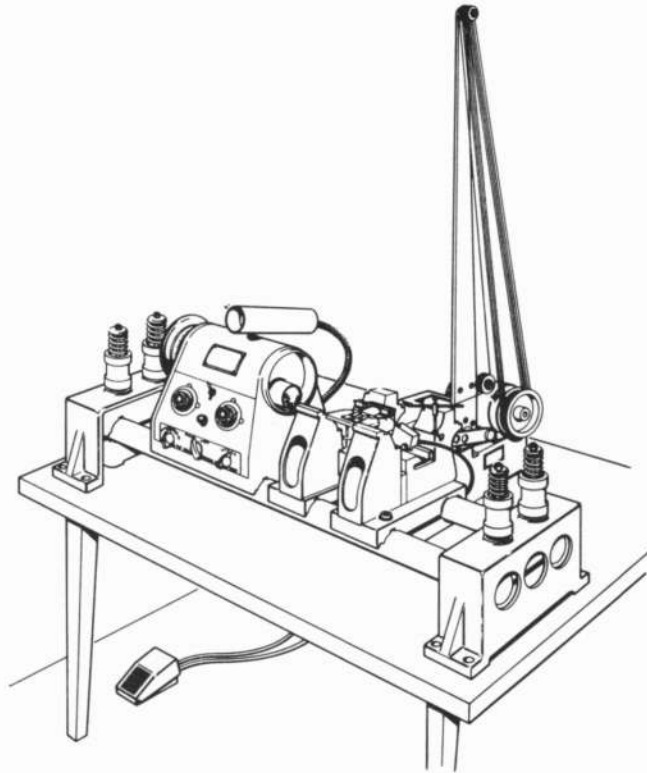


Fig. 3-4. Annis Dynograph Balancer.

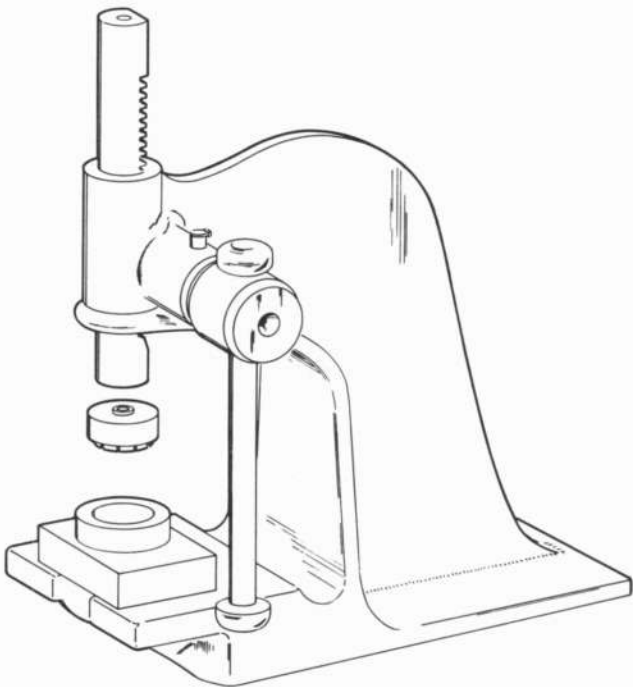


Fig. 3-2. Assembly fixture - hysteresis ring into bushing.

Fig. 3-3. Assembly fixture - bushing-and-ring assembly into rotor.

**Note**

*These assembly fixtures differ only in the size of the heating pad that is used.*



Fig. 3-5. Air gauge.

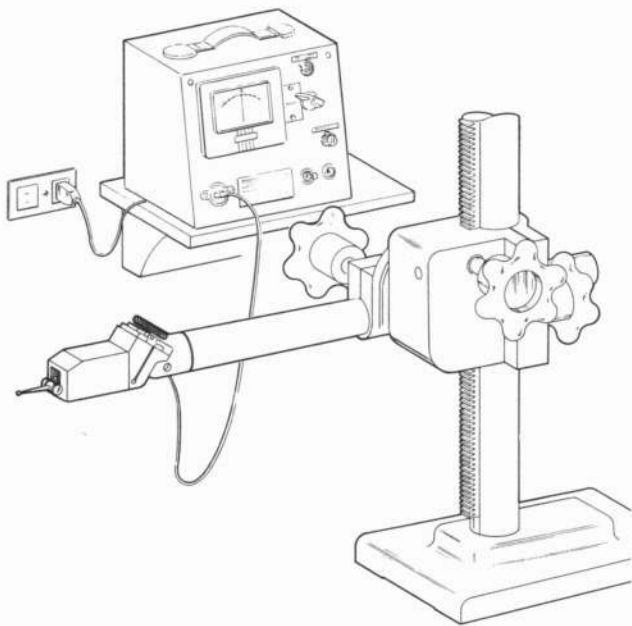


Fig. 3-6. Electronic indicating gauge.

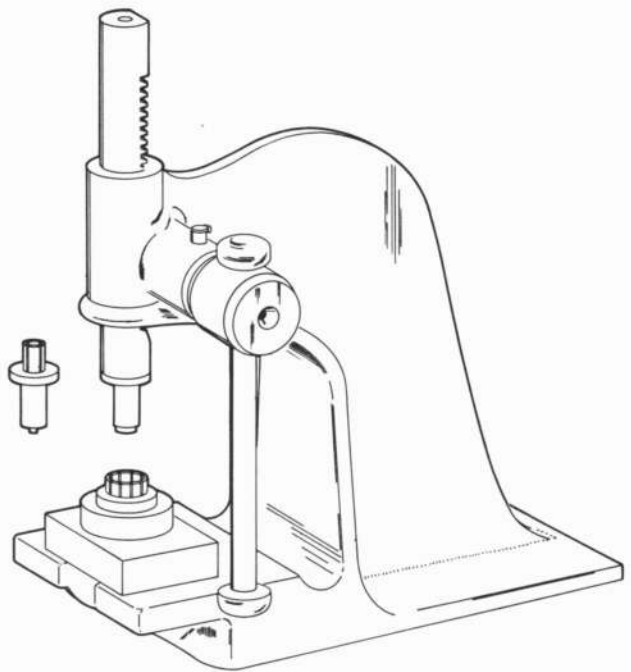


Fig. 3-8. Assembly fixture – spin axis bearings and preload spacers into rotor.

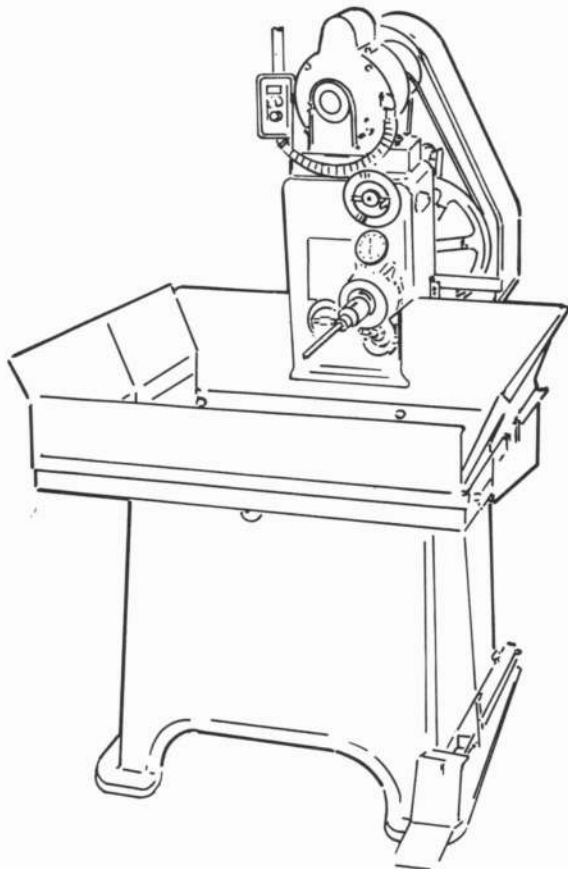


Fig. 3-7. Honing machine.

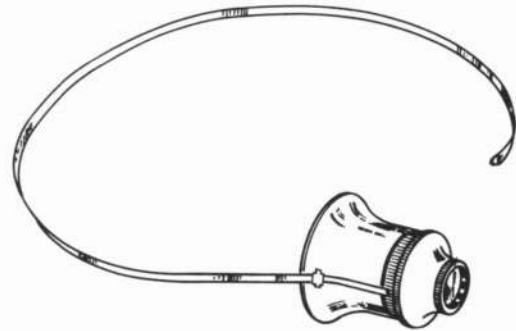


Fig. 3-9. Jeweler's loupe.

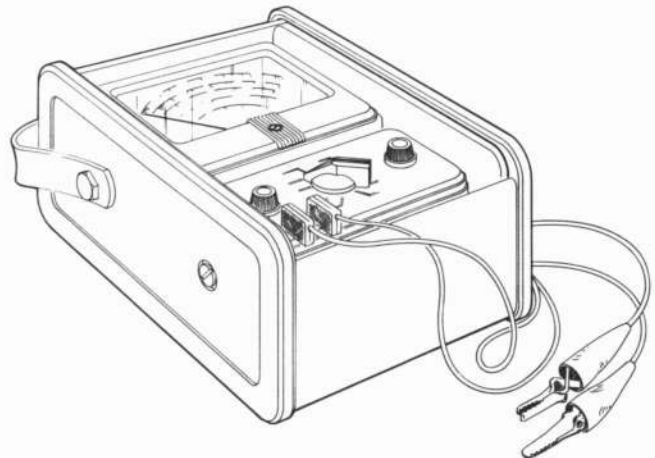


Fig. 3-10. Simpson Multimeter.

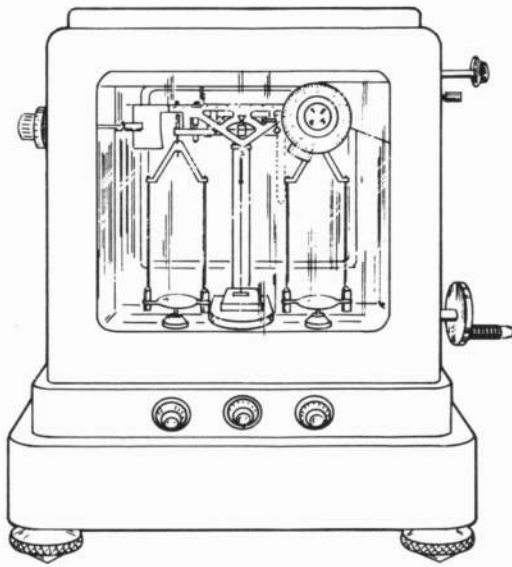


Fig. 3-11. Analytical balance.

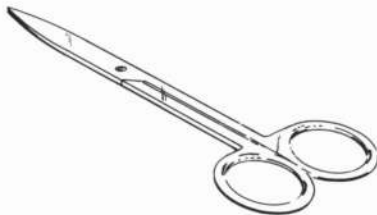


Fig. 3-12. Surgical shears.

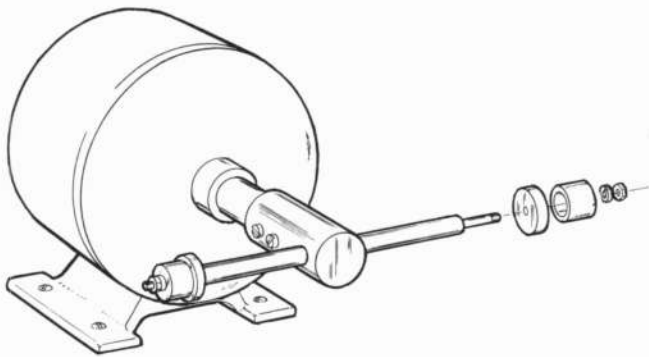


Fig. 3-13. Centrifuge.



Fig. 3-14. Small hole gauges.



Fig. 3-15. Micrometer.

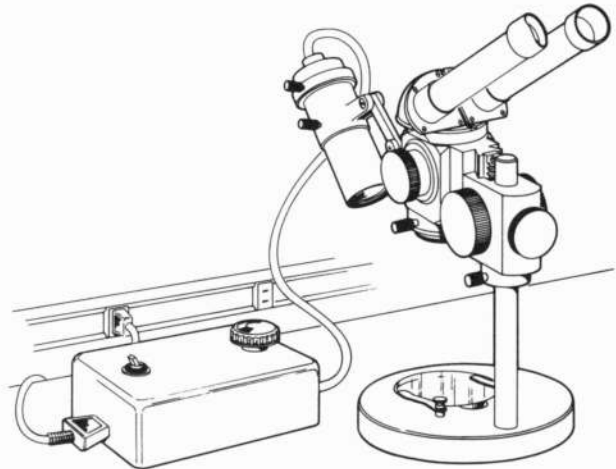


Fig. 3-16. Microscope and light.

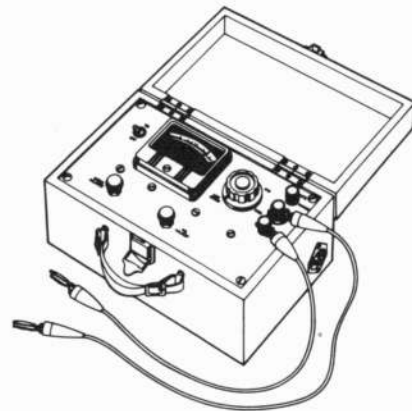


Fig. 3-17. Insulation resistance meter.

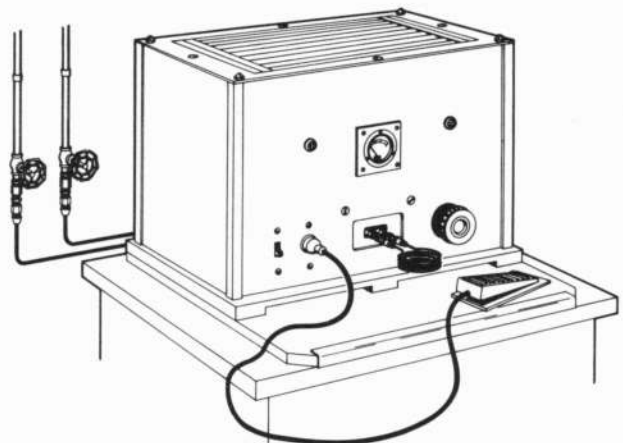


Fig. 3-18. Induction soldering machine (including soldering coils).

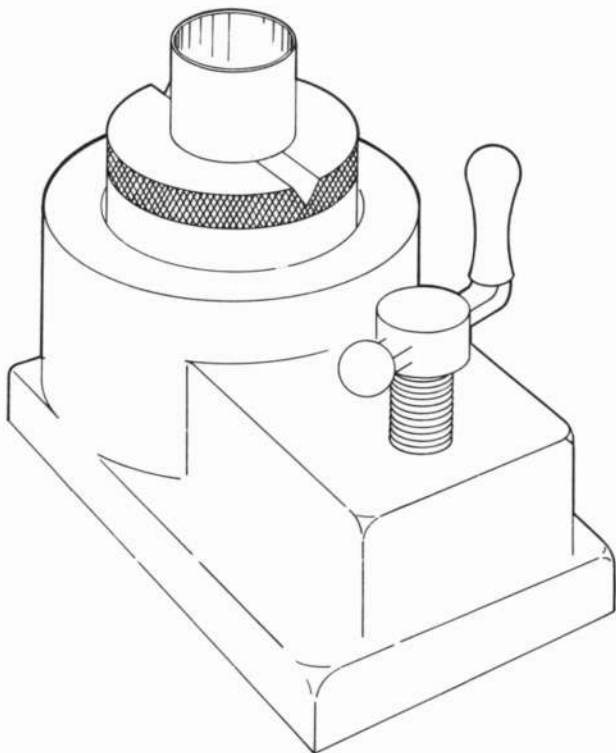


Fig. 3-19. Induction soldering setup.

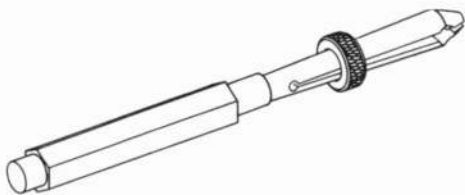


Fig. 3-20. Pivot wrench.

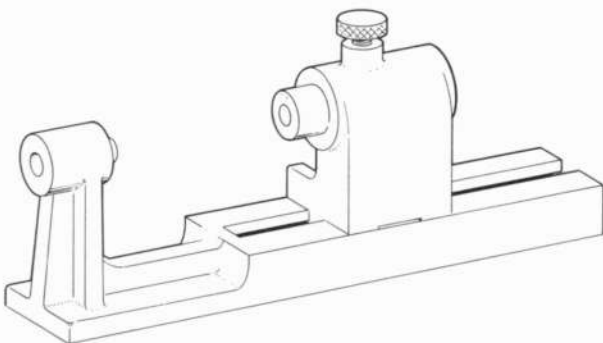


Fig. 3-21. Test fixture for measuring float runout.

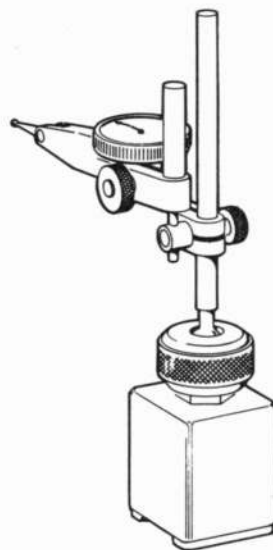


Fig. 3-22. Dial indicator and support.

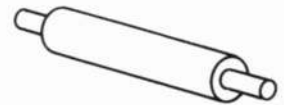


Fig. 3-23. Special poising arbor.

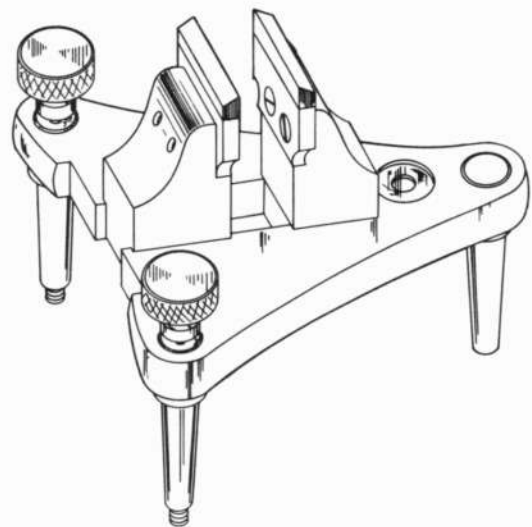


Fig. 3-24. Watch-balance-wheel poising tool.

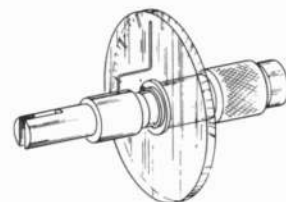


Fig. 3-25. Torque wrench.



Fig. 3-26. Telescoping gauge.

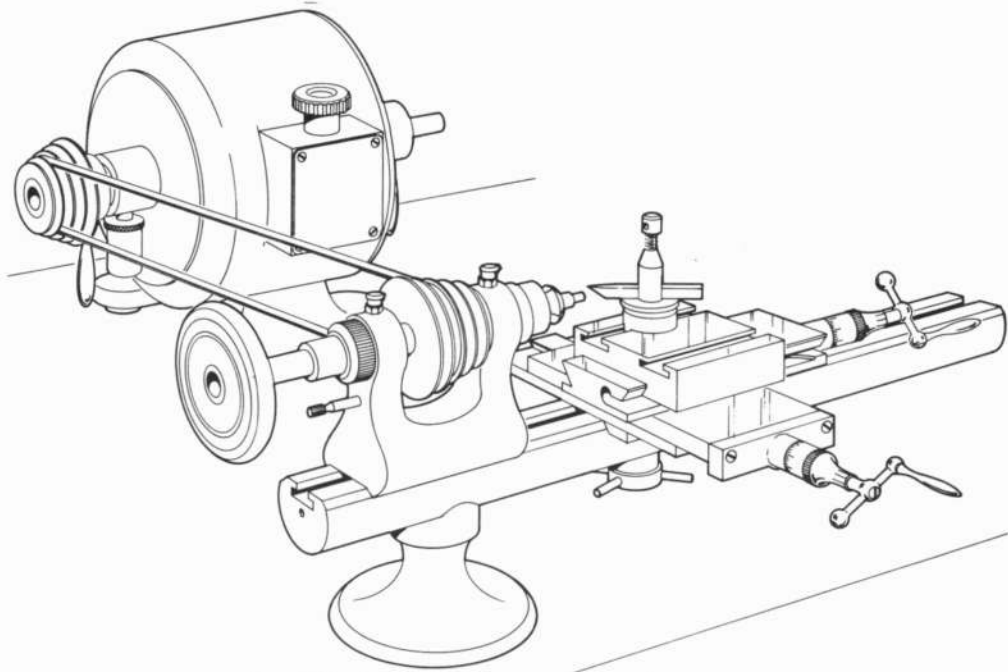


Fig. 3-27. Jeweler's lathe and associated equipment.

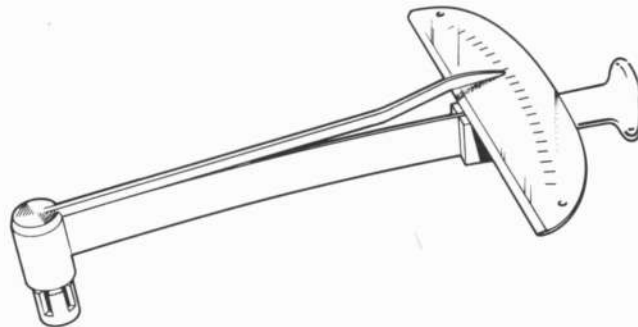


Fig. 3-28. Torque wrench.

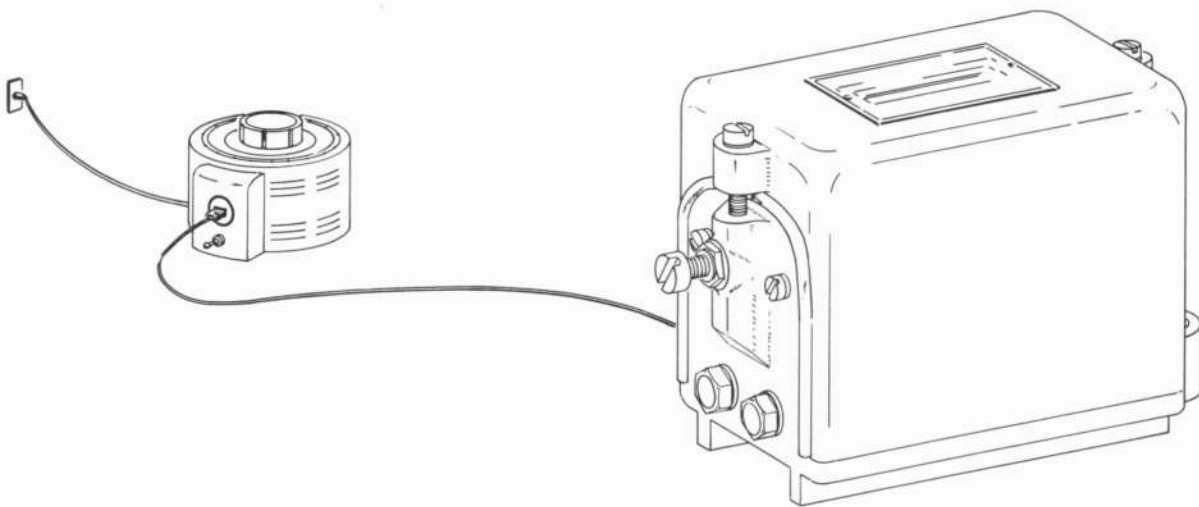


Fig. 3-29. Vibrator.

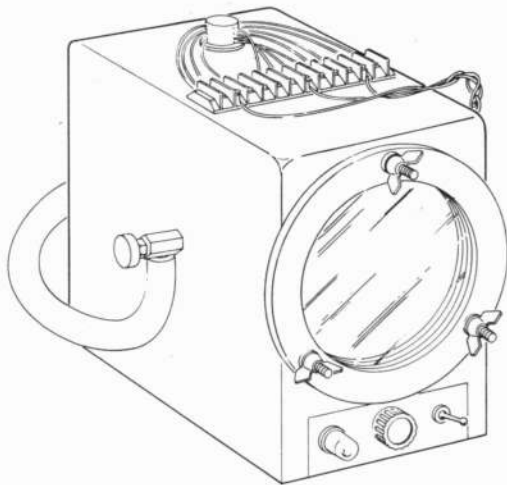


Fig. 3-30. Temperature-controlled oven.

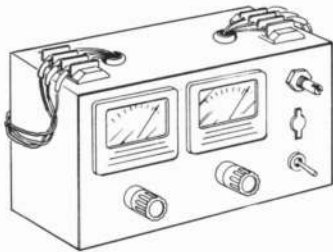


Fig. 3-31. Test console.

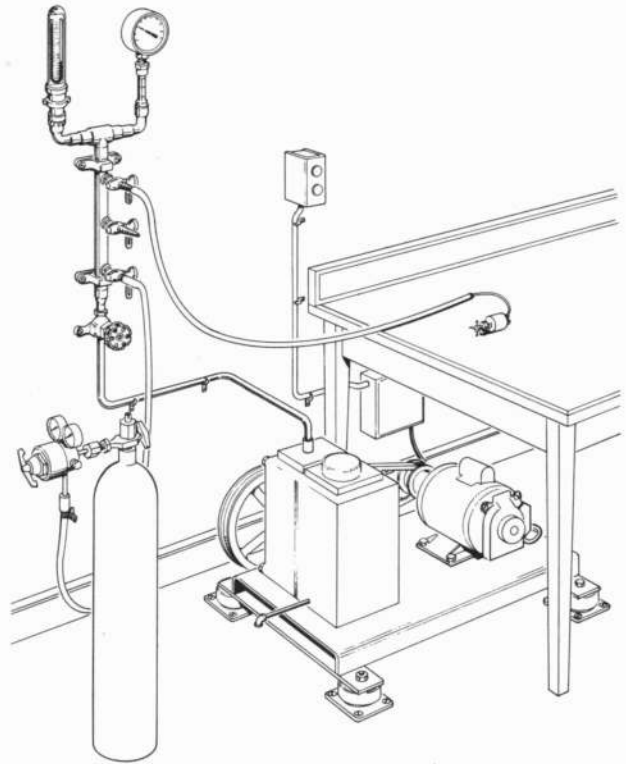


Fig. 3-33. Gimbal shell evacuation and pressurization equipment.

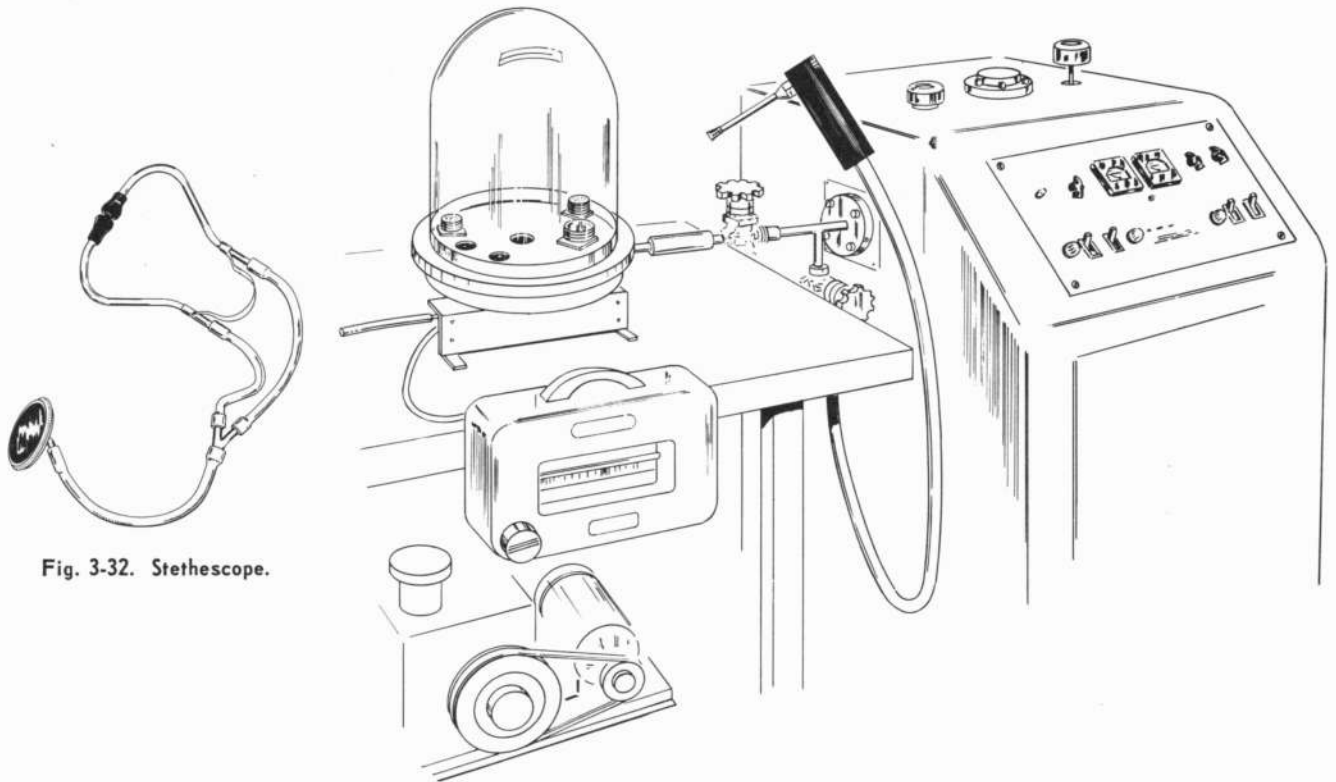


Fig. 3-32. Stethoscope.

Fig. 3-34. Mass spectrometer.

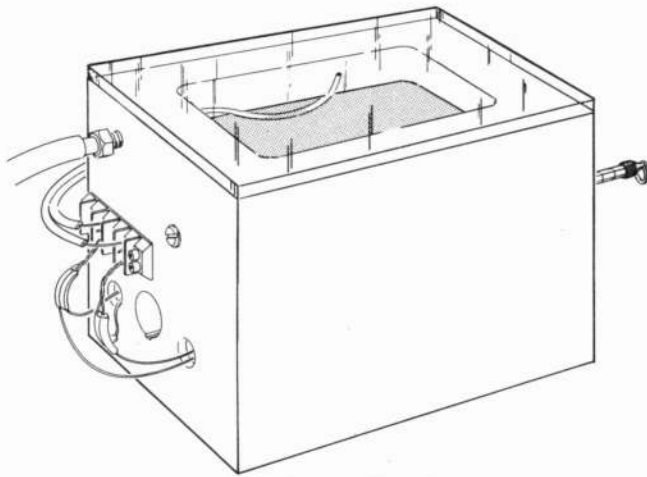


Fig. 3-35. Thermally controlled aluminum tank.

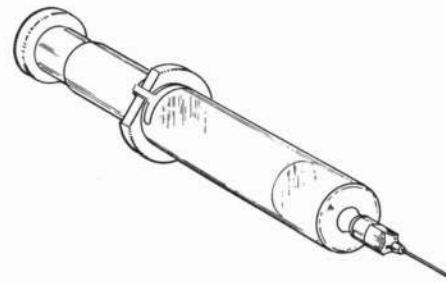


Fig. 3-37. Hypodermic needle.

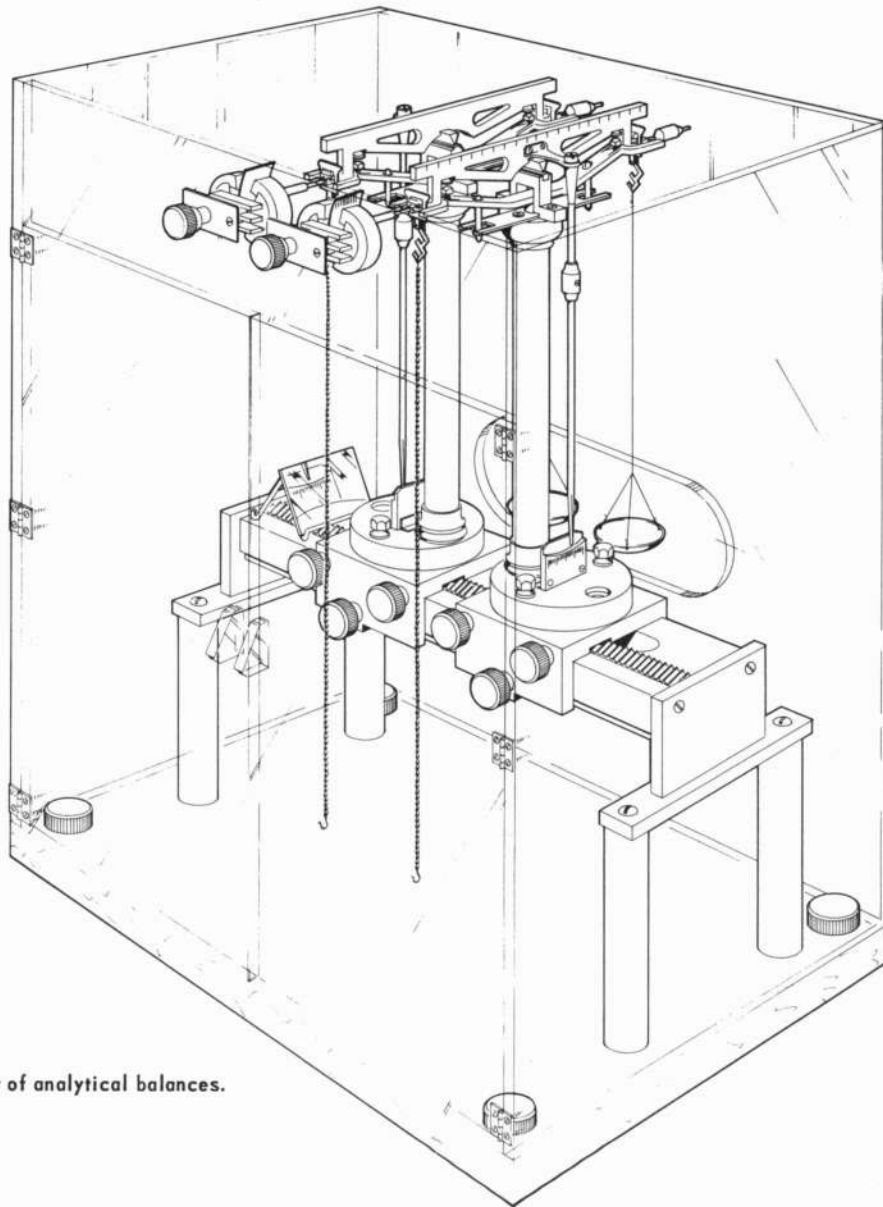


Fig. 3-36. Pair of analytical balances.



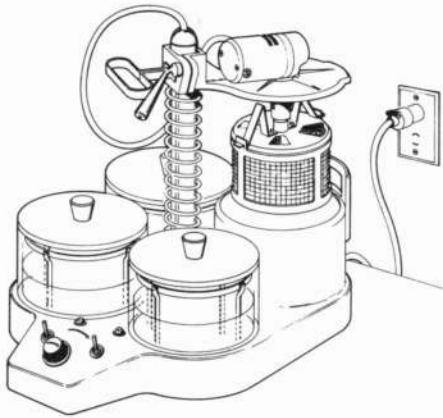


Fig. 3-38. Industrial washing machine.

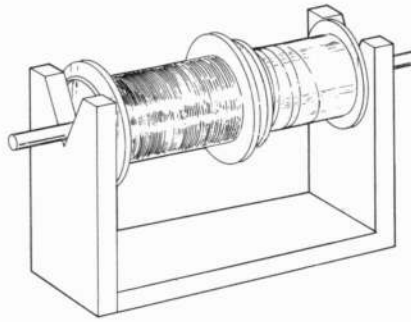


Fig. 3-39. Winding fixture.



Fig. 3-40. Wheatstone bridge.

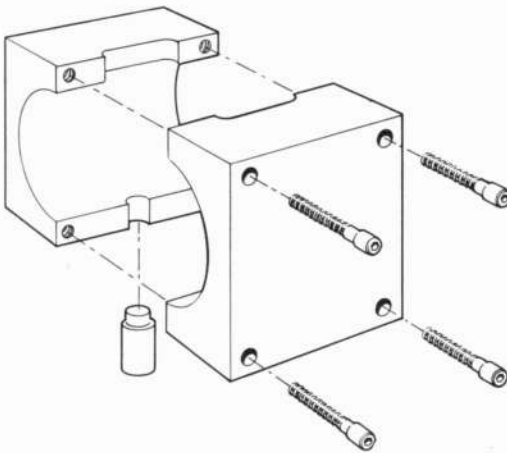


Fig. 3-41. Two-part potting mold.

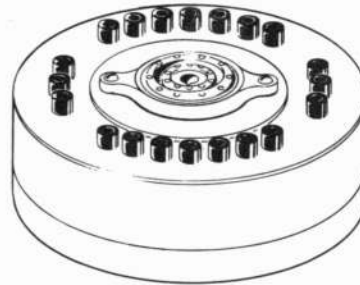


Fig. 3-42. Assembly test stand.

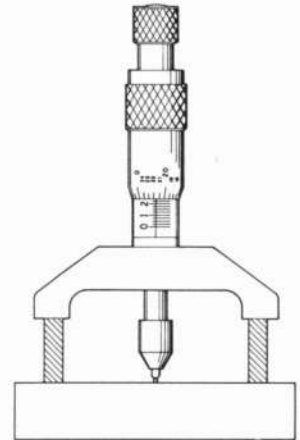


Fig. 3-43. End-shake measuring equipment.

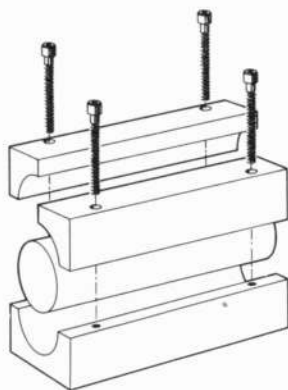


Fig. 3-44. Annealing fixture.

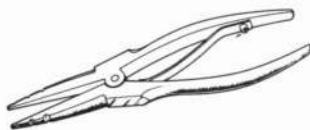


Fig. 3-45. Removing tool.

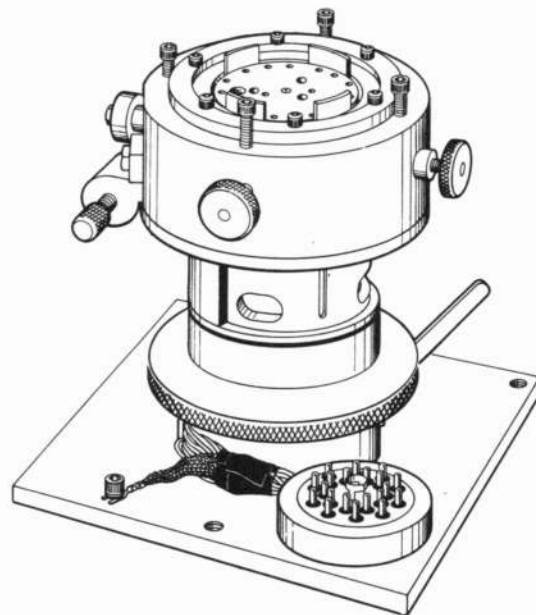


Fig. 3-46. Microsyn centering fixture.

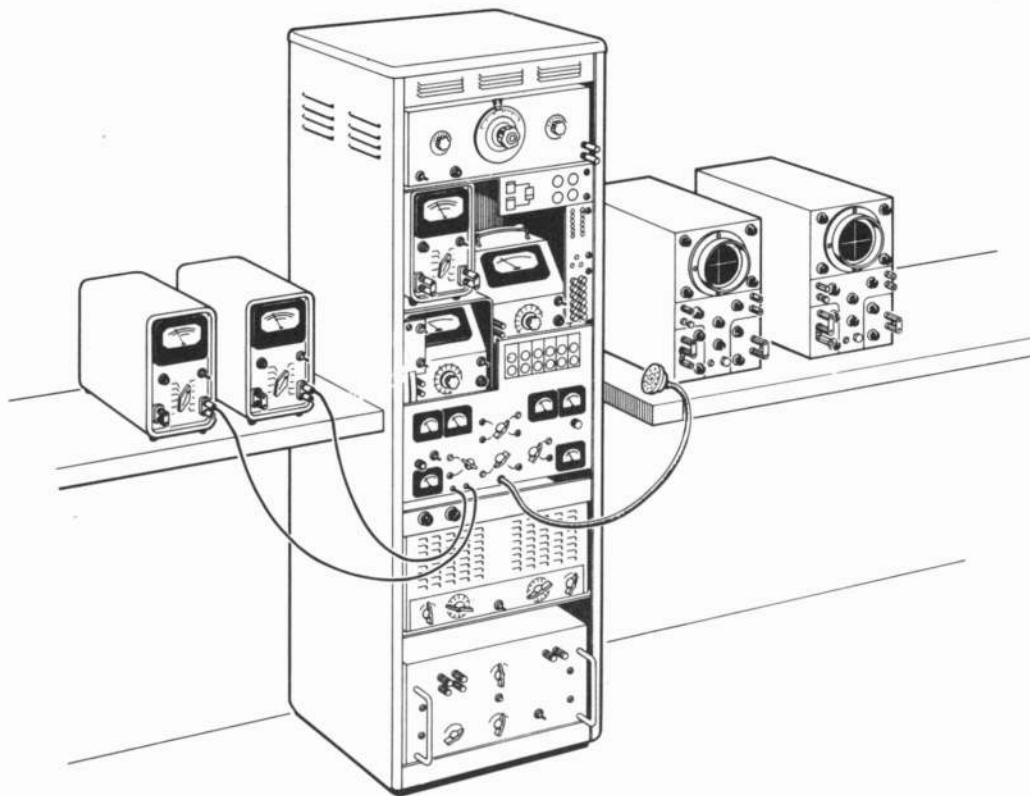


Fig. 3-47. Test console and associated equipment.

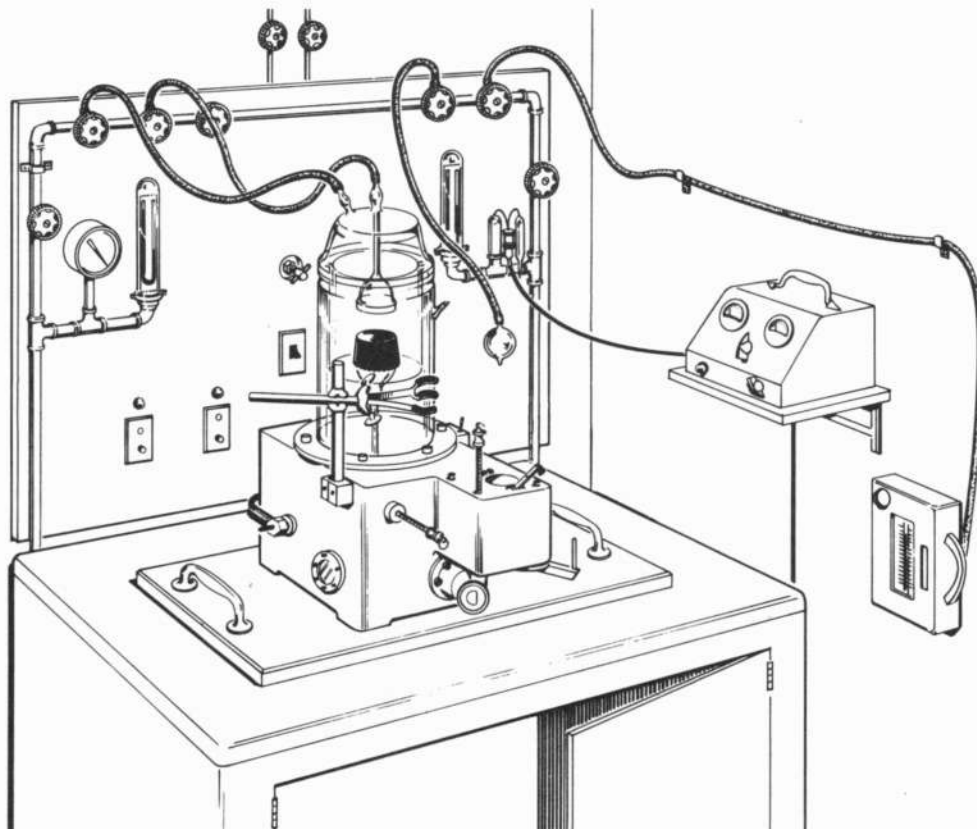


Fig. 3-48. Filling equipment.

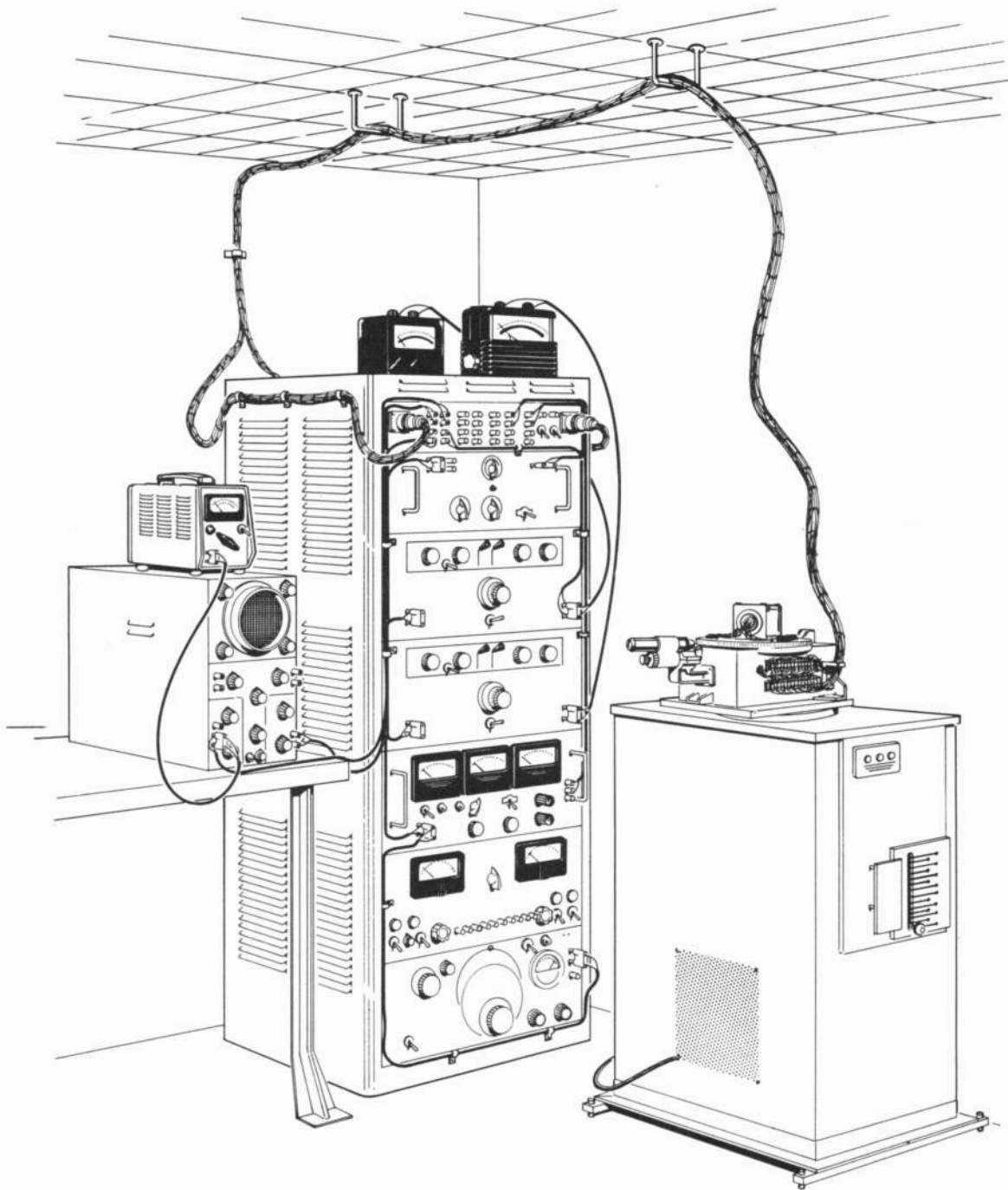


Fig. 3-49. Basic test setup.

## SECTION IV

# COMPONENT ASSEMBLY

### 4-1. INTRODUCTION.

4-2. The M.I.T. 20IG Integrating Gyro Unit is a precision-built indicating instrument, and the manufacture of the individual gyro unit parts entails close machining tolerances, high-quality surface finishes, and a high degree of concentricity and squareness in order to achieve an over-all accurate assembly. The expected degree of accuracy is improved if the tools used and gyro unit parts required are kept clean, for the presence of dirt or foreign matter increases the friction level of movable parts to a great extent. To this end, the cleanliness of the gyro assembly areas and assembly personnel play an important part. Use of plastic-covered boxes (ref. Fig. 3-1) with individual sections to package the parts has been found to be an effective aid in keeping them clean. In addition, the use of the plastic box enables the assembler to readily identify each individual part if appropriate labels are pasted on the box cover over each section. Further means frequently used for keeping parts clean during assembly involve the use of various mechanical devices such as vacuum cleaners, air hoses, watch-washing machines and ultrasonic generators. As the various parts are assembled into completed components, these components are thoroughly cleaned and then packaged in clean plastic bags pending further use in the assembly procedure.

4-3. The following paragraphs of Section IV give the detailed procedures for assembling the various major components of the 20IG Integrating Gyro Unit, which are described in Section II. These procedures are covered under four major headings:

- a. Motor assembly (ref. paragraphs 4-5 through 4-40).
- b. Microsyn units (ref. paragraphs 4-41 through 4-50).
- c. Floated units assembly (ref. paragraphs 4-51 through 4-73).

d. Housing assemblies and associated components (ref. paragraphs 4-74 through 4-101).

4-4. Under these headings, the assembly of each component concerned is described to the full extent required for satisfactory performance of this operation by qualified personnel. Appropriate explanations as to the reasons for the various steps are given where they are of value. No attempt at theoretical analysis is made in the explanations, however, as such information is adequately covered elsewhere (ref. paragraph 1-6). The assembly procedures follow those outlined in the Assembly Record Book, which is used to keep track of the work done on each gyro unit during its assembly. A separate record book is used for each gyro unit being assembled and is identified by the serial number assigned to the particular gyro unit to which it applies. The Assembly Record Book and its use are described in Appendix A.

#### Note

*This handbook does not concern itself with the manufacture or procurement of the individual parts used in the assembly. This is because, aside from various preassembly inspection checks specifically noted, the personnel performing the assembly need have no detailed knowledge of the manufacturing details involved. These personnel should be alert, however, to spot and discard any parts that are obviously defective.*

4-5. MOTOR ASSEMBLY (see Figs. 2-16 and 4-1).

4-6. PROCEDURE FOR ASSEMBLING THE MOTOR ASSEMBLY. The procedure for assembling the motor assembly follows that outlined in the Assembly Record Book (ref. Appendix A). Briefly, the basic steps of the procedure, which are covered in detail in the ensuing paragraphs, are as follows:

- a. Assembling the hysteresis ring, bushing, and rotor (ref. paragraphs 4-7 through 4-11).
- b. Balancing the rotor and associated parts (ref. paragraphs 4-12 through 4-17).
- c. Selecting the spin-axis bearings and the motor shaft (ref. paragraphs 4-18 through 4-31).

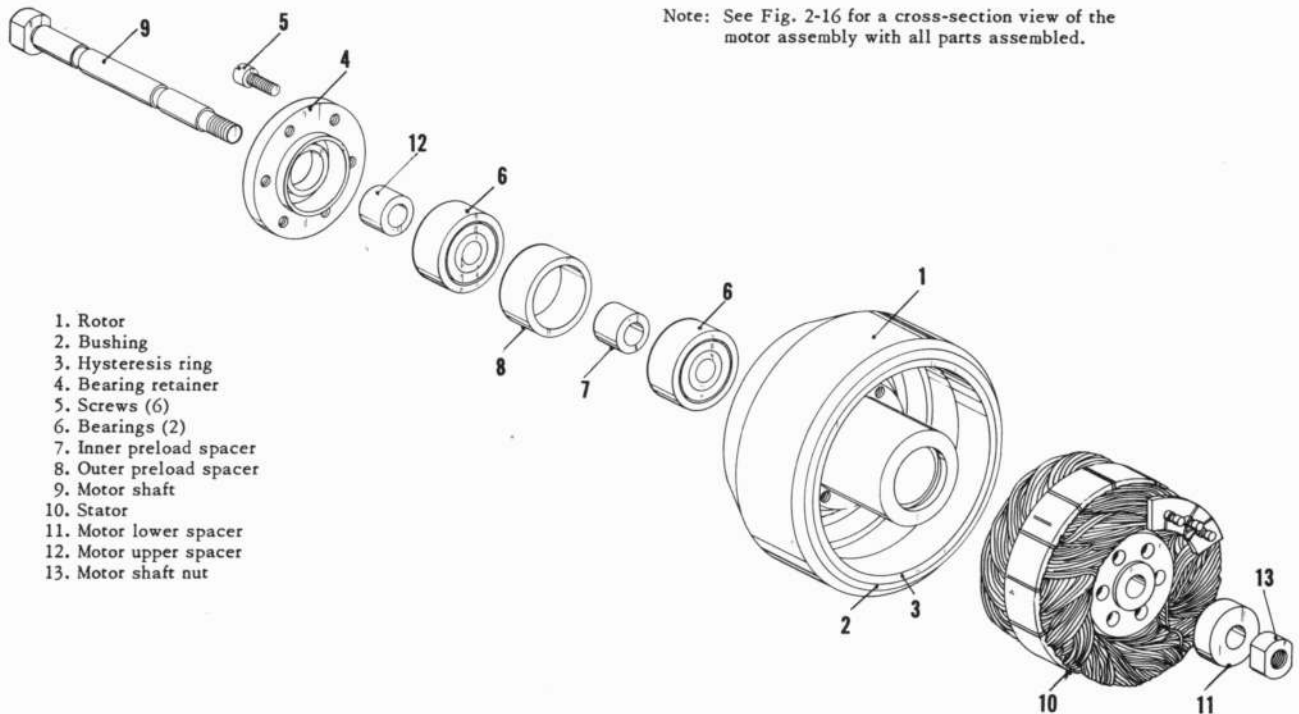


Fig. 4-1. Exploded view of the motor assembly.

d. Assembling the spin-axis bearings and the preload spacers (ref. paragraphs 4-32 and 4-33).

e. Assembling the bearing retainer (ref. paragraph 4-34).

f. Checking the motor stator (ref. paragraphs 4-35 through 4-38).

g. Checking the motor spacers and the motor shaft nut (ref. paragraph 4-39).

h. Packaging the motor assembly components prior to further use (ref. paragraph 4-40).

4-7. ASSEMBLING THE HYSTERESIS RING, BUSHING, AND ROTOR. Figures 4-2 through 4-4 give detailed dimensions of the rotor, bushing, and hysteresis ring used in a typical motor assembly of a 20IG unit. In addition to satisfying the tolerances noted on these figures, the parts as received for assembly satisfy concentricity requirements as follows:

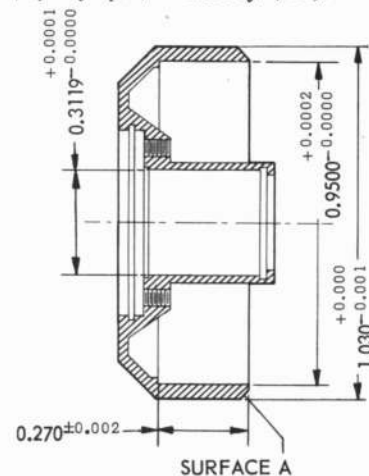
a. The dimensioned diameters shown for the rotor in Fig. 4-2 are concentric within 0.0002 inch total indicator reading, and all other diameters are concentric within 0.001 inch total indicator reading.

b. The dimensioned diameters shown for the bushing in Fig. 4-3 are concentric within 0.0002 inch total indicator reading.

c. The dimensioned diameters shown for the hysteresis ring in Fig. 4-4 are concentric within 0.0005 inch total indicator reading.

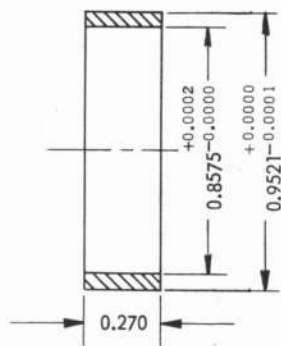
Note

The total indicator readings are made before the machined pieces are removed from the lathe. The dial indicator used to obtain the readings is of the type used to check the floated units assembly run-out (ref. paragraph 4-58 and Fig. 4-29).



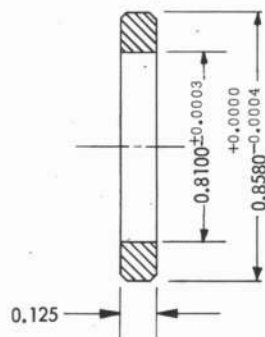
- Notes: 1. All dimensions are in inches.  
2. The high point of eccentricity between the 0.3119-inch and 0.9500-inch diameters is marked with a scribe mark on surface A of each rotor, as received for assembly.

Fig. 4-2. Cross-section view of a typical rotor.



- Notes: 1. All dimensions are in inches.  
2. The high point of eccentricity between the inside and outside diameters is marked on both faces of each bushing, as received for assembly.

Fig. 4-3. Cross-section view of a typical bushing.



Note: All dimensions are in inches.

Fig. 4-4. Cross-section view of the hysteresis ring.

4-8. These close tolerances are required for acceptable balance characteristics of the rotating parts of the motor assembly. The high point of eccentricity between the 0.3119-inch and 0.9500-inch diameters of each rotor as received for assembly is marked with a scribe on surface A (ref. Fig. 4-2). The high point of eccentricity between the inside and outside diameters of each bushing is similarly marked on both its faces. By locating these scribe marks 180 degrees apart when assembling a rotor and bushing, any residual unbalance is minimized.

4-9. Figures 4-5 and 4-6 illustrate the method used for inserting the hysteresis ring inside the bushing and the resulting bushing-and-ring assembly inside the rotor.

4-10. The detailed procedure for inserting the hysteresis ring inside the bushing is as follows:

a. Place the bushing on an appropriate-size heating pad as shown in Fig. 4-5 and heat it to a

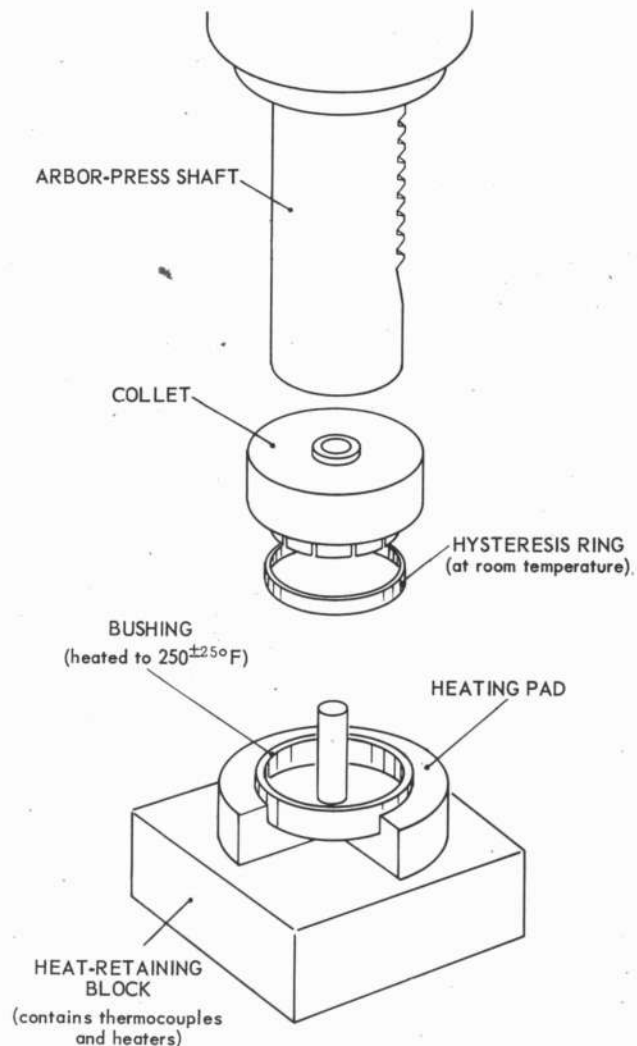


Fig. 4-5. Exploded view showing the method for inserting the hysteresis ring inside the bushing.

temperature of approximately 250° F by means of a heat-retaining block. This causes the bushing to expand radially to the extent that the hysteresis ring (which is at room temperature) can be inserted.

b. Mount the hysteresis ring and an appropriate-size collet on the shaft of an arbor press in the relative positions indicated by Fig. 4-5. Either face of the hysteresis ring may be placed next to the collet.

c. Push-fit the hysteresis ring inside the bushing by operating the arbor press.

**Note**

*Check that the hysteresis ring rests squarely against the shoulder on the collet before attempting to push the ring inside the bushing. Otherwise, the ring will not seat squarely in the bushing.*

d. Elevate the arbor-press shaft and collet, raising the bushing-and-ring assembly with it.

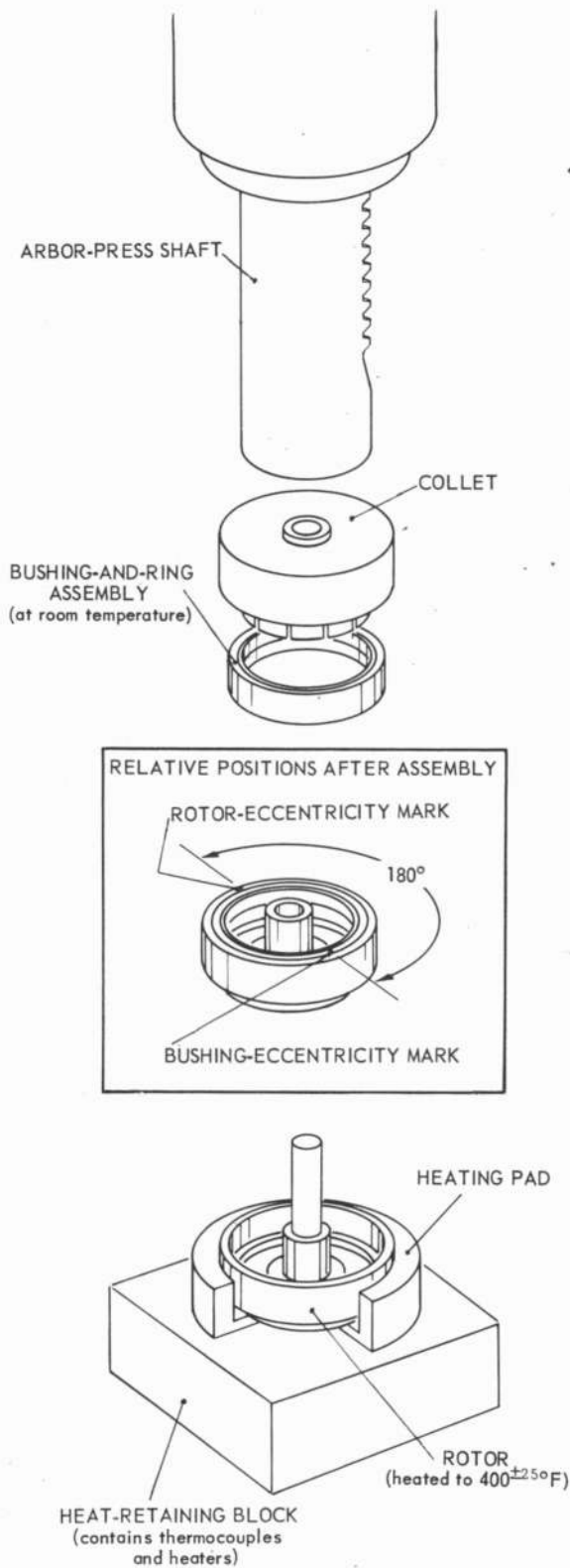


Fig. 4-6. Exploded view showing the method for inserting the bushing-and-ring assembly inside the rotor.

4-11. The detailed procedure for inserting the bushing-and-ring assembly in the rotor is as follows:

a. Place the rotor on an appropriate-size heating pad as shown in Fig. 4-6 and heat it to a temperature of approximately  $400^\circ\text{F}$  by means of the same heat-retaining block used to heat the bushing.

b. Position the bushing-and-ring assembly (which is still mounted on the collet on the arbor-press shaft) with respect to the rotor so that the eccentricity markings (one on the bushing, the other on the rotor) are 180 degrees apart (ref. insert on Fig. 4-6).

c. Push-fit the bushing-and-ring assembly inside the rotor with the arbor press so that bushing sets flush against the shoulder in the rotor.

d. Elevate the arbor-press shaft and allow the assembled parts to cool before removing them from the collet.

e. When cool, place the assembled rotor, bushing, and hysteresis ring in a clean plastic bag and leave them there until further required in the assembly procedure (ref. paragraph 4-16).

#### 4-12. BALANCING THE ROTOR AND ASSOCIATED PARTS.

##### Note

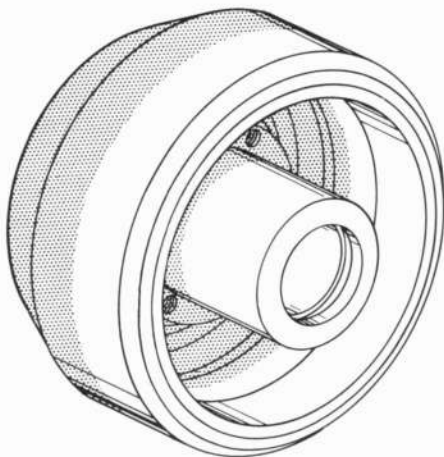
*For convenience in the following discussion, the rotating part of the motor assembly - which is comprised of the rotor, the bushing, the hysteresis ring, the bearing retainer, and the six screws that secure it to the rotor - are referred to collectively as the rotor assembly.*

Each rotor assembly must be balanced in order that it run smoothly and efficiently at its operating speed. Centrifugal forces acting on the assembly - that is, the forces that act radially from the motor shaft - are proportional to the square of the angular velocity. Therefore, at its high operational speed of rotation (8000 revolutions per minute), a small amount of unbalance in the rotor assembly will cause vibratory forces within the gyro unit. The balancing of the rotor assembly is therefore completed before further assembling of the motor assembly takes place.

4-13. There are two types of rotor assembly unbalance:

- a. Static unbalance.
- b. Dynamic unbalance.

A rotor assembly is unbalanced statically if the force of gravity will cause it to revolve when it is set in any position on a level surface. Static balance can be readily obtained by removing weight from the heavy regions until the rotor assembly has no tendency to revolve due to the force of gravity. Even though a rotor assembly may be balanced statically, however, it may still be unbalanced dynamically – that is, when the assembly is rotating. This is because each part of the rotor assembly tends to act independently during rotation. As a general rule, the unbalance in one half of the rotor assembly (ref. Fig. 4-7) differs in amount and angular position from the unbalance in the other half. Dynamic balance of the rotor assembly is obtained by appropriate removal of weight from the heavy region on each side of the rotor assembly.



As a general rule, the unbalance in the half of the rotor assembly that is shown shaded differs in amount and angular position from the unbalance in the other half, even though the assembly may be balanced statically. This feature results in dynamic unbalance of the rotor assembly.

Fig. 4-7. Characteristic feature of unbalance in the rotor assembly.

4-14. Balancing a rotor assembly dynamically requires the use of a specially designed electronic device, such as the Annis Dynograph Balancer, made by the R. B. Annis Company of Indianapolis, Indiana. This device, shown set up for the dynamic balancing operation in Fig. 4-8, allows both the amount and angular position of any unbalance in either half of the rotor assembly to be determined. Refer to the manufacturer's instructions for a generalized description of its operation.

4-15. The procedure for balancing the rotor assembly requires the use of the special stainless-steel balancing arbor shown in Fig. 4-9, one of which is furnished with the Dynograph Balancer. This arbor is used to mount the rotor assembly on the Dynograph Balancer. The cylindrical surfaces of the arbor are made to be concentric within very close tolerances in order not to contribute any additional unbalance.

4-16. The detailed procedure for balancing the rotor assembly is as follows:

a. Finger-push-fit the special arbor inside the rotor of the assembled rotor, bushing, and hysteresis ring (ref. paragraph 4-11e) and seat it against the shoulder in the rotor bore as shown in Fig. 4-9.

b. Fasten the bearing retainer (4, Fig. 4-1) to the rotor with the six screws (5). These are No. 00-96, 3/32-inch long, stainless steel, fillister-head machine screws.

c. Make a phasing mark on the bearing retainer side of the gyro rotor by means of vapor blast or etching.

d. Remove the belt from the belt rest on the Dynograph Balancer (ref. Fig. 4-8) and slip the rotor assembly – balancing arbor combination underneath the belt.

e. Place the shafts of the balancing arbor in the vibrator bearings – which are fixed to the nodal bar – so that the bearing retainer side of the rotor assembly is nearest the photoelectric scanning head.

*Note*

*Be sure the vibrator bearings are lubricated, but only sparingly.*

f. Start the motor drive by depressing the foot switch.

g. Switch on the cathode-ray-tube circuits and adjust the controls until a trace of the shape shown in the blowup on Fig. 4-8 is obtained.

h. Turn the MASTER GAIN switch to the stop position on the right-hand side (position 4). In this position, the height of the unbalance trace is a maximum.

i. Increase the width of the phasing pip (the horizontal pip on the cathode-ray tube), if necessary, by turning the PHASING PIP control in a clockwise direction.



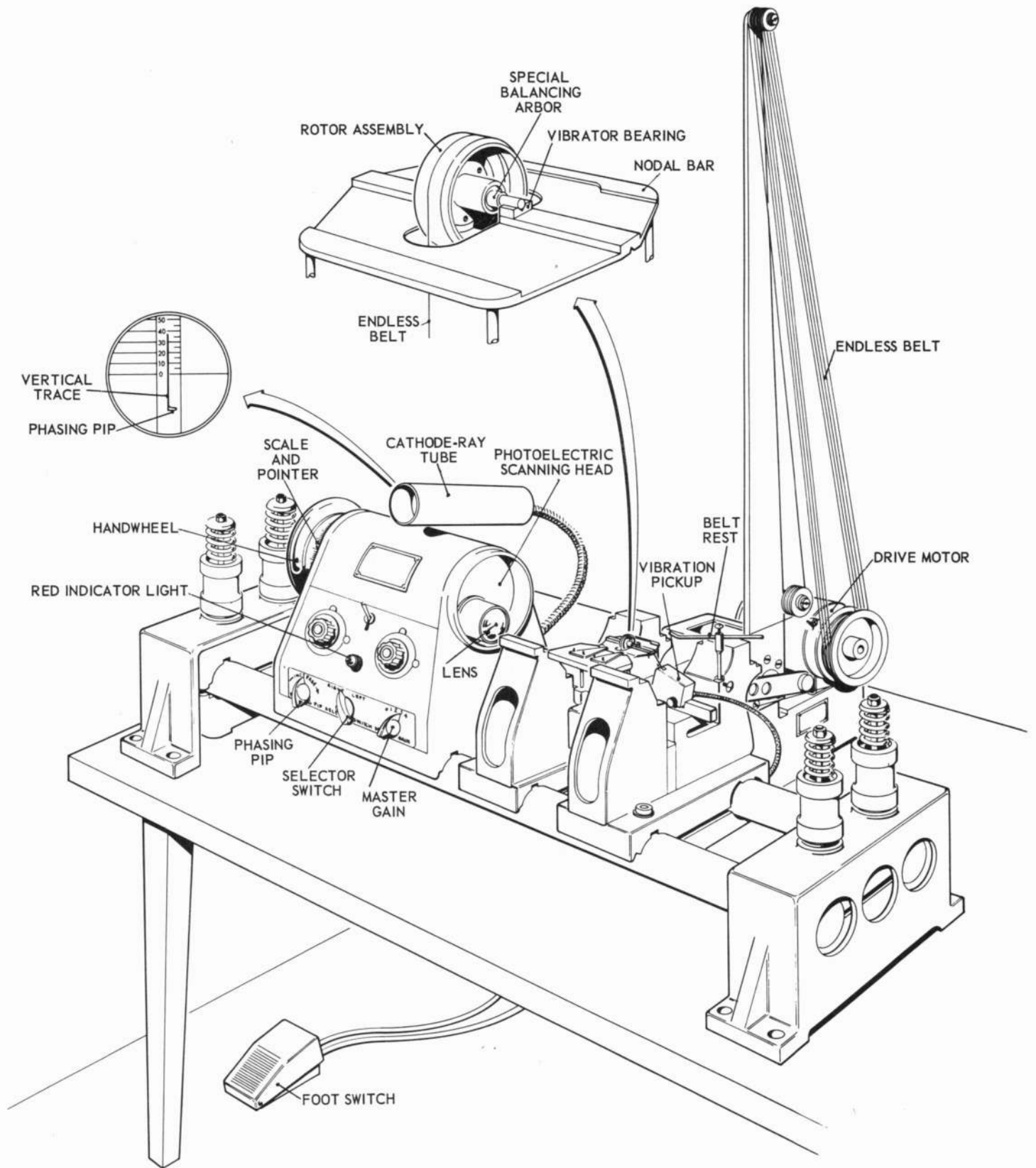


Fig. 4-8. Pictorial view of the Annis Dynograph Balancer, set up to obtain the dynamic balancing of the rotor assembly.

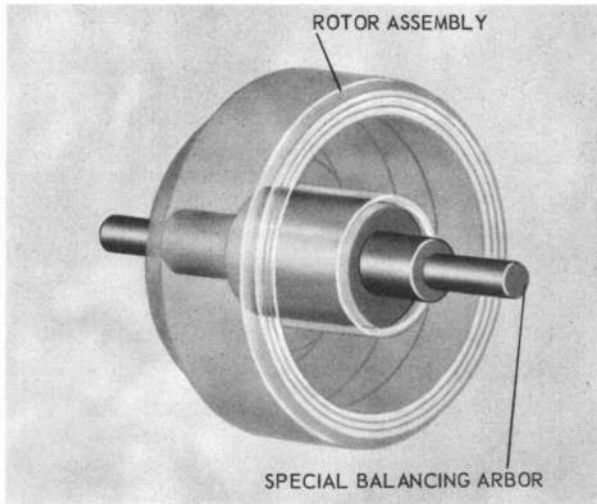


Fig. 4-9. Pictorial view showing the special balancing arbor inserted in the rotor assembly.

j. Move the **SELECTOR SWITCH** to the **RIGHT** or **LEFT** position in accordance with the side of the rotor assembly (viewed from the front of the Dynograph Balancer) for which unbalance is to be obtained.

*Note*

*As shown in Fig. 4-8, the unbalance of the right-hand side of the rotor assembly is being obtained. To obtain the unbalance of the left-hand side, move the selector switch clockwise, so that it indicates LEFT.*

k. Using the handwheel, rotate the scanning head until the phasing pip is at the bottom of the vertical trace.

l. Stop the motor by depressing the foot switch.

m. Read the angle on the scale underneath the pointer by the handwheel. This angle indicates that the position of heaviness is at the observed angle, measured counterclockwise from the phasing mark as a reference.

n. Place some Tackiwax 180 degrees from the heavy spot on the right-hand side of the rotor assembly in order to compensate for the unbalance.

o. Restart the motor, and observe the length of the vertical trace. Vary the amount of Tackiwax until the vertical trace is as small as possible.

p. Turn the selector switch clockwise to the **LEFT** position and view the vertical trace. If the left-hand side of the rotor is unbalanced, locate the angular position of the heavy spot by the procedure of steps k through m.

q. Remedy the unbalance by applying the procedure of steps n and o.

r. Turn the selector switch to the **RIGHT** position again and observe if any difference in the length of the vertical trace occurred after the right-hand side was balanced. If necessary, repeat the right-hand and left-hand balancing procedures until the lengths of the two vertical traces are made equal and as small as possible.

s. When the objective of step r has been achieved, remove weight from the heavy spots of the rotor assembly (180 degrees from the Tackiwax) as follows. Remove weight from the outer edge of the bearing retainer if the left-hand side of the rotor assembly is heavy in any region. Remove weight from the outer edge of the rotor on the right-hand side if this side is heavy. Remove only a little weight at a time, and check the balance frequently by steps k through r in order not to remove too much weight. It is advisable to remove the weight by using a small file.

4-17. Upon completion of the dynamic balancing procedure, remove the bearing retainer from the rotor assembly. Then place the rotor-bushing-ring assembly, the bearing retainer, and the six screws in a clean plastic bag until further required in the assembly procedure (ref. paragraph 4-21a).

4-18. **SELECTING THE SPIN-AXIS BEARINGS AND THE MOTOR SHAFT.** The two spin-axis bearings (6, Fig. 4-1) and the associated preload spacers (7 and 8) support the rotor assembly on the motor shaft (9) and minimize any shift of the rotor assembly's center of gravity along the spin axis. The bearings used are of a type known as "rad-angular contact bearings." The typical features of these bearings are shown by Fig. 4-10. Also shown are the design features of the preload spacers. The inner preload spacer has a smaller width than the outer preload spacer, so that when pressure is applied to the inner races by subsequent tightening of the motor shaft nut (13, Fig. 4-1) the bearing-contact pattern shown in Fig. 4-10 is obtained. This feature is used to preload the bearings (ref. paragraphs 4-62 through 4-68), an operation that causes the rotor assembly to have a very tight mechanical coupling to the motor shaft as far as translational motion parallel to the shaft

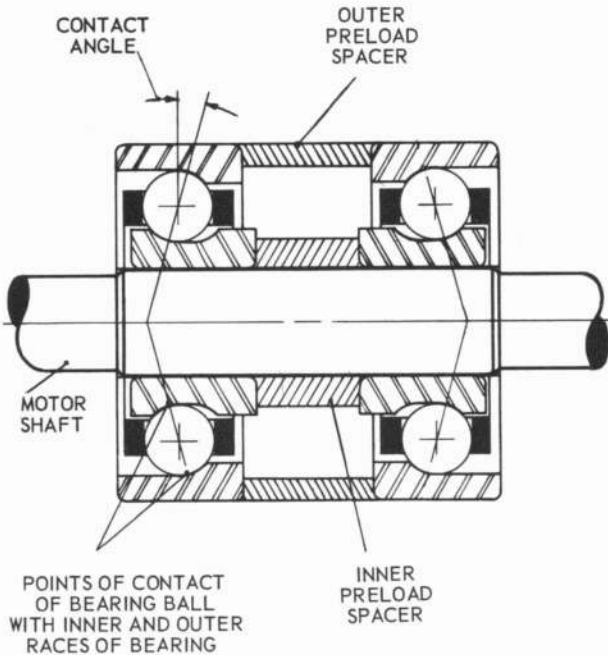


Fig. 4-10. Typical features of the spin-axis bearings and the associated preload spacers.

is concerned. This is essential for precise control of the center-of-gravity position of the rotor assembly, which is required for rotational balance of the floated units assembly (ref. paragraphs 4-51 through 4-73).

4-19. The bearings and spacers are supplied by the Barden Corporation of Danbury, Connecticut. They come in sets, with two bearings plus an inner and an outer spacer to a set. Each set is hermetically sealed in an individual package. Printed on the package is a code designation by means of which the dimensional characteristics of the bearings may be determined. In addition, there are instructions as to the manner in which the parts should be placed with respect to one another in assembly.

4-20. The two bearings in each packaged set are identical. In order to allow for variations in motor shaft diameters and the bore diameters of different rotor assemblies, a range of bearing sizes is provided. The particular size of the bearings in each package is indicated by the code designation on the outside of the package. In each instance, this code designation will follow one of two forms described in Table 4-1.

Table 4-1. Explanation of code letters and numerals in bearing code designations having either the form C-AB or the form C-1B.\*

<u>Code</u>	<u>Use</u>
When the code letter following the hyphen in a bearing code designation of the form C-AB is	
A	use the bearing with a motor shaft whose bearing-surface diameter (in inches) lies within the range
B	0.09375 to 0.09380
C	0.09370 to 0.09375
D	0.09365 to 0.09370
0.09360 to 0.09365	
<u>Code</u>	<u>Use</u>
When the code numeral following the hyphen in a bearing code designation of the form C-1B is	
1	use the bearing with a motor shaft whose bearing-surface diameter (in inches) lies within the range
2	0.09370 to 0.09380
	0.09360 to 0.09370
<u>Code</u>	<u>Use</u>
When the final code letter in a bearing code designation of the form C-AB or C-1B is	
A	use the bearing with a rotor assembly in which the diameter of the rotor bore (in inches) lies within the range
B	0.31210 to 0.31215
C	0.31205 to 0.31210
D	0.31200 to 0.31205
	0.31195 to 0.31200

\* The first letter in each bearing code designation (it should always be C) is the manufacturer's designation for the particular type of bearing used for the spin-axis bearing in the 20IG unit.

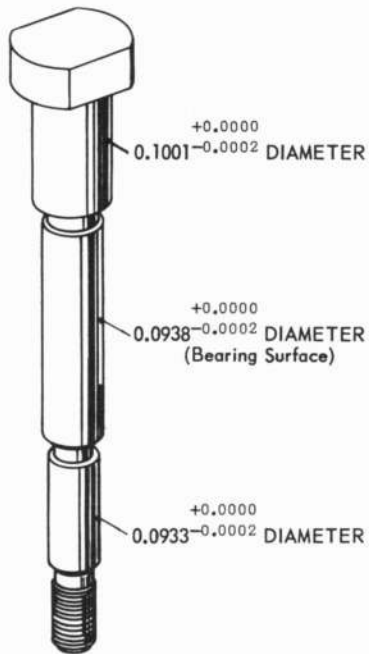
4-21. The appropriate spin-axis bearings and motor shaft to be used with a given rotor assembly are selected by the following detailed procedure:

a. Using an air gage (ref. Fig. 3-5) having 25 millionths of an inch for each scale division, measure the diameter of the rotor bore of the particular rotor assembly concerned (ref. paragraph 4-17), and enter this value in the Assembly Record Book (ref. Appendix A).

b. Applying this information to the bottom code tabulation in Table 4-1, determine the final letter that the code designation of the selected set of bearings must have. (For example, suppose the measured value of the rotor bore to be 0.31198 inch. From the bottom tabulation of Table 4-1, the final letter in the code designation of the selected set of bearings would have to be D. This would narrow the choice of acceptable bearing sets down to those with the code designation C-AD, C-BD, C-CD, C-DD, C-1D or C-2D.)

c. Base the final selection of spin-axis bearings and motor shaft upon the bearing sets and motor shafts in stock. Any combination that satisfies the requirements given in Table 4-1 and step b is acceptable. (For the example noted in step b,

a bearing set identified by either the code designation C-BD or C-1D would be acceptable for use with an available motor shaft whose bearing-surface diameter happened to be 0.09373 inch.) In carrying out this step, measure the diameter of the motor shafts at the bearing surface (ref. Fig. 4-11) with an electronic indicating gage (ref. Fig. 3-6) having a sensitivity of 25 millionths per scale division.



Notes: 1. All dimensions are in inches.  
2. All diameters of each motor shaft, as received for assembly, are concentric within 0.0002 inch total indicator reading.

Fig. 4-11. Dimensional details of the motor shaft.

d. Record the bearing-surface diameter of the selected motor shaft in the Assembly Record Book, together with the code designation of the selected bearing set.

**Note**

*Ideally, of course, there will always be a sufficient stock of different-sized bearing sets and motor shafts available to allow the foregoing procedure to be applied. If there is not, however, it is permissible to hone a rotor bore (ref. paragraphs 4-22 through 4-31) and/or polish a motor-shaft bearing surface to the required diameters to fit an available bearing set. Should either, or both, of these steps be necessary, the modified bearing-surface diameter and/or rotor-bore diameter must be recorded in the Assembly Record Book.*

e. Remove any excess oil from the two selected spin-axis bearings by whirling them in a centrifuge (ref. Fig. 3-13).

4-22. The honing process is a machine operation in which metal surfaces are finished by the application of a gritty substance that removes any tool or machining marks from the work piece. A base metal finish free from heat check and "smear metal" can be produced easily. A particular application of the honing operation is the honing of the rotor bore by an abrasive stone mounted on a rotating mandrel that is part of the honing machine. The over-all result obtained by honing an inside diameter is a truly cylindrical surface that has a precision of 0.0001 inch, with a 4 micro-inch root mean square surface finish on the inside diameter.

4-23. Shown in Fig. 4-12 is the honing machine used in the present operation. While an operator holds the rotor assembly, the rotating honing tool hones the inside diameter of the rotor bore. The drive motor mounted on top of the honing machine is a 1/2 horsepower, single-phase, capacitor-type drive motor having a shaft speed of 1750 rpm. Mounted on the motor shaft and spindle shaft are step pulleys that enable the operator to select spindle speeds of 300, 450, 650 and 850 rpm. In order to shift the belt for varying speeds, the machine operator must swing the wire belt guard back and shift the belt by hand. For honing gyro rotors, a spindle speed of 300 rpm is selected. This gives the slowest stock removal and hence the best control when approaching the final dimension. The spindle is set in motion by stepping on a pedal linked to an idler pulley that swings into contact with the drive belt. The foot pedal also controls the radial advance of the cutting stone.

4-24. Located inside the base of the machine is a 12-gallon-capacity oil reservoir that, when pumped by a small centrifugal pump, provides a steady stream of honing oil for keeping the rotor clean and cool and for assisting the honing action. The pump is belt-driven also from the electric motor. A flexible tubing is connected to the discharge side of the pump and a small jet is connected to the end of the tubing through which the oil stream is directed against the rotor. The honing oil then runs back to the oil reservoir through a hole in the drain pan on the front of the machine. In order to discharge the honing oil, start the electric motor and then wait a few seconds for the oil pressure to build up.

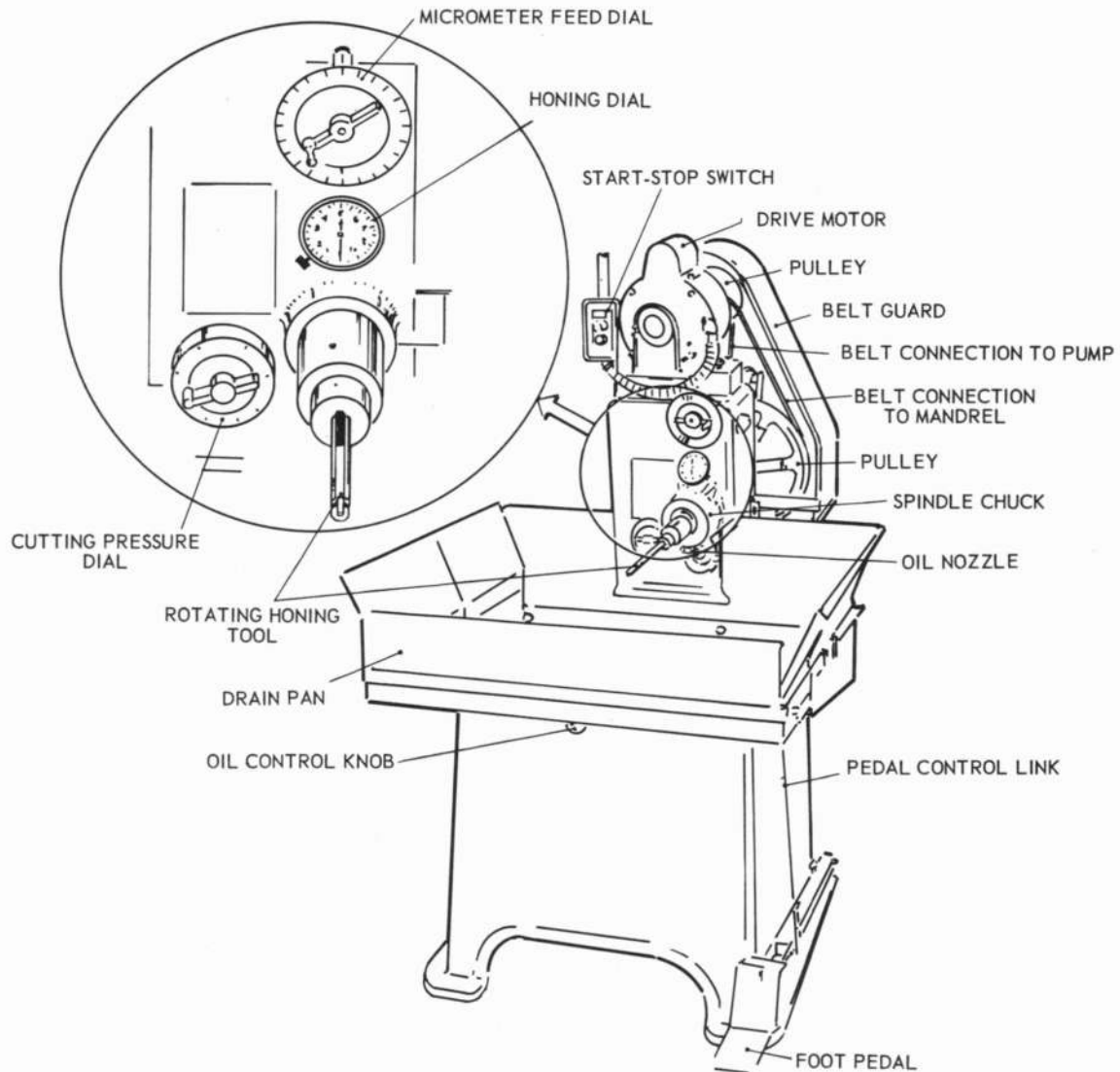


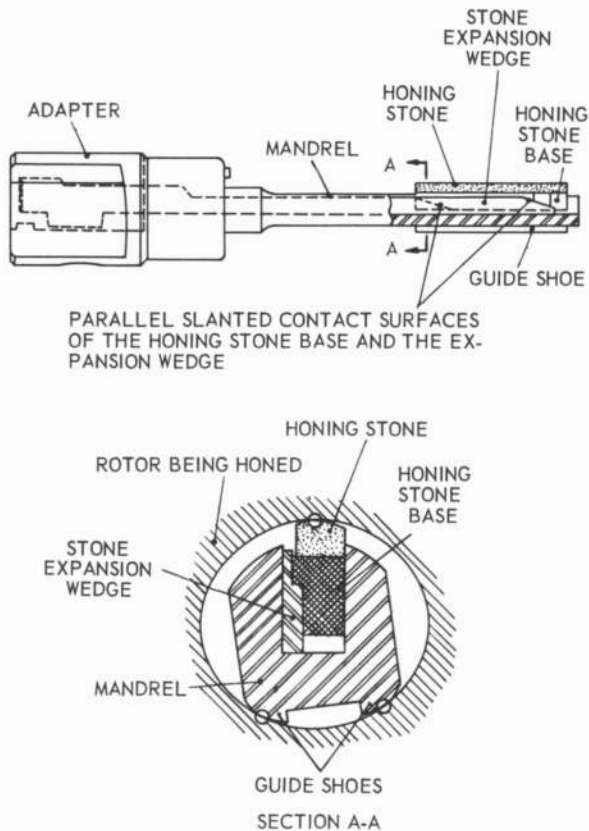
Fig. 4-12. Pictorial view of the honing machine.

Turn the oil control knob counterclockwise to increase oil flow. If the pump does not pick up oil immediately, shut the motor off and jiggle the pump pulley up and down a few times to expel air from the pump impellers. Best honing results are obtained only when a continuous and ample supply of the proper honing oil is used.

4-25. The honing tool, which changes when the work requirements change, consists of a mandrel, adapter, stone expansion wedge, and abrasive stone. These parts are shown in Fig. 4-13. The cutting stone consists of thousands of small abrasive grains bonded together to present a surface of small cutting edges. Particular attention must

be given to stone hardness and grit size for the material to be honed. In general, the harder the metal, the softer should be the stone and vice versa. It must also be determined whether a single honing operation will do the job, or if a roughing operation followed by a finishing operation is necessary to remove the stock and obtain the desired surface finish. It is recommended that coarse grit stones be used for roughing to within 0.0005 inch to 0.001 inch of final size, and then fine stones be employed for finishing.

4-26. The blown-up section in Fig. 4-13 is taken at right angles to the other section. Note the point contacts (encircled) of the stone and the guide



Note: The encircled points represent the point contacts of the honing stone and the two guide shoes with the inner diameter of the rotor that exist at any cross section.

Fig. 4-13. Construction of the honing tool.

shoes with the inside diameter of the rotor. The unequal spacing of the honing stone and the two guides corrects any out-of-roundness that may be present, prevents any pattern from developing, and therefore produces a perfectly round hole. When the rotor is placed over the honing tool, it is self-centered – thus eliminating fixtures and chucking distortions.

4-27. Located on the front of the machine head are a micrometer feed dial, a cutting pressure dial and a honing dial. The feed dial controls the stone feedup, and therefore, the amount of stock that can be removed. The dial is connected to the foot pedal by a linkage. To expand the stone radially, turn the dial clockwise. (The dial is preset with the machine OFF and with the foot pedal depressed to the floor.) When the foot pedal is depressed to a stop position, the stone expands radially, but it cannot expand past the limit set on the feed dial.

Therefore, when stock removal and stone wear add up to the dial setting, the stone ceases to cut. The cutting pressure dial controls the pressure of the stone against the inside diameter of the rotor. It is necessary that the rotor be on the honing tool while the cutting pressure is adjusted. The purpose of the dial is to preload a spring that automatically feeds the cutting stone to the work during the honing operation. Turn the dial to the right to increase the stone pressure against the work. The recommended practice is to use the lowest pressure that will give good cutting action and still stabilize the work on the honing tool. If desired, the automatic feedup of the stone can be made inoperative by turning the dial fully to the right.

4-28. In order to keep the cutting stone and guide shoes in parallel alignment – that is, parallel to the mandrel axis – a truing sleeve made of very hard metal is supplied with the machine. The inside diameter of the truing sleeve should be as near to the rotor bore diameter as feasible, so that the guide shoes will be seated in the proper radius. The truing operation is performed when starting with a new mandrel or stone. To perform the truing operation, apply a small quantity of honing oil to the stone occasionally, to form a lapping compound. Retract the cutting stone by turning the feed dial all the way counterclockwise. With the motor OFF, place the truing sleeve on the honing tool at the rear stroking position (sleeve nearest the machine head) and depress the foot pedal. Advance the feed dial (clockwise) until the cutting stone contacts the inside diameter of the truing sleeve. This means that the cutting surface is in contact with the rotor bore when the foot pedal is depressed to a stop position. Release the foot pedal and turn the motor ON. Now, depress the foot pedal slowly (idler comes into operation and spindle rotates) and begin stroking the sleeve forward and backward as the cutting stone contacts the work. Adjust the cutting pressure so that the torque can be held by hand. Release the pedal, turn the sleeve end for end on the mandrel and hone again. Notice that as the pedal is depressed, the feed dial moves away from the operator. As honing proceeds, the dial moves toward the operator until the stone "cuts free." At that point, no axial movement of the feed dial is present and there is

no pressure on the stone. The cutting pressure should be adjusted by means of the cutting pressure dial, not by the feed dial. The net result of this truing operation is that the honing-stone surface becomes accurately aligned with the axis of rotation of the mandrel.

4-29. The honing dial is actuated by the stone feed mechanism and indicates when to remove the rotor and check the bore diameter with an air gage (ref. Fig. 3-5), and also indicates the rate of stock removal and stone wear. It is necessary to calibrate the dial before performing the honing process. See the manufacturer's catalog for a detailed calibration procedure.

4-30. Different types of stones are used for a particular honing application. For example, a multi-stone open-hole honing unit, a single-stone open-hole honing unit, and a single-stone blind-hole honing unit are some of the honing units available. The insertion of these different types of cutting stones in the honing mandrel is adequately described in the manufacturer's catalog and therefore is not repeated here.

4-31. A summary of the operating procedure for the honing machine is as follows:

a. Set cutting pressure dial to the proper pressure for the honing operation.

b. True the mandrel and the stones with the truing sleeve.

c. With the motor OFF, place the gyro rotor on the honing tool and depress the foot pedal all the way.

d. Advance stone feed dial until the honing dial pointer advances several divisions, but no more than the amount of stock to be removed. (See instructions on the honing machine nameplate regarding relationship between divisions on feed dial and actual stone advance for different types of mandrels.)

e. Hone until the honing dial pointer reads "0." Remove the rotor and check the bore with an air gage (Fig. 3-5). It will be undersize by the amount of stone wear.

f. Turn the feed dial clockwise and advance the stone enough to bring the part to size. Hone until the honing dial again reads "0" and check with the air gage.

g. The rotor should now be to size.

h. If the honing dial pointer moves at a rate out of proportion to the stock removal, one of the following conditions may exist.

(1) The pointer moving too fast indicates that the stone is too soft or the cutting pressure is too high.

(2) The pointer moving too slowly or not at all indicates that the stone is too hard, or is glazed, or the cutting pressure is not high enough.

*Note*

*Never remove the rotor when mandrel is rotating as the rotor and the stones may be damaged.*

4-32. ASSEMBLING THE SPIN-AXIS BEARINGS AND THE PRELOAD SPACERS. Figure 4-14 is an exploded view showing the method for assembling the selected spin-axis bearings and the associated preload spacers inside the rotor bore.

*Note*

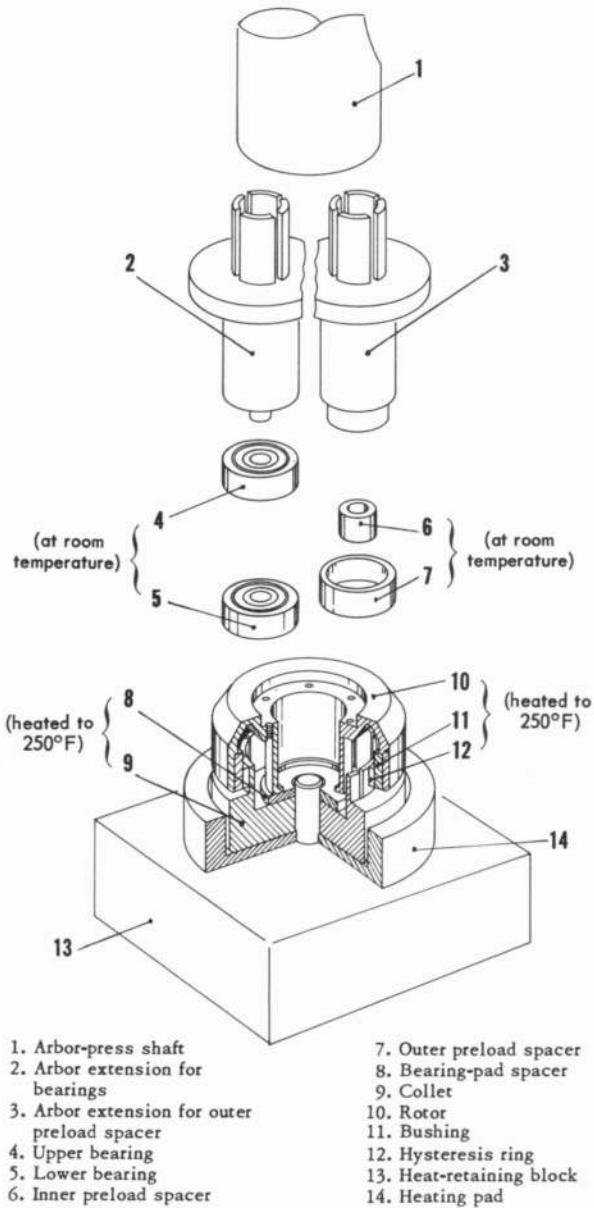
*The use of a plastic hammer or any rapping device is prohibited for inserting the bearings and the preload spacers.*

The arbor press is not used to force the bearings and spacers in place, but rather to ensure their correct alignment. It is important to place the bearing-pad spacer (8, Fig. 4-14) between the end of the rotor bore and the collet (9) in order to avoid breaking off the bearing seat of the rotor when the lower bearing is inserted. The bearings should be mounted back-to-back, that is, with the lettering on the outer races facing each other. There are two arbor extensions shown in Fig. 4-14. One is for the two bearings, the other for the outer preload spacer. No arbor extension is needed for the inner preload spacer since it may be readily dropped in place.

4-33. The detailed procedure for assembling the bearings and the preload spacers is as follows:

a. Mount the rotor-bushing-ring assembly on an appropriate-size collet as shown in Fig. 4-14, with the bearing-pad spacer snugly in place between the end of the rotor bore and the collet.

b. Place the rotor-bushing-ring assembly - collet combination on an appropriate-size heating pad and heat it to a temperature of approximately 250° F by means of the heat-retaining block. This allows the bearings and spacers (which are at room temperature) to be more readily inserted.



Notes: 1. No arbor extension is required for the inner preload spacer.  
 2. The upper and lower bearings are assembled with the lettering on the outer races facing each other.

Fig. 4-14. Exploded view showing the method for assembling the bearings and the preload spacers inside the rotor bore.

c. Insert the lower bearing, using the arbor extension for bearings, with the lettering on the outer race facing upward.

d. Insert the outer preload spacer, using the arbor extension for this spacer.

e. Insert the inner preload spacer.

f. Insert the upper bearing, using the arbor extension for bearings, with the lettering on the outer race facing downward.

**Note**

*Molykote may be applied to the inside of the rotor bore to ease the assembly of the bearings and the outer preload spacer, but all excess must be sucked away with a vacuum hose.*

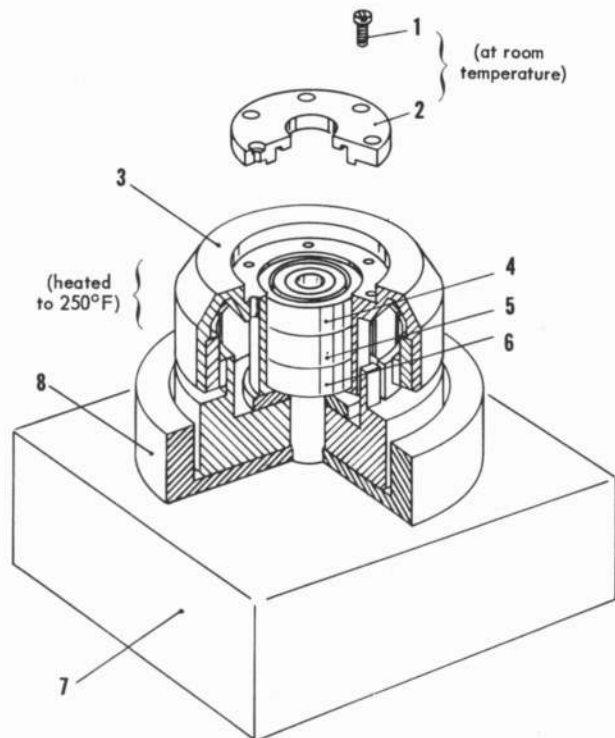
**4-34. ASSEMBLING THE BEARING RETAINER.**

The bearing retainer (4, Fig. 4-1), which holds the bearings and the preload spacers inside the rotor, serves as a vital element in the bearing preload procedure (ref. paragraphs 4-62 through 4-68). For this reason, it is important that it not be cocked with respect to the rotor. The detailed procedure for assembling the bearing retainer to the rotor is as follows:

a. While the rotor-bushing-ring assembly is maintained at a temperature of about 250° F by the heat-retaining block (see Fig. 4-15), insert the bearing retainer at room temperature.

**Note**

*The same combination of bearing retainer, screws, and rotor-bushing-ring assembly for which dynamic balance was obtained (ref. paragraphs 4-12 through 4-17) must be used here.*



- 1. Six No. 00-96 x 3/32-inch, stainless-steel, flat, fillister-head machine screws
- 2. Bearing retainer
- 3. Rotor
- 4. Upper bearing
- 5. Outer preload spacer
- 6. Lower bearing
- 7. Heat-retaining block
- 8. Heating pad

Fig. 4-15. Exploded view showing the method for assembling the bearing retainer.



b. Screw the bearing retainer in place on the rotor assembly.

**Note**

*No torque wrench is available for screwing down the machine screws. Hence, care should be exercised to obtain as equal a pressure distribution as possible around the circumference of the outer race. This will avoid any cocking of the bearing retainer with respect to the rotor.*

c. Place the assembled rotor assembly, spin-axis bearings, and preload spacers in a clean plastic bag together with the selected motor shaft and leave them there until further required in the assembly procedure (ref. paragraph 4-39c).

4-35. CHECKING THE MOTOR STATOR. Figure 4-16 is a pictorial view showing a typical motor stator used in the 20IG unit. It is a six-pole stator having 12 slots and 12 pole faces (2 faces per pole).

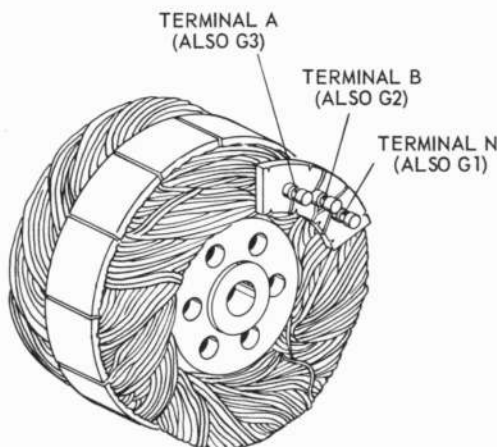


Fig. 4-16. Pictorial view of a typical motor stator.

4-36. Before using a stator in the assembly of the gyro unit, the following checks should be made:

a. Inspect the stator, using a jeweler's loupe (ref. Fig. 3-9), for any impregnation sloppiness on the laminations, stator hub, and hub seat faces.

b. Ascertain that the stator terminal board is secure on the stator windings.

c. Check the stator shaft hole and mating motor shaft for a push fit.

4-37. In addition, electrical checks of the stator windings should be made at various stages of the gyro unit assembly. Table 4-2 shows the stator winding check sheet used. Nominal resistances between the stator terminals are given in the second column of the check sheet. Note that there

are two alternative sets of letter designations used to identify the stator terminals: A, B, and N or G3, G2, and G1, corresponding in the order given. These terminals are identified in Fig. 4-16; no designations appear on the stator itself.

4-38. The electrical checkout of the stator windings is made with a Simpson Multimeter (ref. Fig. 3-10). For the resistance measurements G1 - G2, G1 - G3, and G2 - G3, the resistance readings are read on the R×1-ohm scale. To make a resistance measurement such as G1 - G2, place one Simpson lead on the G1 terminal of the motor stator and the other Simpson lead on the G2 terminal of the motor stator. The needle should indicate a resistance of approximately 4.2 ohms. If the needle should indicate a resistance that is much lower than 4.2 ohms, an internal short circuit may be present in the G1 - G2 windings. If the needle does not move over the R×1-ohm scale, a break, or internal open circuit, is present between the two terminals. To check the ground connections, the R×10,000-ohm scale of the Simpson Multimeter is used. If a resistance reading of more than 2 megohms (2,000,000 ohms) is obtained when one Simpson lead is on a stator terminal and the other on a stator pole face, the stator is acceptable for assembly.

4-39. CHECKING THE MOTOR SPACERS AND THE MOTOR SHAFT NUT. The motor spacers (11 and 12, Fig. 4-1) and the motor shaft nut (13) are used later in the assembly procedure for assembling the motor shaft, rotor assembly, spin-axis bearings, preload spacers, and motor stator to the gimbal fork (ref. paragraphs 4-62 through 4-64). At the present stage of assembly, the motor spacers and the motor shaft nut are selected and given an inspection as follows:

a. Select a motor upper spacer from stock and measure its thickness with a micrometer. It should lie within the range  $0.140^{+0.000}_{-0.001}$  inch. If the spacer is satisfactory, enter the measured value in the Assembly Record Book. If not, discard it and repeat the procedure.

b. Repeat the procedure of step a for the motor lower spacer. Its thickness should lie within the range  $0.080 \pm 0.001$  inch.

Table 4-2. Gyro motor stator-winding resistance check list.

Resistance Across	Nominal Value of Resistance (ohms)	Check Before Assembly of Power Leads	Check After Assembly of Power Leads	Check Before Filling Gyro	Check After Filling When Gyro is Hot	Check After Filling When Gyro is Cold	Check Before Delivery of Gyro
G1 - G2 or N - B	4.2						
G1 - G3 or N - A	4.2						
G2 - G3 or B - A	9						
G1 - Ground or N - Ground	More than 2 megohms						
G2 - Ground or B - Ground	More than 2 megohms						
G3 - Ground or A - Ground	More than 2 megohms						

c. Select a motor shaft nut from stock and check that it threads satisfactorily onto the selected motor shaft (ref. paragraph 4-34c).

4-40. PACKAGING THE MOTOR ASSEMBLY COMPONENTS PENDING FURTHER USE. Place the selected motor stator, motor spacers, and motor shaft nut in the plastic bag used to contain the selected motor shaft and assembled rotor assembly, spin-axis bearings and preload spacers (ref. paragraph 4-34c). Secure the bag and store until the contents are further required in the assembly procedure (ref. paragraph 4-63b). Figure 4-17 shows these components at the present stage of assembly.

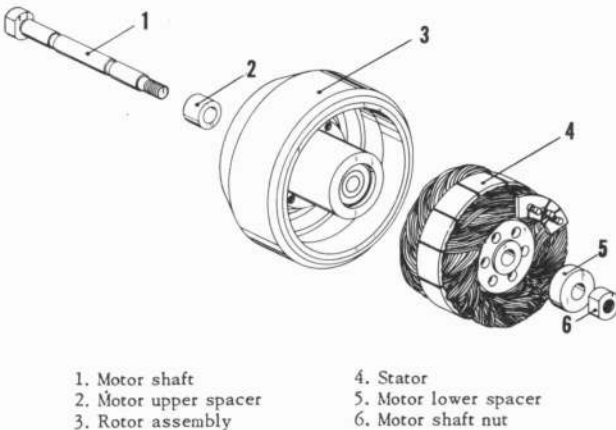


Fig. 4-17. Motor assembly components ready to be packaged for further use.

4-41. MICROSYN UNITS.

4-42. PROCEDURE FOR PREPARING THE MICROSYN UNITS FOR ASSEMBLY. As noted in Section II (ref. paragraphs 2-23, 2-27, 2-33 and 2-35), there are two types of Microsyn units in the 20IG gyro unit:

- a. The Microsyn torque motor.
- b. The Microsyn signal generator.

The basic physical construction is the same in these two units. The essential difference between them lies in the electrical windings of the four identical coil assemblies on each stator core and in the manner in which these windings are connected.

4-43. In preparing the Microsyn torque motor and the Microsyn signal generator for assembly, the differences between them play such a small part that the procedures for both units can be treated in one set of instructions. This set of instructions breaks down into two basic divisions:

a. Preparing the Microsyn torque motor rotor and the Microsyn signal generator rotor for assembly (ref. paragraphs 4-44 and 4-45).

b. Preparing the Microsyn torque motor stator assembly and the Microsyn signal generator stator assembly for final assembly (ref. paragraphs 4-46 through 4-50).

4-44. PREPARING THE MICROSYN TORQUE MOTOR ROTOR AND THE MICROSYN SIGNAL GENERATOR ROTOR FOR ASSEMBLY. The Microsyn units used in the M. I. T. 20IG units are supplied by the Electromagnetic Engineering Section of the Instrumentation Laboratory, M. I. T. Each unit is tested before leaving this section. A production test data sheet incorporating the results of the test accompanies each Microsyn unit received from the Electromagnetic Engineering Section. This sheet (see typical form on accompanying page) indicates whether the tested Microsyn unit is a torque motor or a signal generator and identifies it by means of the serial numbers that are inscribed on the respective rotor and stator. These serial numbers, in conjunction with the production test data sheet, enable the assembler to positively identify the mating components of a particular Microsyn unit.

4-45. The detailed procedure for preparing the Microsyn rotors for assembly is as follows:

- a. Using a production test data sheet, pair off a mating rotor and stator assembly for the Microsyn torque motor, and package the pair in a plastic bag.
- b. Using another production test data sheet, pair off a mating rotor and stator assembly for the Microsyn signal generator, and package the pair in a separate plastic bag.
- c. Record the serial numbers of the rotors and the stator assemblies in the Assembly Record Book (ref. Appendix A).
- d. Weigh each of the two rotors separately on an analytical balance (ref. Fig. 3-11), and record the weight, in grams, in the Assembly Record Book.
- e. Return the rotors to their respective plastic bags, pending use later in the assembly procedure (ref. paragraph 4-69k).

4-46. PREPARING THE MICROSYN TORQUE MOTOR STATOR ASSEMBLY AND THE MICROSYN SIGNAL GENERATOR STATOR ASSEMBLY FOR FINAL ASSEMBLY. As received from the Electromagnetic Engineering Section, each Microsyn stator assembly is not yet equipped with the electrical leads necessary for the excitation current, the input signals and the output signals. However, the required interconnections between coil windings have

been made by means of solder jumpers connecting the appropriate terminal pins, and a stator mount has been bonded to the stator core with Plastilock. The task of soldering on the so-called "pigtail" electrical leads belongs to the assembler. It is also part of his task to further secure the stator mount and stator core together with screws, bushings and nuts. The procedure for preparing each Microsyn stator assembly for final assembly has the following basic steps:

- a. Securing the stator mount to the stator core (ref. paragraph 4-47).
- b. Checking the resistances of the coil windings (ref. paragraph 4-48).
- c. Soldering the pigtail leads onto the terminal pins (ref. paragraph 4-49).
- d. Checking the mounting feet for squareness and smoothness (ref. paragraph 4-50).

4-47. The detailed procedure for securing the stator mount to the stator core is as follows (ref. Fig. 4-18):

- a. Push small teflon bushings over each of the four No. 2-56, 5/16-inch long, stainless steel, fillister head screws used with each stator mount.
- b. Insert the screws, with their teflon bushings, through the four holes in the stator mount and then through the mating holes in the laminations of the stator core.
- c. Add the four mating nuts and tighten snugly.

4-48. At this stage of the assembly, it is advisable to check the resistances of the coil windings. This should be done with a Simpson Multimeter (ref. Fig. 3-10). Table 4-3 shows the resistances to be checked and the nominal reading for each resistance. The table also indicates subsequent checks to be made at various stages of assembly. Enter the resistance readings obtained into the Assembly Record Book.

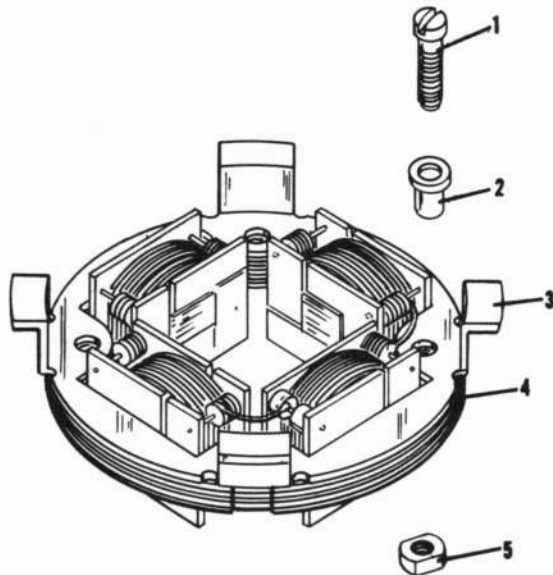
4-49. The detailed procedure for soldering the pigtail leads onto the terminal pins is as follows (ref. Figs. 4-19 and 4-20):

- a. Cut 14 3-inch lengths from a spool of No. 28 HI TEMP wire.
- b. Strip about 1/4 inch of the booting away from each end of the wires.
- c. Inspect the remaining booting and the exposed strands to see that there are no loose

**MICROSYN PRODUCTION TEST DATA** \_\_\_\_\_

**BOOK** \_\_\_\_\_ **PAGE** \_\_\_\_\_

MODEL MY <u>1.5-19</u> <u>Torque</u> GENERATOR		E. E. S. WORK ORDER W. _____		DATE TESTED <u>2/5/55</u>	
FOR PROJECT NO. _____				STATOR NO. S- <u>5653</u>	
				KOTOR NO. S- <u>1946</u>	
			NULL OUTPUT VOLTS		
			FREQ. _____ C. P. S.		FREQ. _____ C. P. S.
			PRI. EXC. _____ AMPS.		PRI. EXC. _____ AMPS.
NO QUADRATURE RESISTANCE OR FILTER					
FILTER ONLY					
FILTER AND QUADRATURE RESISTANCE _____ OHMS					
FILTER PLUS 10% QUADRATURE RESISTANCE _____ OHMS					
FILTER MINUS 10% QUADRATURE RESISTANCE _____ OHMS					
		ROTOR ANGLE			
		DEGREES	MILLIRADIANS	ROTOR DIAL DEGREES	WIRE DIAL A DEGREES
		DEGREES	DEGREES	DEGREES	ANGLE DIFFERENCE A and B DEGREES
		DEGREES	DEGREES	DEGREES	REACTION TORQUE DYNE Cm
FREQUENCY _____ C. P. S.		0	0		
PRI. EXC. _____ AMPS.					
			OUTPUT VOLTS		
			NO QUAD RES. NO FILTER		QUAD _____ OHMS # _____ FILTER
FREQUENCY _____ C. P. S.		+5.7	+100		
PRI. EXC. _____ AMPS.					
LOAD IMP. _____ OHMS		-5.7	-100		
SENSITIVITY @ _____ C. P. S. →					MV/MR
FREQUENCY _____ C. P. S.		+5.7	+100		
PRI. EXC. _____ AMPS.					
LOAD IMP. _____ OHMS		+5.7	-100		
SENSITIVITY @ _____ C. P. S. →					MV/MR
PRI. T <sub>1</sub> T <sub>2</sub> TURNS PER COIL <u>1200 1/2</u> WIRE SIZE <u>40</u>		REMARKS			
SEC. T <sub>3</sub> T <sub>4</sub> TURNS PER COIL <u>1200 1/2</u> WIRE SIZE <u>40</u>					
D.C. RES. OF PRI. T <sub>1</sub> T <sub>2</sub> CKT. <u>693.3</u> OHMS FOR <u>4</u> COILS					
D.C. RES. OF SEC. T <sub>3</sub> T <sub>4</sub> CKT. <u>498.3</u> OHMS FOR <u>4</u> COILS					
PRI. T <sub>1</sub> T <sub>2</sub> CIRCUIT IMP. <u>1550</u> OHMS AT <u>400</u> C. P. S.					
SEC. T <sub>3</sub> T <sub>4</sub> CIRCUIT IMP. _____ OHMS AT _____ C. P. S.					
PRIMARY INPUT _____ VOLTS		TESTED BY: _____			



- |   |                 |
|---|-----------------|
| 1. Screw (4)<br>(No. 2-56, 5/16 in. long) | 3. Stator mount |
| 2. Teflon bushing (4)                     | 4. Stator core  |
|   | 5. Nut (4)      |

Note: As received from the Electromagnetic Engineering Section of the Instrumentation Laboratory, M. I. T., the stator mount and stator core are bonded together with Plastilock. The additional hardware shown supplements this bond.

Fig. 4-18. Exploded view showing the method for securing the stator mount to each Microsyn stator core.

strands of booting and that none of the original 7 strands of wire are cut off. Use surgical shears (ref. Fig. 3-12) to cut away any loose strands of booting.

d. Clean thoroughly the ends of each pigtail lead and all parts of each stator assembly, using 95 percent pure ethyl alcohol and a short-bristled stiff brush.

e. Using a Variac, apply 90 volts to the soldering iron.

f. Tin the ends of the pigtail leads, using 50/50 solder (melting point 418° F) and No. 1544 Kester flux.

g. Use Figs. 4-19 and 4-20 as the guides for soldering the 7 pigtail leads to the various terminal pins of each Microsyn stator assembly.

**Note**

*These two figures show the two stator assemblies oriented such that a) the direction of the spin reference axis is toward the top of the page and b) the stator mounting feet are toward the assembler. The split quadrature pin makes a good reference guide for aligning the actual assemblies with the respective views shown in Figs. 4-19 and 4-20.*

h. Loop the end of the pigtail lead, apply a little flux to the pigtail and to the terminal pin of the Microsyn, place the loop of pigtail around the pin and touch the soldering iron to the pigtail until solder begins to flow and a good bond between the pin and the pigtail is obtained.

**Note**

*Care must be exercised so that the wire from the Microsyn coil to the pin does not become loosened in the soldering process and that no solder build-up occurs between the terminal pin and the coil windings.*

i. Inspect every soldered joint for any loose connections that may have resulted during the pigtail soldering procedure. Resolder as required.

j. Using a small stiff brush, wash off any excess flux with alcohol and clean with a vacuum hose.

**Note**

*Do not use any solvents (trichlorethylene, acetone, carbon tetrachloride, etc.) on the Microsyn stator assembly.*

k. Recheck the resistances of the coil windings as indicated in Table 4-3, and enter the results in the Assembly Record Book.

l. Obtain a neat arrangement of the pigtail leads by tucking each lead behind the adjacent mounting foot, as shown in Figs. 4-19 and 4-20.

4-50. Prior to packaging the two Microsyn stator assemblies for future use, it is necessary to check the squareness of the mounting feet relative to a perpendicular axis. If the mounting feet of a Microsyn unit are not square, the radial air gap between the rotor and the stator core in the assembled gyro unit will not be uniform and a nonuniform flux density across the air gap will occur. This will lower the performance of the Microsyn unit. In addition, it is necessary to remove any sharpness or roughness along the edges of the mounting feet. If this is not done, there is the possibility that some of the pigtail leads may be cut during the assembly of the Microsyn stator assemblies into the gyro unit housings (ref. paragraphs 5-8 through 5-11). The detailed procedure for checking and fixing the stator mounting feet is as follows:

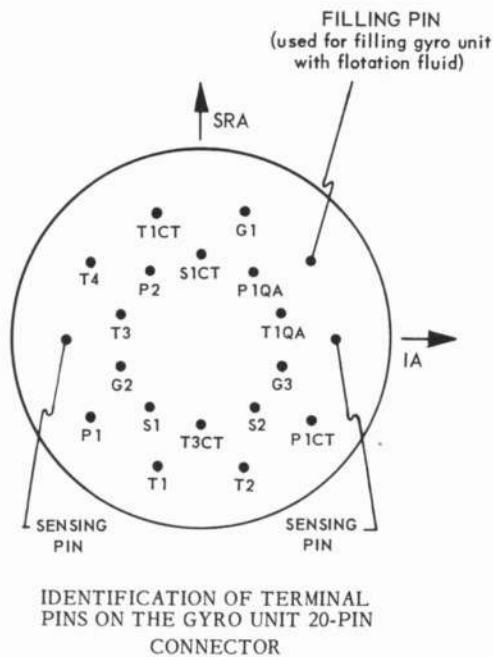
a. To check for squareness of the mounting feet, place each stator assembly - feet downward - on a flat surface plate. If any of the four feet do not rest flat against the surface plate, a lack of squareness is present.

Table 4-3. Microsyn resistance check sheet.

Signal generator MY 1.5-25  
Torque motor MY 1.5-4

Rotor No. \_\_\_\_\_ Stator No. \_\_\_\_\_  
Rotor No. \_\_\_\_\_ Stator No. \_\_\_\_\_

Resistance Across	Nominal Value (ohms)	Check Before Soldering Pigtails	Check After Soldering Pigtails	Check Before Assembly into Unit	Check After Assembly into Unit	Check Before Centering	Check Before Filling	Check After Filling
P1 - P2	7.0							
P1 - P1CT	3.5							
P2 - P1CT	3.5							
P1 - P1QA	5.0							
P2 - P1QA	2.0							
P1CT - P1QA	2.0							
S1 - S2	280							
S1 - S1CT	140							
S2 - S1CT	140							
P1 - GND	more than 2 megohms							
P2 - GND								
P1CT - GND								
P1QA - GND								
S1 - GND								
S2 - GND								
S1CT - GND								
P1 - S1								
T1 - T2	32							
T1 - T1CT	16							
T2 - T1CT	16							
T3 - T4	24							
T3 - T3CT	12							
T4 - T3CT	12							
T1 - T1QA	24							
T2 - T1QA	8							
T1CT - T1QA	8							
T1 - GND	more than 2 megohms							
T2 - GND								
T1CT - GND								
T3 - GND								
T4 - GND								
T3CT - GND								
T1QA - GND								
T1 - T3								



Note:  
This is the direction that is aligned with the positive direction of the spin reference axis in the assembled gyro unit.

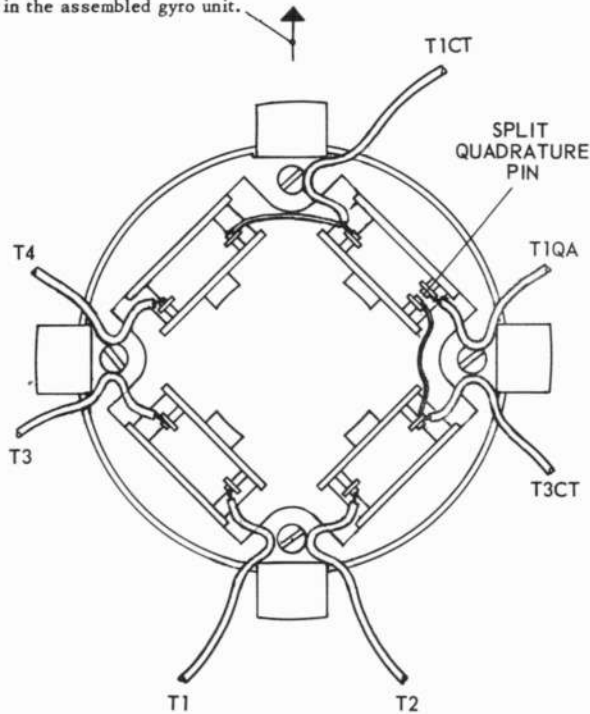


Fig. 4-19. Top view of the Microsyn torque motor stator assembly, with the mounting feet upward.

Note:  
This is the direction that is aligned with the positive direction of the spin reference axis in the assembled gyro unit.

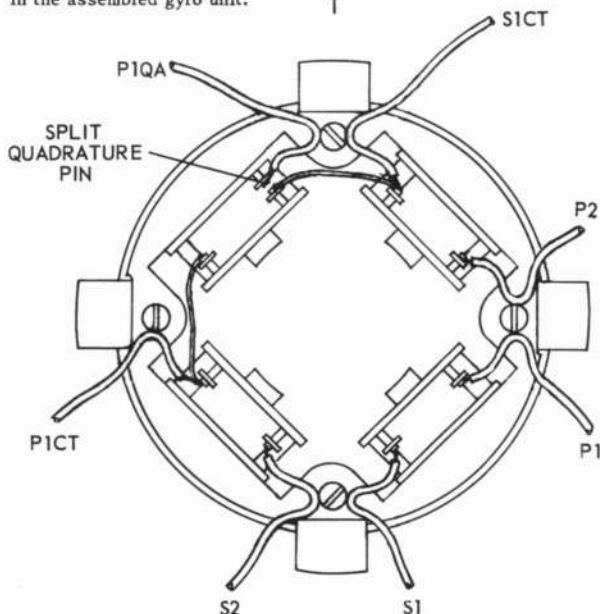


Fig. 4-20. Top view of the Microsyn signal generator stator assembly, with the mounting feet upward.

b. Correct any defect in the squareness with two pairs of long-nose pliers – one as a clamping device, the other to apply force. Bend the feet until the desired squareness is obtained.

c. To eliminate any sharpness or roughness along the edges of the stator feet, use a smooth oil stone as an abrasive.

d. Place the completed Microsyn torque motor stator assembly and Microsyn signal generator stator assembly in their respective plastic bags until required for final assembly into the gyro unit housings (ref. paragraphs 5-8 through 5-11).

4-51. FLOATED UNITS ASSEMBLY (ref. Fig. 4-21; also Fig. 2-12).

4-52. PROCEDURE FOR ASSEMBLING THE FLOATED UNITS ASSEMBLY. The procedure for assembling the floated units assembly follows that outlined in the Assembly Record Book (ref. Appendix A). Briefly, the basic steps of the procedure, which are covered in detail in the ensuing paragraphs, are as follows:

a. Checking the gimbal shell and the gimbal fork (ref. paragraph 4-53).

b. Selecting and checking the power lead-in body (ref. paragraphs 4-54 and 4-55).

c. Assembling the power lead-in body in the gimbal fork shaft (ref. paragraph 4-56).

d. Checking the float runout (incorporates the checking and assembly of the balance assembly and the two pivot assemblies) (ref. paragraphs 4-57 and 4-58).

e. Assembling the power lead-in clamp and checking the power lead-ins for grounds (ref. paragraph 4-59).

f. Checking and assembling the balance nuts (ref. paragraphs 4-60 and 4-61).

g. Selecting the motor spacers (ref. paragraphs 4-62 and 4-63).

h. Assembling the motor assembly in the gimbal fork (ref. paragraph 4-64).

i. Minimizing the pendulosity of the floated units assembly (ref. paragraphs 4-65 and 4-66).

j. Checking the coast-down time and running-in the bearings (ref. paragraphs 4-67 and 4-68).

k. Assembling the gimbal fork, gimbal shell, and associated parts (ref. paragraph 4-69).

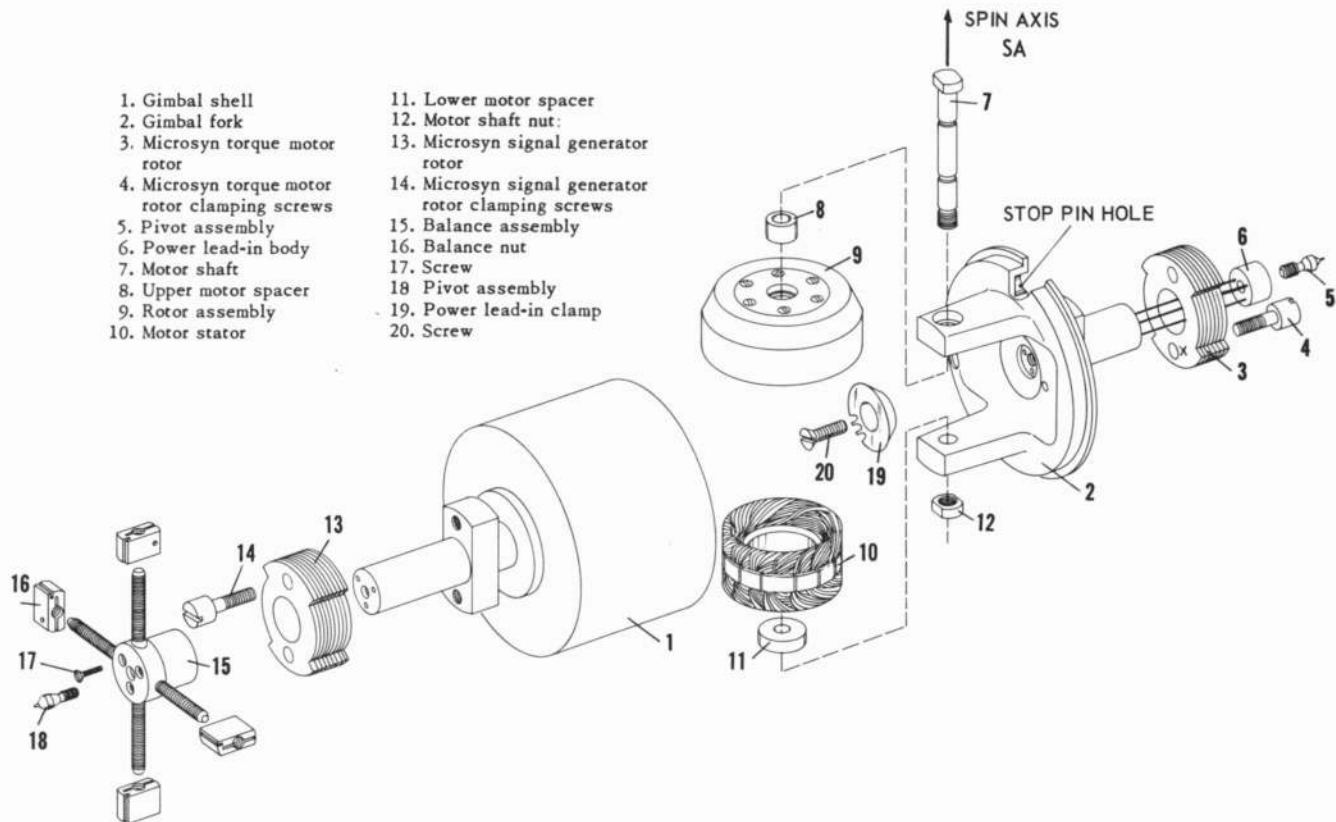


Fig. 4-21. Exploded view of the floated units assembly.

l. Evacuating the gimbal shell and adding helium under pressure (ref. paragraphs 4-70 and 4-71).

m. Obtaining a balance in Fluorolube (ref. paragraphs 4-72 and 4-73).

4-53. CHECKING THE GIMBAL SHELL AND THE GIMBAL FORK. As noted in Section II, both the gimbal shell (1, Fig. 4-21) and the gimbal fork (2) are of aluminum, with a copper plating (ref. paragraphs 2-28 and 2-32). The copper plating allows an induction-soldered joint to be made between the two units. Inspect the copper plating of the gimbal shell and the gimbal fork to be used in the floated units assembly to insure that there are no blisters, pock marks, or bad scratches on critically mating surfaces. If either is found defective in this respect, discard and replace with a suitable part.

4-54. SELECTING AND CHECKING THE POWER LEAD-IN BODY. The power lead-in body (6, Fig. 4-21) is manufactured by the Stupakoff Ceramic and Mfg. Co., of Latrobe, Pennsylvania. For this reason, it has received the nickname "Stupakoff."

To select a suitable "Stupakoff," or power lead-in body, for assembly in the gimbal fork, perform the following steps:

a. Measure with a ball gage (ref. Fig. 3-14) the diameter of the gimbal-fork bore into which the power lead-in body is to be placed.

b. Select a power lead-in body whose outside diameter, as measured with a micrometer (ref. Fig. 3-15) does not exceed the diameter of the gimbal-fork bore.

4-55. Once a power lead-in body with a satisfactory diameter has been obtained, it should be further checked as follows (ref. Fig. 4-22):

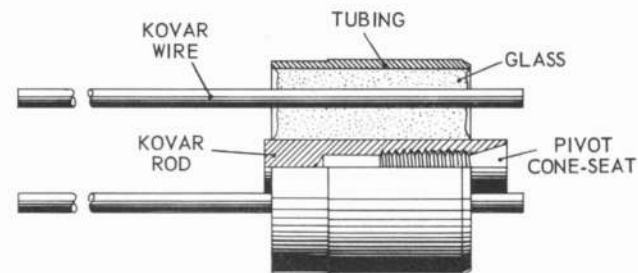


Fig. 4-22. Cutaway view of the power lead-in body.



a. Inspect the part under a microscope (ref. Fig. 3-16) for the presence of through cracks. If such cracks are present, the part is unacceptable.

b. Check for any grounds between the three Kovar wires and the outside Kovar tubing with a General Electric Resistance Meter (ref. Fig. 3-17). A resistance less than 2 megohms is unacceptable.

c. Check the pivot cone-seat and also the thread of the recess. Clean as required.

**4-56. ASSEMBLING THE POWER LEAD-IN BODY IN THE GIMBAL FORK SHAFT.** The power lead-in body is induction-soldered in the gimbal fork shaft. The detailed steps of this procedure are as follows:

a. Retap the 1-64 NC-2 tapped hole in the shaft of the gimbal fork and remove any metal chips or dirt with a vacuum hose. This is necessary because the power lead-in clamp (19, Fig. 4-21) for the three power lead-ins (the three Kovar wires of the power lead-in body) must be capable of being drawn up snugly by the 1-64 NC-2 screw (20), so that it is flush with the inside surface of the gimbal fork (ref. paragraph 4-59d).

b. Slip silicon-rubber-fiberglass insulating sleeves over the entire lengths of the three Kovar wires of the power lead-in body.

c. Clean and size the three power lead-in holes in the gimbal fork so that they can receive the silicon-rubber-fiberglass insulating sleeves.

d. Coat the inside of the gimbal fork shaft with soldering flux.

e. Insert the power lead-in body in the entrance to the bore of the gimbal fork shaft (ref. Fig. 4-23), with the three Kovar wires and their insulating sleeves lined up with and fed through the three power lead-in holes in the gimbal fork.

f. Push the power lead-in body into the bore of the gimbal fork shaft, maintaining the orientation of the three Kovar wires so that one of the wires, the center line of the power lead-in body, and the stop pin hole remain lined up. Seat the power lead-in body firmly against the shoulder near the bottom of the bore. In its final position, the top rim of the power lead-in body should be 0.005 to 0.010 inch below the top of the gimbal fork shaft.

g. Mount the gimbal fork in a soldering fixture as shown in Fig. 4-24.

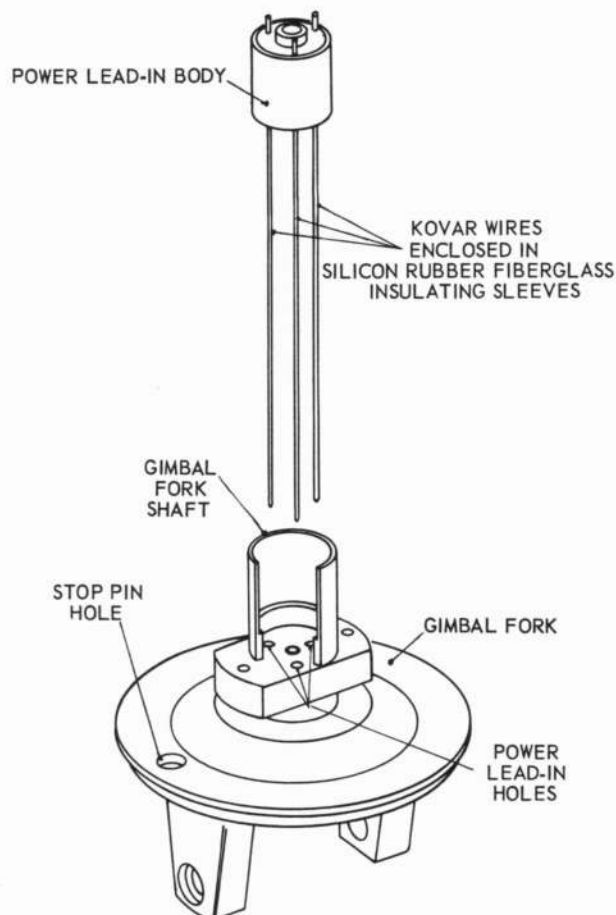


Fig. 4-23. Exploded view showing the procedure for inserting the power lead-in body in the gimbal fork.

**Note**

*A discarded gimbal shell serves quite satisfactorily as the soldering fixture.*

h. Mount the soldering fixture on a standard bench block that has been placed in a specially constructed positioning device as shown in Fig. 4-24.

i. Place the positioning device beneath a soldering machine (ref. Fig. 3-18), in which an appropriate-size induction soldering coil is used, so that the coil fits around the gimbal fork shaft as shown in Fig. 4-24.

j. For fine positioning, turn the handle of the positioning device to raise or lower the gimbal fork with respect to the induction soldering coil.

k. Place a ring of 50/50 solder (50 percent tin, 50 percent lead) around the upper circumference of the power lead-in body. For this purpose, the gimbal fork shaft is designed with a chamfer on the outer end of its bore, and the power lead-in body (ref. Fig. 4-22) has a mating chamfer on its outer edge.

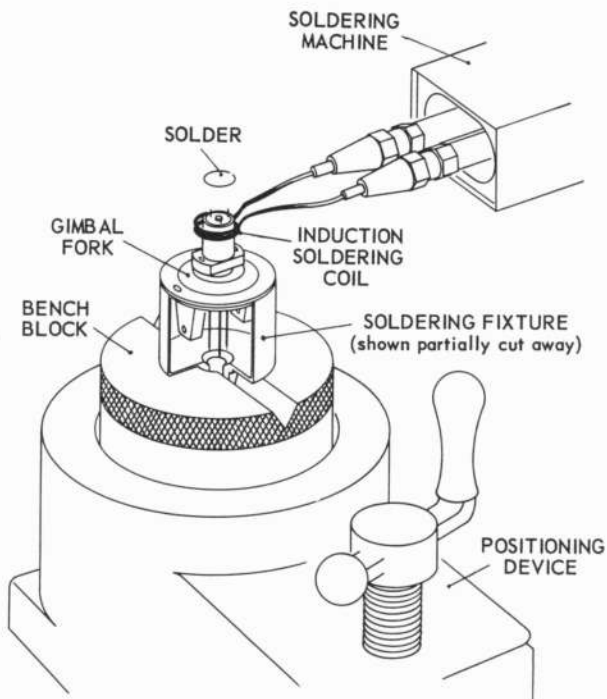


Fig. 4-24. Pictorial view showing the procedure for soldering the power lead-in body in the gimbal fork.

1. By means of the soldering machine, heat the gimbal fork shaft to a temperature that will melt the solder.

**Note**

For the detail steps of the soldering procedure, see steps e through j of paragraph 4-84. For the present procedure, the dummy load should consist of a discarded gimbal fork - power lead-in body combination mounted in the soldering fixture.

m. Once this temperature is reached, turn off the soldering machine. This completes the induction-soldering procedure.

**Note**

Allow the gimbal fork to cool to room temperature before going further with the assembly procedure.

4-57. CHECKING THE FLOAT RUNOUT. The next step following the soldering operation is to measure the runout, or eccentricity, of the floated units assembly, both at the balance assembly end of the gimbal shell and the power lead-in body end. To do this, the gimbal fork and gimbal shell are temporarily assembled - that is, without being induction soldered - to form the float. They must be positioned with respect to one another just as in final assembly, that is, so that the positive spin

axis direction associated with the gimbal fork (ref. Fig. 4-25) lines up with a corresponding fixed direction associated with the gimbal shell (ref. Fig. 4-26). As indicated in Fig. 4-21, the spin axis passes through the center lines of the two holes in the gimbal fork through which the motor shaft is inserted. Its positive direction, which is identical with the direction the thumb of the right hand has when the fingers of that hand are curled in the direction that the rotor turns, is on the side of the gimbal fork containing the stop pin hole. The corresponding fixed direction associated with the gimbal shell lies along a line perpendicular to the center line of the gimbal shell shaft and in line with the two tapped holes in the Microsyn signal generator rotor mounting pad. Its positive sense with respect to the three tapped holes used for mounting the balance assembly is as shown by Fig. 4-26.

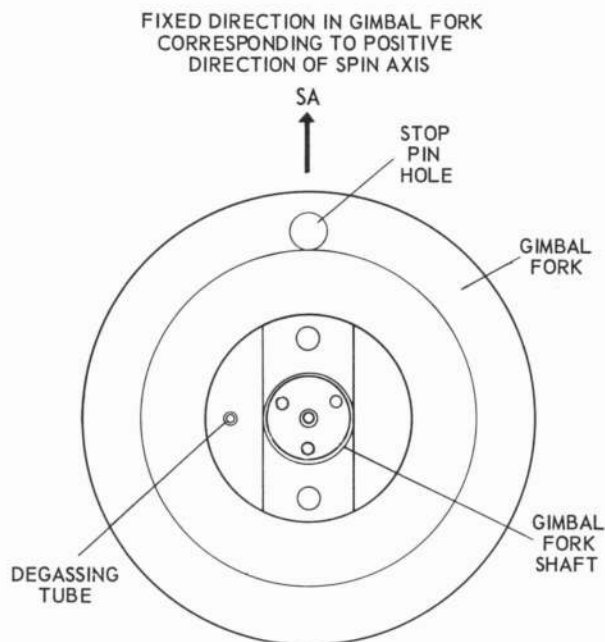


Fig. 4-25. End view of the gimbal fork shaft showing the positive direction of the spin axis.

With the balance assembly assembled to the gimbal shell shaft, the positive direction of the spin axis is along the one balance stud that is directly opposite one of the three screws securing the balance assembly (ref. Fig. 4-21). Subsequently in the assembly procedure, after the motor assembly has been added to the gimbal fork, the gimbal shell and gimbal fork are soldered together with

these two positive spin-axis directions in alignment. This will ensure that the final runout will not exceed the runout determined at this stage of assembly.

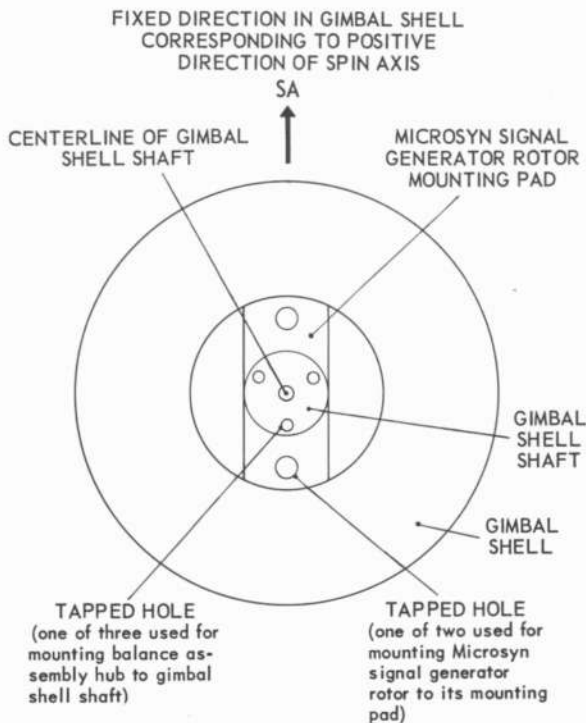


Fig. 4-26. End view of the gimbal shell shaft showing the positive direction of the spin axis.

4-58. The detailed procedure for checking the float runout is as follows:

a. After the gimbal fork has cooled to room temperature following completion of the soldering operation, remove it from the soldering fixture.

b. Temporarily assemble the gimbal fork to the gimbal shell so that the positive spin-axis direction of one lines up with the corresponding direction of the other (ref. paragraph 4-57). Exact alignment is obtained by supporting the gimbal fork - gimbal shell combination at the Microsyn rotor pads on two blocks lying on a flat surface, as shown in Fig. 4-27. When the flats of both rotor pads lie flush against the blocks, correct alignment is assured.

c. Attach the balance assembly (15, Fig. 4-21) to the gimbal shell shaft with the three screws (17), in the orientation noted in paragraph 4-57. If necessary, polish the shaft outside diameter until the balance assembly goes on with a light push fit. It is unimportant whether or not the balance nuts are

on the studs of the balance assembly at this time. However, the following measurements are to be made and the results entered in the Assembly Record Book: 1) the distance from the end of each stud to the end of the opposite stud, with a micrometer (ref. Fig. 3-15) (this dimension shall be  $1.124^{+0.000}_{-0.005}$  inches and shall be centered on the axis of the gimbal shell shaft); 2) the gimbal shell shaft outside diameter, using a micrometer; and 3) the mating inside diameter of the balance assembly hub, using an air gage (ref. Fig. 3-5).

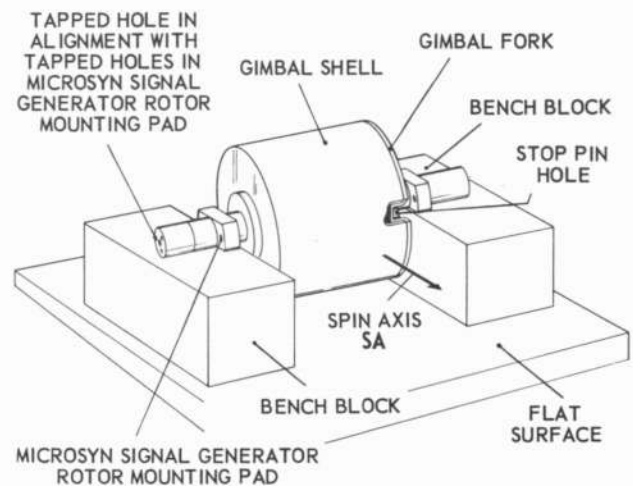


Fig. 4-27. Pictorial diagram showing the procedure for aligning the gimbal fork and the gimbal shell.

d. Insert one of the two pivot assemblies (5 and 18, Fig. 4-21; both are identical) in the pivot wrench as shown in Fig. 4-28, securing it in place by means of the adjustable knurled ring.

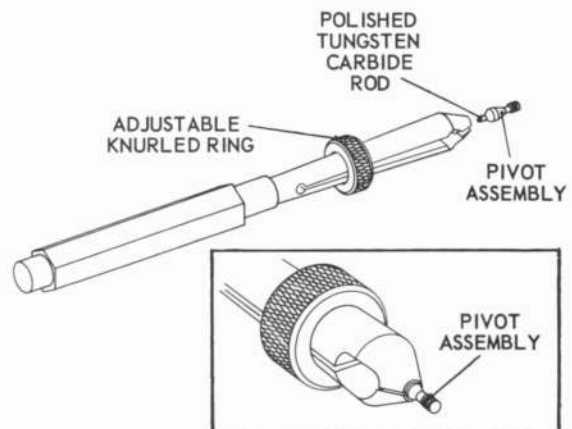


Fig. 4-28. Pictorial view showing how the pivot assembly is mounted in the pivot wrench.

e. Thread the pivot assembly through the hole at the end of the balance hub and into the tapped hole in the end of the gimbal shell shaft until it fits snugly in the pivot seat.

f. Repeat step d for the other pivot assembly and thread it into the tapped hole of the power lead-in body in the end of the gimbal fork shaft until it fits snugly in the pivot seat (ref. Fig. 4-22).

**Note**

*Care should be exercised not to bend the pivot assembly. Each pivot assembly as received for use in the assembly procedure has a known runout of less than 0.0001 inch total indicator reading.*

g. Support the floated units assembly, by means of the pivots, between the two jewel assemblies of a special test fixture that is mounted on a flat, leveled surface as shown in Fig. 4-29.

h. Mount a dial indicator on a dial indicator support as shown in Fig. 4-29, making appropriate adjustments for fine positioning. For convenience in positioning, the dial indicator support has a magnetized base and a ball-and-socket joint. As

set up in Fig. 4-29, the dial indicator will indicate the runout at the signal-generator end of the float.

i. If the runout (that is, the eccentricity) at either end of the float exceeds 0.0002 inch total indicator reading, the soldering procedure for the power lead-in body (ref. paragraph 4-56) must be repeated until the runout tolerance specified is met at both ends of the float.

**Note**

*Whenever a doubt arises about the concentricity of the float, the pivots should be checked by substituting pivot assemblies known to be good before assuming the soldering procedure for the power lead-in body is at fault.*

4-59. ASSEMBLING THE POWER LEAD-IN CLAMP AND CHECKING THE POWER LEAD-INS FOR GROUNDS. After the runout has been found to be satisfactory, the following detail steps should be carried out:

a. Remove the floated units assembly from the special test fixture and disassemble the gimbal fork from the gimbal shell.

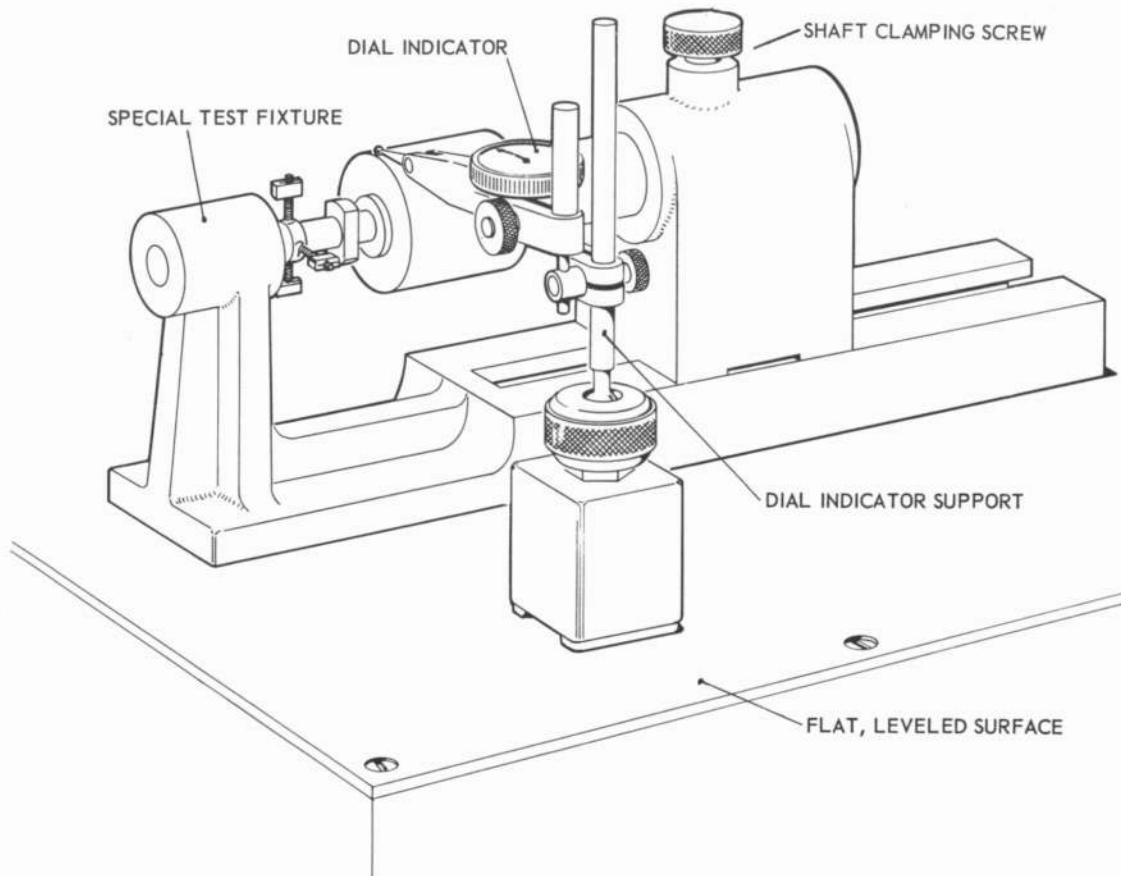


Fig. 4-29. Pictorial view showing the test setup for measuring the float runout.

b. Clean the gimbal shell and balance assembly combination, and place in a clean plastic bag until required for further use (ref. paragraph 4-61f).

c. Clean the entire gimbal fork in acetone to remove any excess soldering flux.

d. Insert the power lead-in clamp, with the three power lead-ins positioned as shown in Fig. 4-30a, and tighten it snugly against the gimbal fork with the appropriate screw (1-64 NC-2). Its final position should be flush with the inside surface of the gimbal fork and in the orientation shown in Fig. 4-30b. This will allow the three power lead-ins to be readily connected to the motor assembly after it is inserted in place.

**Note**

*The counterbalance slot shown in Fig. 4-30a compensates for the unbalance introduced by the off-center position of the three power lead-ins.*

e. Note the identification of the three power lead-ins on Fig. 4-30 by the designations A, B, and N. This indicates which lead is to be subsequently connected to each of the three terminals on the motor stator (ref. paragraph 4-37). These leads are identified also by Fig. 4-31, which shows an end view of the gimbal fork shaft. No designations appear on the lead-ins themselves.

f. Using a General Electric Resistance Meter (ref. Fig. 3-17), check for grounds between each of the three power lead-ins and the gimbal fork. Enter the exact readings in the Assembly Record Book. A measured value in excess of 2 megohms in each instance is acceptable.

g. Clean the gimbal fork and place it in a plastic bag until required for further use (ref. paragraph 4-63a).

4-60. CHECKING AND ASSEMBLING THE BALANCE NUTS. The balance of the floated units assembly about the output axis - the axis of the pivots - is adjusted by four balance nuts that are carried by the balance studs (ref. Fig. 4-32). The two larger balance nuts mounted along the negative directions of the spin axis and the input axis are the so-called rough adjustment nuts, and are used for making rough balance adjustments prior to final assembly of the gyro unit. The two smaller nuts mounted along the positive directions of these axes are used for effecting a finer balance after

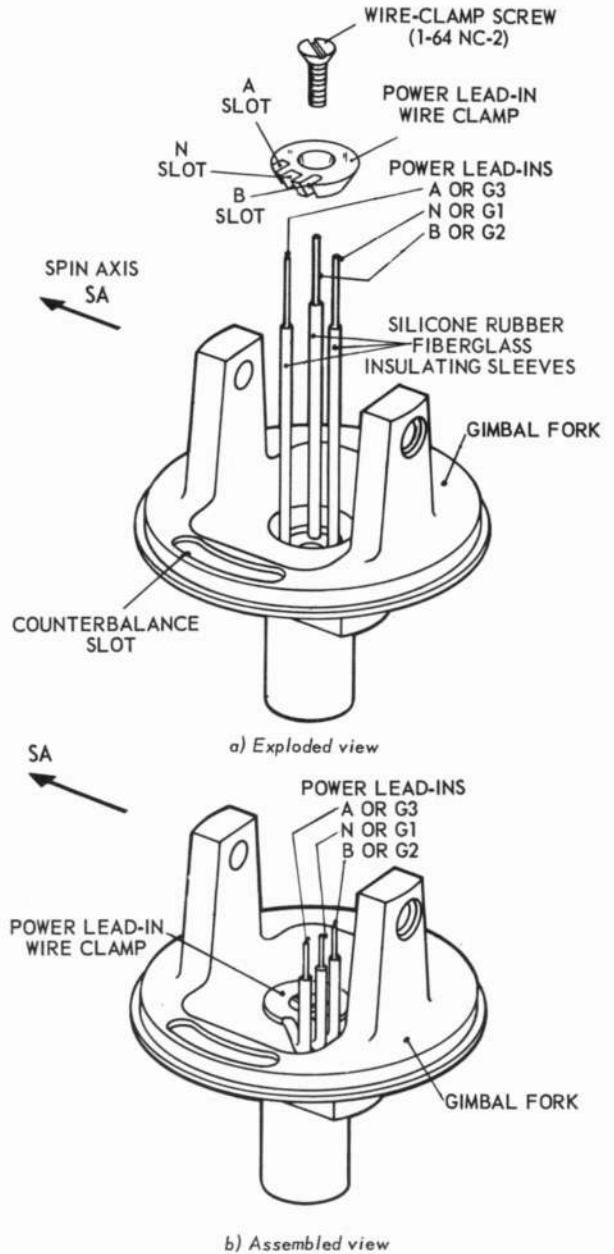


Fig. 4-30. Exploded and assembled views showing the procedure for inserting the power lead-in clamp.

the gyro unit assembly is completed (ref. Section VIII). The weights of the small balance nuts are sufficiently small that precise balancing of the float assembly can be accomplished by these balance nuts after the gyro unit is assembled. The balance nuts are made of beryllium copper and have various lengths (see Fig. 4-32 for definition of length) as follows: 0.093, 0.109, 0.125, 0.140, 0.156, 0.171, and 0.187 inch. Initially, a length of either 0.109 inch or 0.125 inch for the two small nuts and a

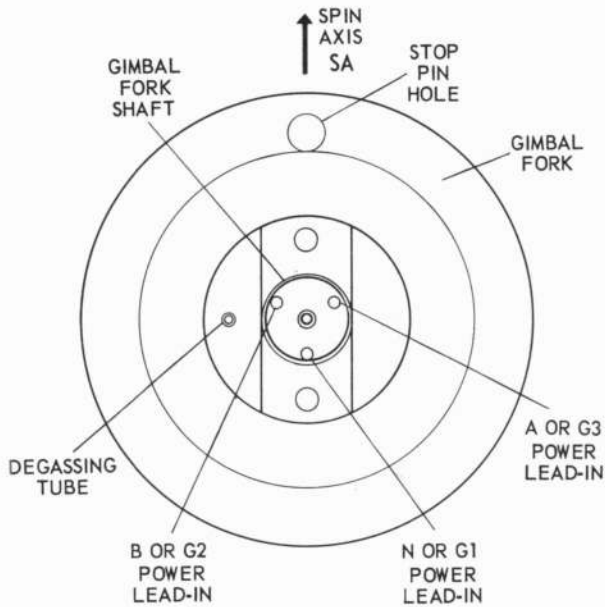


Fig. 4-31. End view of the gimbal fork shaft identifying the three power lead-ins of the power lead-in body.

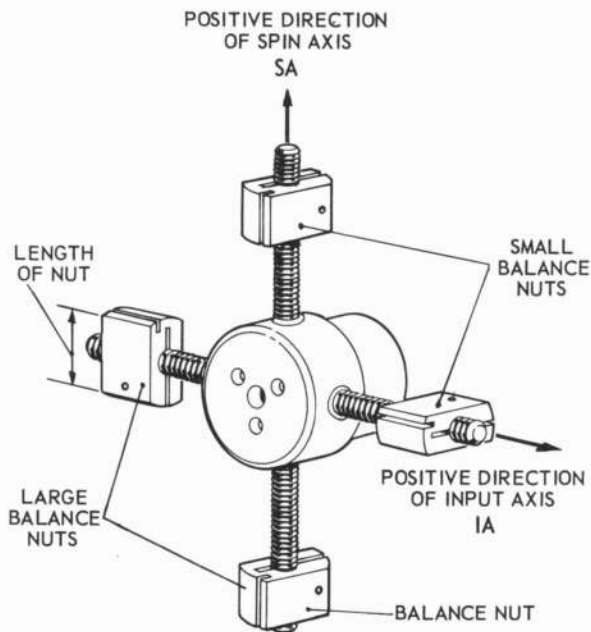


Fig. 4-32. Pictorial view showing the four balance nuts mounted on the balance assembly.

length of either 0.156 inch or 0.171 inch for the two large nuts are logical choices. Later in the assembly procedure (ref. paragraph 4-73) it may be found necessary to replace one or more of the four nuts with nuts of a different length. The tapped stud hole in each nut is undersize, so that the slots cut in each nut provide a soft spring pressure against

the studs. Before the small balance nuts are threaded onto the balance studs, they should be statically balanced or poised, in order to avoid upsetting the end-for-end balance of the floated units assembly (ref. paragraphs 4-72 and 4-73) when the final rotational balance is obtained for the assembled gyro unit (ref. Section VIII). To accomplish this, each small nut, one at a time, is fitted with a special poising arbor, as shown in Fig. 4-33. This arbor is then supported, as indicated, by the two knife edges of a leveled watch-balance-wheel poising tool, and the behavior of the nut is observed and modified as required to obtain static balance.

4-61. The detailed procedure for checking and assembling the balance nuts is as follows:

- a. Fit the balance nut to be tested onto the special poising arbor, and then support the arbor on the leveled poising tool as shown in Fig. 4-33.

*Note*

*Leveling is obtained at this stage by the spirit level and is only an approximation that will be refined by subsequent steps of the procedure.*

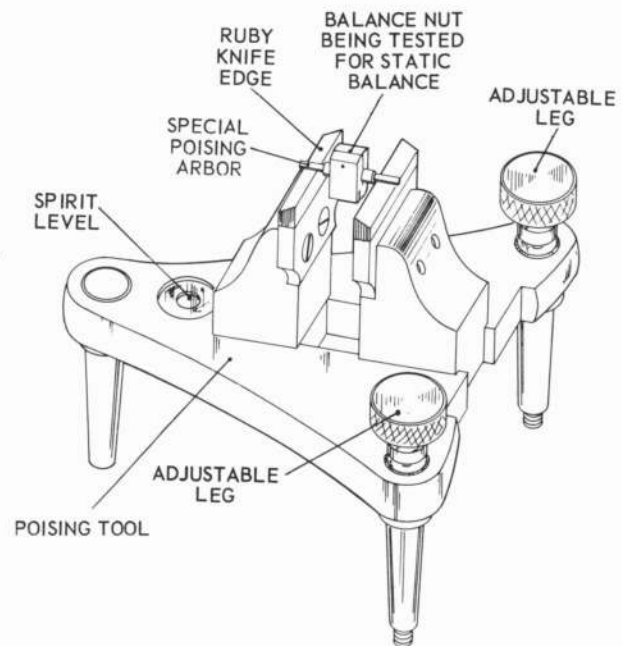


Fig. 4-33. Pictorial view showing how the poising tool is used for statically balancing the balance nuts.

- b. Touch the nut lightly with the edge of a camel's hair brush and observe the behavior of the arbor-nut combination. If the knife edges are not level, the combination will start rolling and pick

up speed. Level the knife edges, by means of the adjustable legs, until the pickup in speed of roll is minimized when the arbor-nut combination is touched with the camel's hair brush.

**Note**

*If the combination is so far off balance that the unbalance offsets the pitch of the knife edges and the combination remains in one spot, this unbalance will have to be reduced first (see step c) before leveling can be accomplished.*

c. Once the leveling procedure is completed, check for the existence of any static unbalance. Such unbalance will be indicated by a tendency of the combination to come to rest repeatedly in a particular position, no matter in what position it is originally placed on the knife edges. Correct for any unbalance by removing material as required from the nut faces that are on the heavy side, that is, below the arbor in the position of rest. This can be done with a fine-pitch file, such as a No. 6 Grobet file. As the unbalance is reduced, the accuracy of the leveling can be improved, using the procedure of step b.

**Note**

*Material should never be removed from the external rounded surfaces of the nuts, since the balance adjustment forks (ref. Fig. 2-1) may then fail to engage the nuts when a finer balance is attempted upon completion of the gyro unit.*

d. Make a final check of the balance by observing whether the nut remains at rest when placed at each of four 90-degree orientations: the two vertical positions and the two horizontal positions.

e. Repeat the procedure of steps a through d for the other small balance nut selected.

f. After the two small balance nuts are checked, remove the gimbal shell and balance assembly combination from its plastic bag (ref. paragraph 4-59b) and thread the selected and tested nuts onto the appropriate studs. Check each balance stud and mating nut to insure smooth threading along the entire length of the stud.

**Note**

*It is recommended that a small amount of Molykote lubricant be applied to the balance studs and that the balance nuts be threaded up and down the studs at least twice to reduce friction.*

g. With a torque wrench (ref. Fig. 3-25), measure the highest turning torque of the two small balance nuts. The maximum allowable torque for

each is 2-1/2 inch-ounces. Also, measure the least turning torque of the same two balance nuts. These four torque-measurement values should be recorded in the Assembly Record Book. No torque measurements are necessary for the two large nuts, as they are not adjustable upon completion of the gyro unit.

h. When everything is satisfactory, rinse the gimbal shell, the balance assembly, and the balance nuts in acetone to remove any dirt or chips. Then place in a clean plastic bag until required for future use (ref. paragraph 4-66a).

4-62. **SELECTING THE MOTOR SPACERS.** Prior to assembling the motor assembly between the prongs of the gimbal fork, two motor spacers are selected and sized so that the fork has to be sprung apart between 0.001 inch and 0.002 inch to permit assembly. This deflection of the prongs is sufficient to insure that substantial portions of the preload to be established will be retained throughout the operating life of the bearings. In this manner, the amount of unbalance torque occurring about the output axis - the axis of the pivots - is minimized, since the preload prevents the rotor assembly from moving along the motor shaft (ref. paragraph 4-18).

4-63. The detailed procedure for selecting the motor spacers is as follows:

a. Measure the opening between the prongs of the selected gimbal fork (ref. paragraph 4-59g) with a telescoping gage (ref. Fig. 3-26) and record the measurement in the Assembly Record Book.

b. Measure with a micrometer the over-all assembled length of the two nominal-sized motor spacers checked earlier (ref. paragraph 4-39), the selected rotor assembly with spin-axis bearings and preload spacers, and the selected motor stator (all packaged together; ref. paragraph 4-40). Record the measurement in the Assembly Record Book.

c. If the second measurement (that of step b) is at least 0.001 inch greater than the first (that of step a) but less than 0.002 inch, the motor spacers are satisfactory. If the second measurement is not at least 0.001 inch greater than the first, locate two motor spacers that will satisfy this dimension requirement. If the second measurement is more than 0.002 inch greater than the first, obtain the

required difference by grinding the surfaces of the spacers. To do this, place each spacer in a wheel chuck and insert the chuck in a jeweler's lathe (ref. Fig. 3-27). With a jeweler's lathe cutting tool, remove the required amount of material. To check for squareness of the surfaces, use a micrometer (ref. Fig. 3-15) to obtain the thickness of the spacer at various places around the circumference.

d. For example, suppose the following dimensions were recorded:

Length of spacers, plus rotor assembly with bearings and spacers plus motor stator; all assembled . . . . .	0.5983 inch
Opening between prongs of gimbal fork . . . . .	0.5960 inch
Difference . . . . .	0.0023 inch

The difference is on the large side, so that the existing motor spacers can be used. However, at least 0.0003 inch will have to be ground from the two spacers so that the spread in the gimbal fork will be between 0.001 inch and 0.002 inch.

4-64. ASSEMBLING THE MOTOR ASSEMBLY IN THE GIMBAL FORK. Figure 4-34 is an exploded view showing the method for assembling the motor assembly in the gimbal fork. The detailed procedure is as follows:

a. Hold the motor upper spacer, rotor assembly (with bearings and preload spacers in place), motor stator, and motor lower spacer as an assembled unit and force slightly as required to insert this combination between the prongs of the gimbal fork.

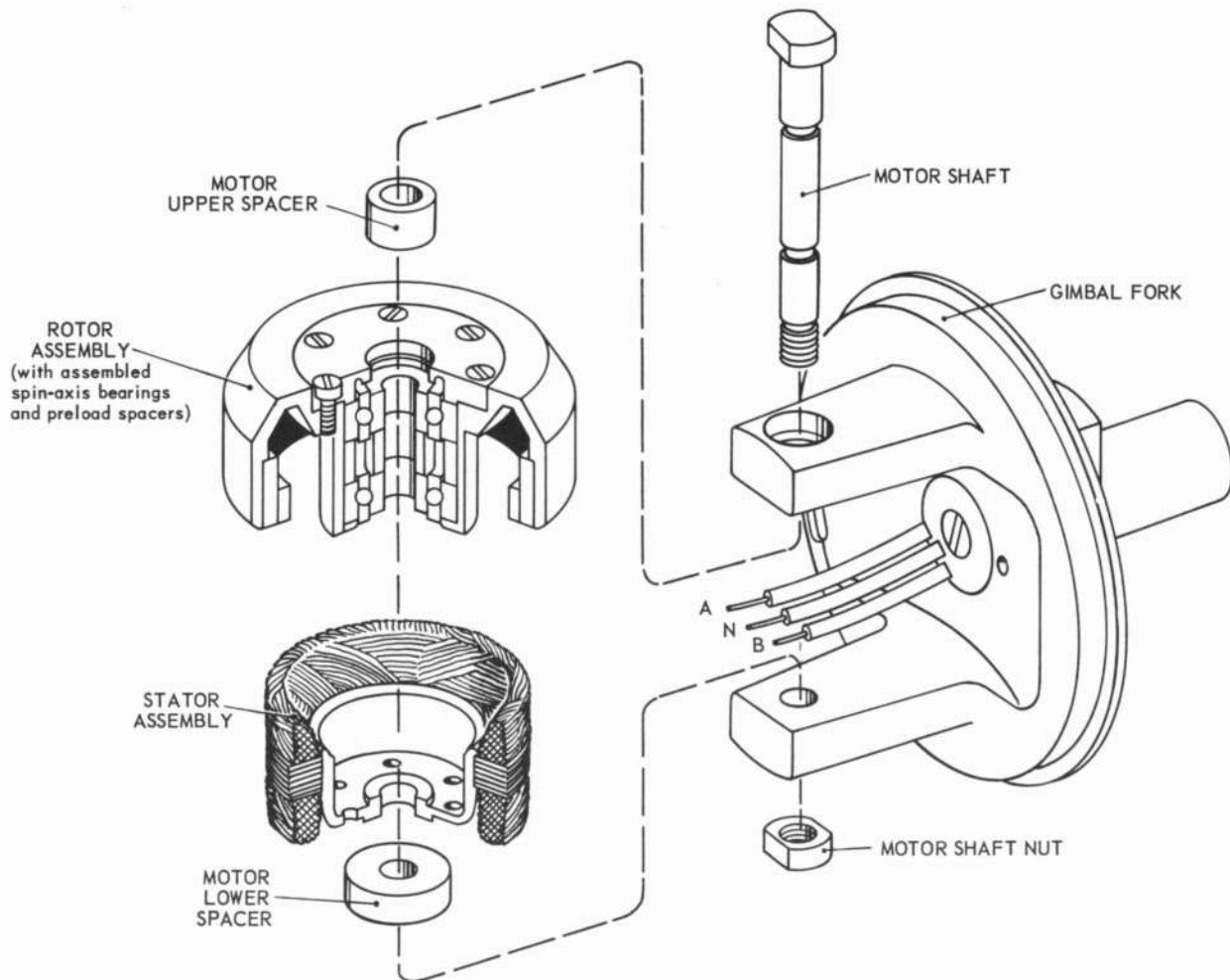


Fig. 4-34. Exploded view showing the method for assembling the motor assembly in the gimbal fork.



b. Align the various components with the motor shaft holes in the gimbal fork, drop the motor shaft into place, and secure with the motor shaft nut.

c. Tighten the motor shaft nut down to 40 inch-ounces using a torque wrench (ref. Fig. 3-28).

**Note**

*Molykote lubricant can be used under the nut to reduce friction.*

d. Make sure that the three power lead-ins clear the rotor.

e. In order to determine whether the motor shaft nut is tightened too much, spin the rotor by hand and count off 5 seconds. The tightness is satisfactory if the rotor does not stop before the end of this 5-second interval.

4-65. MINIMIZING THE PENDULOSITY OF THE FLOATED UNITS ASSEMBLY. Figure 4-35 shows the test setup used to check the pendulosity of the

floated units assembly. The special test fixture is that used in the test setup for measuring float run-out (ref. Fig. 4-29). The vibrator is used to overcome pivot friction. If the amount of pendulosity is satisfactorily small, the entire assembly should remain stopped in any position in which it is placed. If pendulosity is present in a greater degree, it can be readily detected by the fact that the assembly will rotate to a given position, so that the heavy side always hangs down. The unbalance can be minimized by adjusting the position of the motor assembly on the motor shaft in such a way that the balance nuts along the spin axis are centered on their studs. It should be emphasized that this procedure is a rough balance adjustment only. A finer adjustment will be made subsequently in a Fluorolube-filled tank (ref. paragraphs 4-72 and 4-73). The important operation at this stage is to get the motor assembly properly positioned. If not

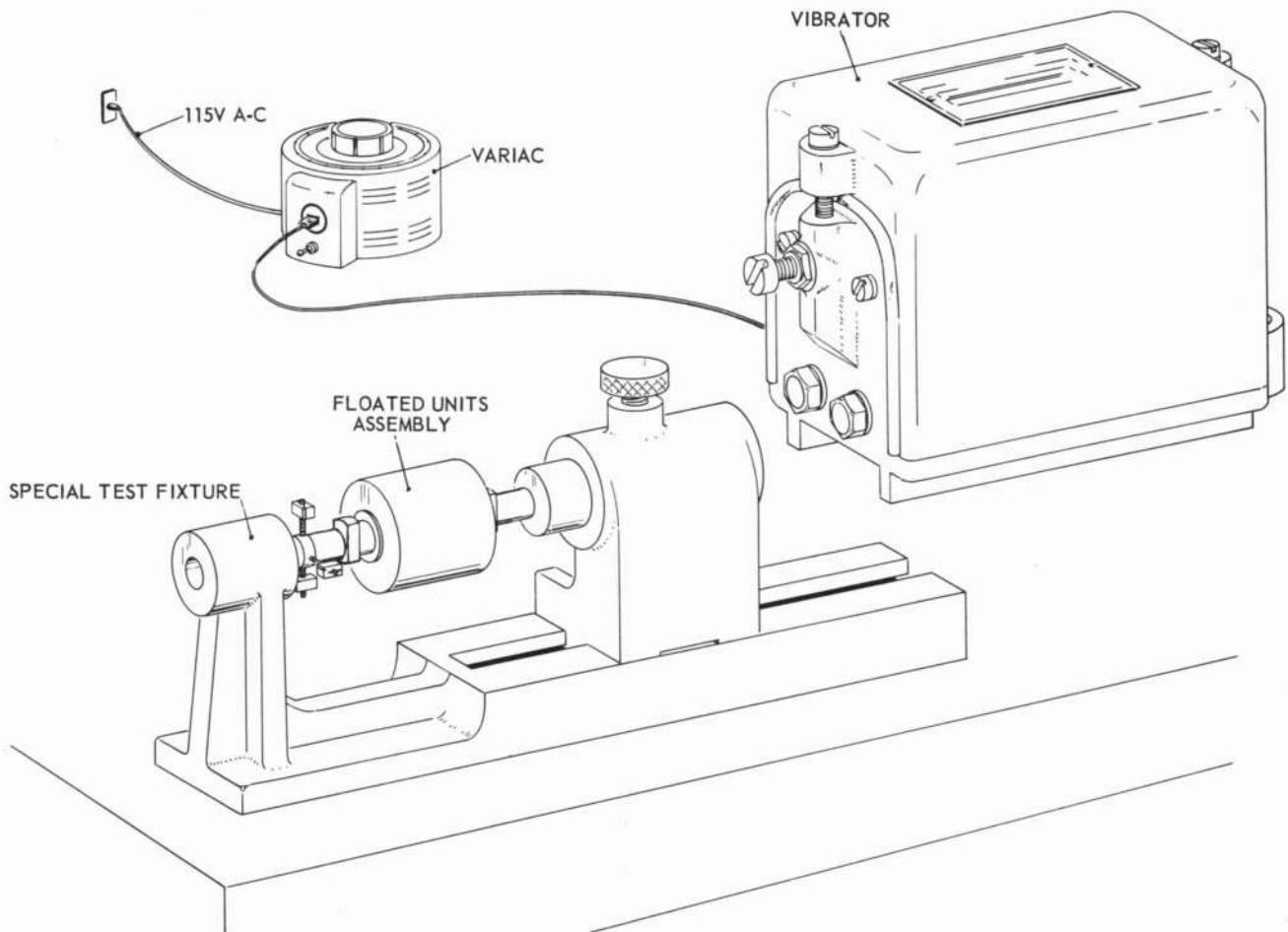


Fig. 4-35. Pictorial view showing the test setup for checking the pendulosity of the floated units assembly.

done now, it will be impossible to do so at the finer-balance-adjustment stage without unsoldering the gimbal fork from the gimbal shell.

4-66. The detailed procedure for minimizing the pendulosity of the floated units assembly is as follows:

a. Remove the gimbal shell - balance assembly combination from its plastic bag (ref. paragraph 4-61h) and temporarily assemble the gimbal fork to the gimbal shell. Obtain correct alignment of the fork and shell by following the procedure given in paragraph 4-58 in connection with the float-runout check.

b. Place the floated units assembly between the two jewel assemblies of the special test fixture as shown in Fig. 4-35. (The vibrator shown in Fig. 4-35 should not be turned on at this stage of the procedure.) Unbalance will be indicated by the heavy side of the floated units assembly always coming to rest in the downward position, no matter in what position the assembly is initially placed. Any pendulosity of the floated units assembly is due to the unsymmetrical distribution of weight about the pivot, or output, axis. The gyro motor assembly and the balance nuts are contributing factors in the unsymmetrical distribution of weight. To obtain the objective of symmetrical weight distribution, a shift of a large balance nut along the input axis and a shift of the motor assembly along the spin axis are employed as corrective measures in the following manner.

c. With the balance nuts along the spin axis centered on their studs and with the small balance nut along the input axis centered on its stud (ref. Fig. 4-32), adjust the large nut along the input axis to bring the total unbalance along the spin axis; this will be evidenced by the spin axis always coming to rest along the vertical. By so doing, the unbalance along the input axis is eliminated and the technician need concentrate on a single-axis unbalance only, rather than on a two-axis unbalance.

d. Note whether it is the positive or negative direction of the spin axis that is in the downward position (ref. Figs. 4-26, 4-31 and 4-32 for identification of the positive direction of the spin axis on an assembled floated units assembly). If the positive direction of this axis is downward, that

is, on the heavy side of the floated units assembly, the motor assembly will have to be shifted down, along the negative direction of the spin axis, with respect to the gimbal fork ("up" being associated with the positive direction of the spin axis). As can be seen from reference to Fig. 4-21, this will require reducing the thickness of the lower motor spacer and using a thicker upper motor spacer. If the negative direction of the spin axis is downward, the reverse holds true; that is, the motor assembly will have to be shifted up with respect to the gimbal fork, along the positive sense of the spin axis. This will require reducing the thickness of the upper motor spacer and using a thicker lower motor spacer. No matter how the individual spacers are changed, however, their combined thickness dimension must remain the same, in order not to upset the bearing preload (ref. paragraphs 4-62 through 4-64).

e. The direction in which the motor assembly must be moved having been determined by step d, the next task is to find the distance the motor assembly must be moved. To do this, minimize the existing unbalance along the spin axis by moving the balance nuts on the spin-axis studs upward, away from the base of the test fixture. Position both of these nuts along the spin axis in such a way that the floated units assembly is statically balanced, that is, always remains fixed in any position in which it is placed. If both nuts have been moved upward as far as they can go without obtaining a balance, remove the balance nut from the spin-axis stud that hangs downward and place it on the upper spin-axis stud. Then adjust the two nuts on this stud as required to obtain static balance.

#### Note

*There are many combinations of nut positions that will yield static balance. Any one of these combinations is satisfactory for carrying out the present procedure.*

f. If the balance nuts are on their respective studs, that is, the large nut along the negative spin axis direction and the small nut along the positive spin axis direction (ref. Fig. 4-32), when static balance is obtained, count the number of threads each nut will have to be moved before it is at the center of its stud.

g. From past experience, a full turn on a large balance nut requires moving the motor assembly 0.0003 inch to obtain a compensating change in moment. A full turn on a small balance nut, on the other hand, requires a shift of the motor assembly of only 0.0002 inch. Therefore, for the condition in step f, the motor assembly will have to be moved a distance equal to 0.0003 inch times the total number of threads counted for the large nut plus 0.0002 inch times the total number of threads counted for the small nut.

h. If the balance nuts are both on the same stud, the procedure of counting threads is not applicable. Instead, measure the distance (in inches) each nut will have to travel before it is at the center of the stud on which it belongs (ref. Fig. 4-32). Then disassemble the gimbal fork from the gimbal shell and remove the motor assembly. Weigh the motor assembly. Weighing the balance nuts is not necessary; it can be satisfactorily assumed for this procedure that a large balance nut weighs 0.3 gram and a small balance nut weighs 0.2 gram. Multiply each nut weight by its respective travel distance and divide this product by the motor assembly weight (in grams) to find the distance (in inches) the motor assembly will have to be moved to compensate for the change in nut position and maintain static balance. If both nuts have to be moved in the same direction to get to their center positions, then the distance the motor assembly will have to be moved is the sum of the two calculated motor-assembly shifts. If the two nuts are not moved in the same direction, the shift in motor assembly position will be the difference of the two calculated shifts.

i. It is now necessary to shift the motor assembly with respect to the gimbal fork by the amount found in either step g or step h, and in the direction determined by step d. Remember, one spacer will have to be cut down, and the other spacer replaced by a thicker one, so that the overall thickness dimension of the spacers is kept the same. To remove the required amount of material from the face of a spacer, use the procedure of paragraph 4-63c. Record the final thickness of each spacer in the Assembly Record Book.

j. Reassemble the floated units assembly and place the assembly between the two jewel assemblies

of the special test fixture. Then turn on the vibrator and observe the motion of the float. If it is statically balanced it should rotate evenly.

k. After satisfactory rotational balance is obtained, take the floated units assembly apart. Package the gimbal shell and associated parts in a clean plastic bag until further required in the assembly procedure (ref. paragraph 4-69a). Disassemble the motor assembly so that the rotor assembly, motor stator, motor spacers, shaft and nut can be weighed.

l. After weighing these parts to the nearest milligram and recording these weights and the total weight in the Assembly Record Book, reassemble the motor assembly between the prongs of the gimbal fork as before (ref. paragraph 4-64).

4-67. CHECKING THE COAST-DOWN TIME AND RUNNING-IN THE BEARINGS. Gyro-rotor coast-down-time procedures have been developed to utilize coast-down time as a measure of 1) satisfactory bearing preload for reducing the possibility of mass shift without overloading the gyro rotor drive motor and 2) the optimum amount of this preload. These procedures require the specification of a satisfactory range of coast-down times after application of preload and also an optimum value of coast-down time. If the coast-down times fall within the specified range, then the preload is specified within limits known to be satisfactory. If the coast-down time is the optimum value, then the preload adjustment is exactly right. A satisfactory range of coast-down times for one type of 20IG unit, for example, has been found to be 10 to 24 seconds. The optimum value of coast-down time for this particular type is 18 seconds.

4-68. The detailed procedure for checking the coast-down time is as follows:

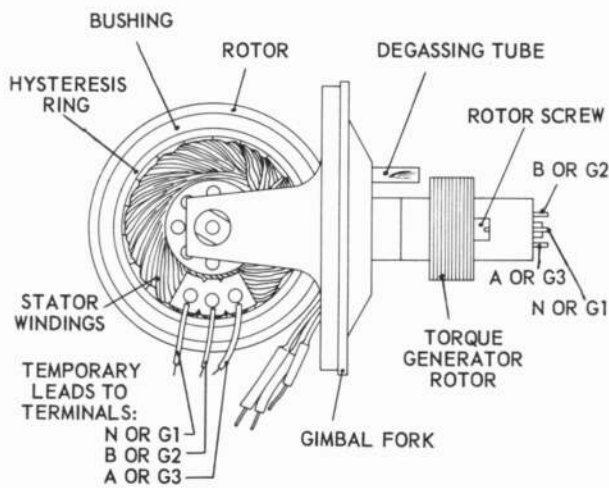
a. Solder three temporary power leads to the gyro motor stator terminals A, B, and N, as shown in Fig. 4-36.

b. Place the gimbal fork - motor assembly combination in the receptacle of a temperature-controlled oven, as shown in Fig. 4-37.

c. Connect the three temporary power leads, inside the oven chamber, to a terminal strip that is appropriately connected to the test console shown in Fig. 4-37.

**Note**

*It is important to connect these wires correctly, that is, terminal A of the motor stator to terminal A of the terminal strip, etc., so that clockwise rotation of the rotor is observed from the terminal side of the motor assembly. With the stator terminals at the bottom when the stator windings are facing the observer, the three motor stator terminals from left to right are N, B, and A (ref Fig. 4-36). There are no terminal identifications on the stator itself. However, there are on the terminal strips.*



**Fig. 4-36.** Side view of the gimbal fork – motor assembly combination as modified for checking coast-down time.

d. In order to operate the gyro motor according to specifications, each phase requires a 6-volt, 400-cps, a-c supply. The phase currents should be equal and not exceed 0.8 ampere per phase (0.4 ampere per phase for high-impedance motors). Adjust the output of the test console to meet these requirements.

e. Run the motor for 15 minutes inside the oven chamber.

f. Then shut off the power input and at the same time obtain the coast-down time by timing the interval elapsed between power shut-off and the stopping of the rotor. If the coast-down time is within the satisfactory range of operation (ref. paragraph 4-67), the preload is sufficient, although attempts should be made to attain the optimum value. If the coast-down time lies below the range

specified for the particular gyro unit, the preload is too much. If the coast-down time lies above the range specified, the preload is insufficient.

g. To obtain the required preload, in the event that the coast-down time lies outside the specified range, check that the bearing retainer is screwed down tightly and evenly. Then readjust the motor shaft nut if necessary to a 40 inch-ounce torque with a torque wrench (ref. Fig. 3-28). If the motor assembly is tightened to this limit, satisfactory preload on the bearings should be obtained, provided the bearings are functioning properly, because the preload is a function of the difference in widths of the inner and outer preload spacers (ref. paragraph 4-18). If the coast-down time still does not fall within the specified range, however, disassemble the motor assembly and inspect for any dirt deposits. If dirt is not the source of the trouble, the bearings are probably at fault. This means replacing the selected bearing set (ref. paragraph 4-21d) with an identical set. Just as heat was required to assemble the bearings and preload spacers (ref. paragraph 4-33), so will it be necessary to apply heat in order to remove them.

**Note**

*It may well be impossible to obtain the optimum value of coast-down time. However, the final value of coast-down time must lie within the satisfactory range specified.*

h. In order to simulate actual operating conditions inside the oven chamber, adjust the gauge pressure and temperature to 1 pound per square inch of helium and 168° F, respectively. Allow the motor assembly to come up to heat, which takes approximately one hour. Then, with a stethoscope (ref. Fig. 3-32) placed against the chamber window, listen to the motor for the purposes of detecting any unusual gritty or erratic tone, which is an indication of motor failure. The motor should have a smooth, dry, metallic whine.

i. Check the coast-down time again. If the coast-down time is found to be satisfactory, run the motor for a period of 40 hours. At the end of each 10-hour period, record the date, time, volts, amperes, and coast-down time. The reason for this run-in period is that previous experience has shown that any bearing failure is most likely to occur during this 40-hour run-in period.

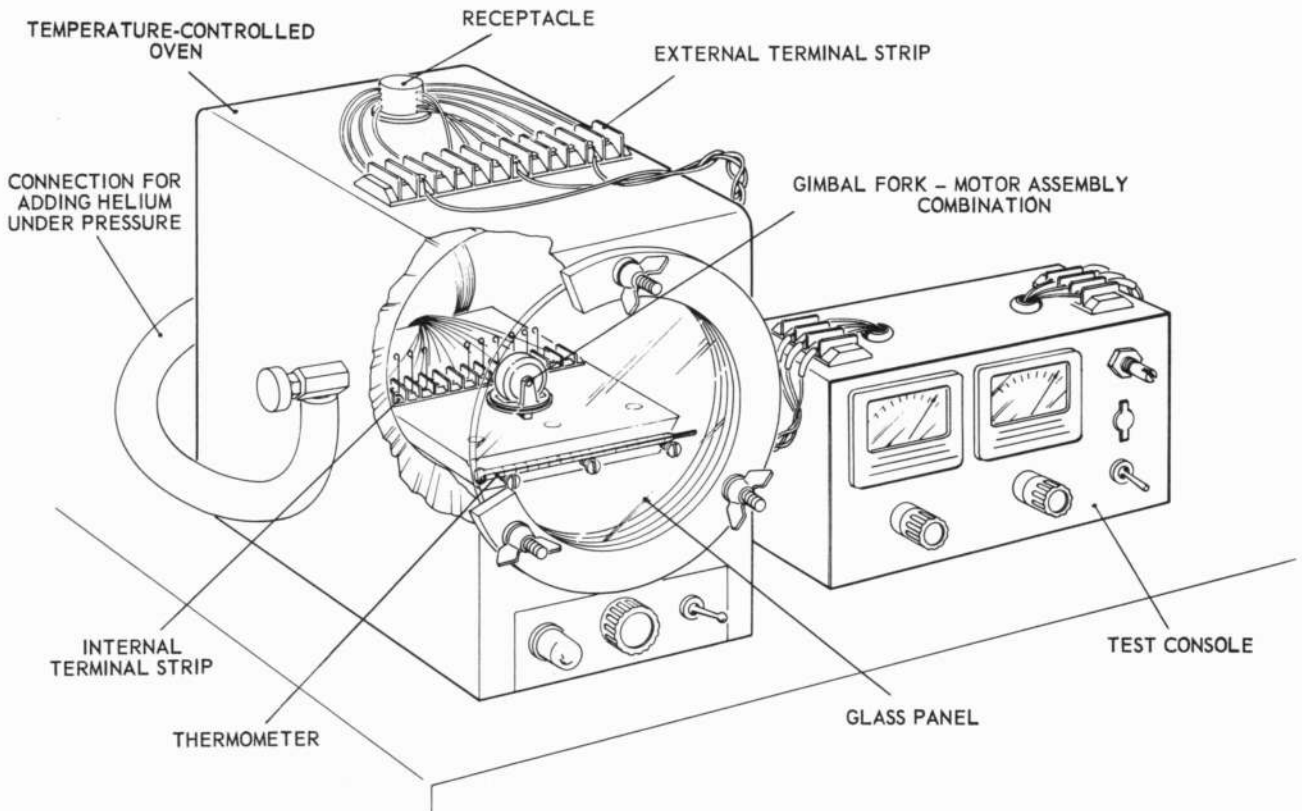


Fig. 4-37. Pictorial view showing how the gimbal fork - motor assembly combination is mounted in the temperature-controlled oven when checking coast-down time.

j. When the run-in period is over, remove the gimbal fork - motor assembly combination from the oven and unsolder the three temporary leads. With the motor assembly and power lead-ins in the relative positions shown in Fig. 4-36, solder lead A to terminal A, etc., making certain that the lead-ins clear the rotor satisfactorily. (Refer to Figs. 4-30 and 4-36 to identify the terminals of the motor stator and the power lead-ins of the power lead-in body.)

**4-69. ASSEMBLING THE GIMBAL FORK, GIMBAL SHELL, AND ASSOCIATED PARTS.** The procedure for assembling the floated units assembly has now reached the point where the gimbal shell should be permanently attached to the gimbal fork. This is done by an induction-soldering procedure similar to that used for assembling the power lead-in body in the gimbal fork (ref. paragraph 4-56). The detailed steps of this procedure are as follows:

a. Remove the balance assembly from the shaft of the checked-out gimbal shell (ref. paragraph 4-66k), as it interferes with the soldering procedure.

b. Coat the inside diameter of the shell as follows. Attach a collet to the shaft of the gimbal shell and place the collet in the head stock of a jeweler's lathe (ref. Fig. 3-27). Then heat the outside circumference of the shell at the open end with a soldering iron. Coat the inside diameter at this end with soldering flux. While another person turns the pulley of the lathe slowly, run solder around the inside diameter of the shell at the end, wiping off the excess solder with a towel.

c. Mount the gimbal shell on a standard bench block, which has been placed in a specially constructed positioning device. Use the same setup that is shown in Fig. 4-24, mounting the gimbal shell on the block, instead of the soldering fixture.

d. Mount the gimbal fork - motor assembly combination inside the gimbal shell, but do not insert all the way. Obtain correct alignment of the fork and shell by following the procedure given in paragraph 4-58 in connection with the float runout check.

e. Support a soldering machine (ref. Fig. 3-18), which contains an appropriate-size induction

soldering coil, so that the coil fits around the gimbal shell (this is similar to the setup used in Fig. 4-24).

f. For fine positioning, turn the handle of the positioning device to raise or lower the gimbal shell - gimbal fork combination with respect to the induction soldering coil.

g. By means of the soldering machine, heat the gimbal shell - gimbal fork combination sufficiently to melt the tip of a length of 50/50 solder when it is fed into the groove left between the external surfaces of the gimbal fork and gimbal shell at their juncture.

*Note*

*For the detailed steps of the soldering procedure, see steps e through j of paragraph 4-84. For the present procedure, the dummy load should consist of a discarded gimbal shell and a discarded gimbal fork that have been assembled together and placed on the positioning device.*

h. Feed the melted tip of the soldering wire into the groove along its entire circumference. Then push the gimbal fork down until it firmly mates with the gimbal shell.

i. Turn off the soldering machine and allow the gimbal shell - gimbal fork combination to cool to room temperature.

j. At this point, scrape off the excess solder from the outside diameter of the shell. To do this, add collets to the shafts of the floated units assembly and mount the assembly in a jeweler's lathe (ref. Fig. 3-27). With a dental chisel held by hand in a scraping position (not a cutting position), scrape off the excess solder while the floated units assembly is rotating in the lathe. Then polish the outside surface of the gimbal shell, thereby removing the copper plating. This can be done with lathe oil poured on the outside surface and a fine piece of emery paper wrapped around the surface while it is in motion.

k. Obtain the Microsyn torque motor rotor and the Microsyn signal generator rotor from their respective plastic bags (ref. paragraph 4-45e) and locate them on the floated units assembly as indicated in Fig. 4-21. Each rotor is scribed with an "X", as shown in Fig. 4-21. Fasten each rotor in place with the "X" marking along the negative direction of the spin axis and facing toward the

gimbal shell. At this point in the assembly procedure, it is unimportant which of the five available types of rotor clamping screws (ref. paragraph 4-73 and Table 4-4) is used to secure the Microsyn rotors. From the standpoint of rotational balance, however, it is best that the same type be used for all four screws.

l. Reassemble the balance assembly to the end of the gimbal shell shaft, maintaining the original orientation (ref. paragraphs 4-57 and 4-58).

4-70. EVACUATING THE GIMBAL SHELL AND ADDING HELIUM UNDER PRESSURE. As noted in Section II (ref. paragraph 2-9), the gyro motor assembly of the assembled gyro unit is surrounded by helium inside the hermetically sealed gimbal shell. The required evacuation of air and addition of helium are accomplished by means of the vacuum-pump arrangement represented pictorially in Fig. 4-38 and schematically in Fig. 4-39. The detailed steps of this procedure are as follows:

a. Secure a short piece of plastic tubing to the degassing tube that protrudes from the gimbal-fork flange (ref. Fig. 4-38).

b. Connect a length (as required) of 1/4-inch inner-diameter rubber tubing from the corrugated outlet of the gyro unit valve (ref. Fig. 4-38) to the short length of plastic tubing on the degassing tube.

c. Connect these two pieces of tubing with a special tubing connector.

d. Connect a length (as required) of 1/4-inch inner-diameter rubber tubing from the corrugated outlet of the helium pressure flask to the gas valve (ref. Fig. 4-38).

e. With the pump valve closed, the vent valve closed, the gas valve open, and the gyro unit valve open, apply 15 pounds per square inch (as indicated by the combination pressure-vacuum gage) to the gimbal shell, using the outlet valve of the helium pressure flask (ref. Fig. 4-39). Give the floated units assembly a preliminary test for leakage by submerging it in hot water and observing for bubbles. If bubbles appear, dry the assembly, fix the leaks with solder and retest for leakage.

*Note*

*Helium is not soluble in hot water, but is in cold water. Thus, escaping bubbles can be more readily detected in hot water.*

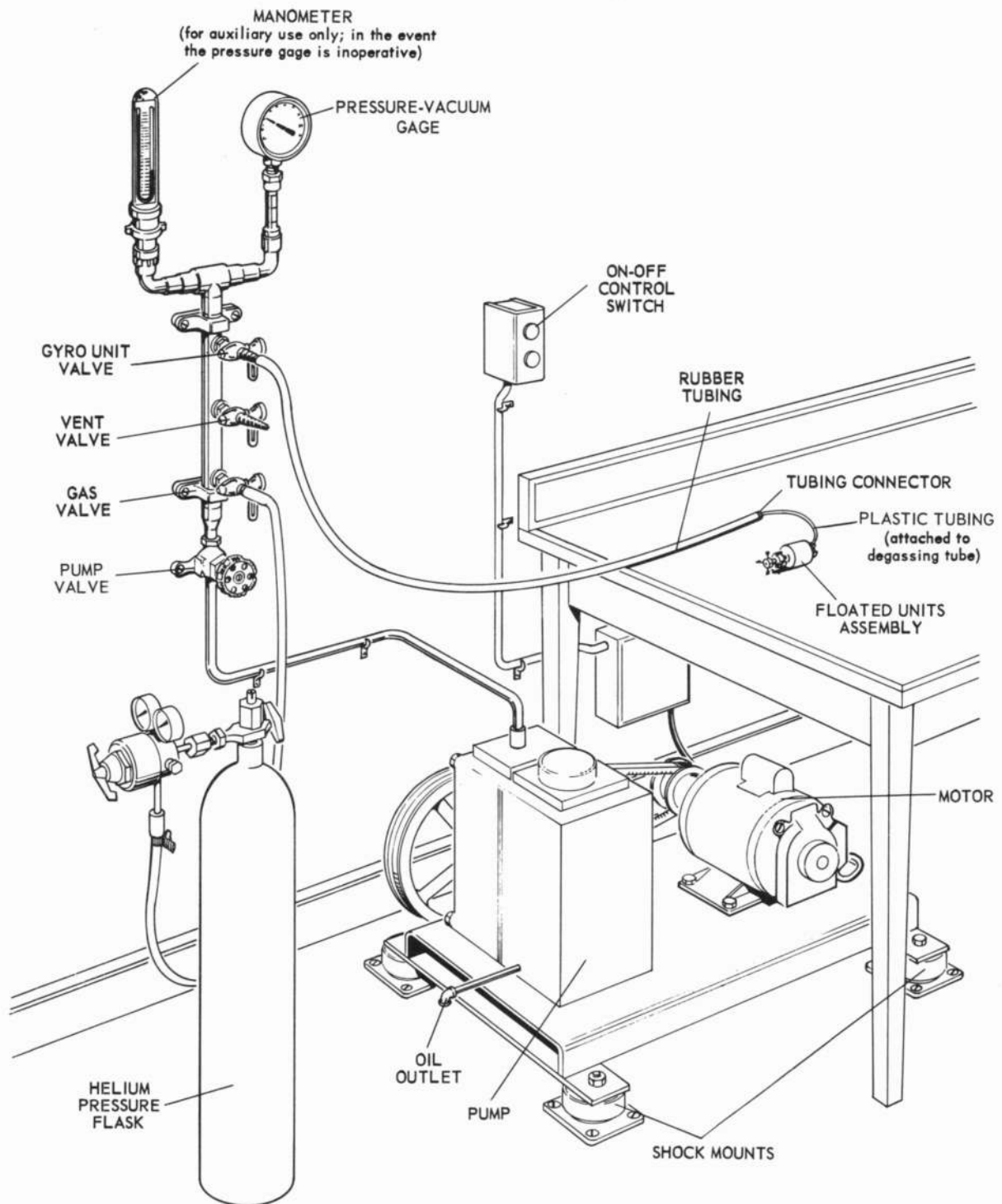


Fig. 4-38. Pictorial view of the vacuum-pump arrangement used in the gimbal-shell evacuation-pressurization procedure.

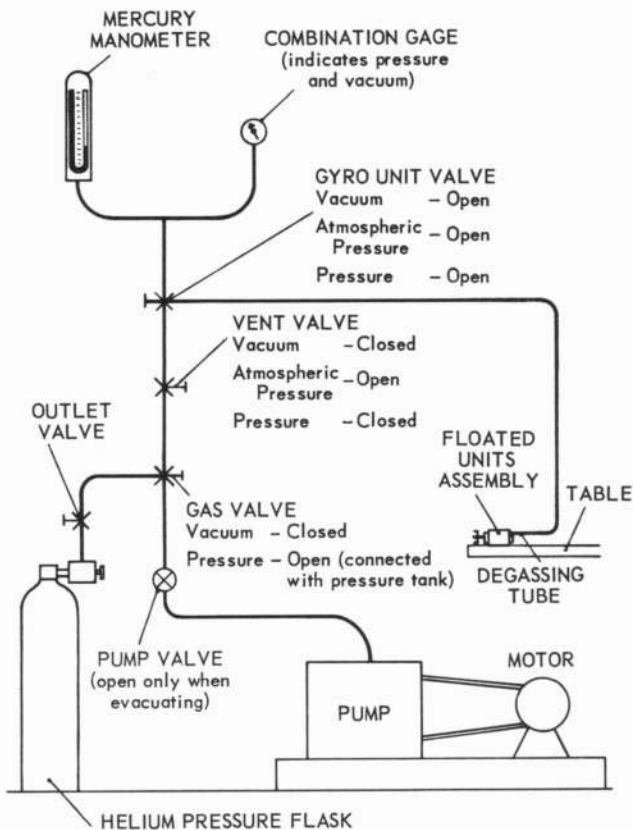


Fig. 4-39. Schematic view of the vacuum-pump arrangement used in the gimbal shell evacuation-pressurization procedure.

f. With the pump valve open, the gas valve closed, the vent valve closed, and the gyro unit valve open (ref. Fig. 4-39), start the pump motor and exhaust the air from the gimbal shell until the combination pressure-vacuum gage gives a steady reading. This indicates that the best vacuum obtainable has been reached.

g. Shut the pump valve (the pump may be left running); then open the gas valve and the outlet valve of the helium pressure flask until a pressure of 3 pounds per square inch is obtained.

h. Repeat steps f and g at least two times, with decreasing gas pressures of 2, and then 1, pounds per square inch.

**Note**

*The cyclical process of evacuating and filling with helium is performed so as to be sure there is no air trapped with the helium. The more times this operation is performed, the less chance of any air being left inside the float.*

i. As soon as the combination pressure-vacuum gage indicates a pressure of 1 pound per square inch (gage), crimp the degassing tube with

a pair of pliers, so that the gimbal shell is completely sealed, and close the outlet valve of the helium pressure flask.

j. Seal the end of the crimped degassing tube with solder.

k. After the degassing tube is sealed, apply a rigorous leakage test by means of a General Electric Company Mass Spectrometer (ref. Fig. 3-34). Follow the detailed operating instructions for this equipment that are furnished by the manufacturer.

**Note**

*This specialized piece of apparatus is used for detecting and locating extremely small leaks in vacuum and pressure systems. Since detailed operating instructions are provided by the manufacturer, they are not repeated here. However, for the benefit of those who may be interested, the pertinent principles of operation for the present application are summarized in the following paragraph.*

4-71. In the Mass Spectrometer leakage test, the floated units assembly is placed in an evacuated bell jar that is an auxiliary part of the Mass Spectrometer equipment. Any leakage of helium through the gimbal shell into the bell jar goes into the Mass Spectrometer proper through a connecting tube. In the Mass Spectrometer, a portion of the helium molecules is ionized (an electron is removed from each of these molecules). The resulting helium ions are focused into a narrow beam by a magnetic field and are accelerated by an electrostatic field. The accelerated ions in the beam pass between the poles of a magnet that deflects the helium ions 90 degrees, so that they pass through a collector slit. Ions of other gases that may have been present with the helium are deflected either more or less than 90 degrees and do not pass through this slit. The helium ions give up their charge to a collector plate, causing an electric current to flow. This current is amplified and fed to instrumentation that registers the concentration of any helium leaking from the gimbal shell. The greater the registered concentration, the greater is the size of the leak. The Mass Spectrometer is sensitive enough to detect leak rates as low as  $5 \times 10^{-10}$  (that is, 0.0000000005) cubic centimeter per second.

4-72. OBTAINING A BALANCE IN FLUOROLUBE. During an earlier state of the assembly procedure, a rough rotational balance of the floated units assembly was effected in air (ref. paragraphs 4-65



and 4-66). It is entirely possible that this balance has been upset by the subsequent soldering, evacuating, and pressurizing procedures (ref. paragraphs 4-69 and 4-70). In addition, the assembly has not yet been balanced end for end. Therefore, at this stage the floated units assembly is given end-for-end and rotational balancing in the same type of Fluorolube as is used later to fill the gyro unit. The test fluid is contained in a thermally-controlled aluminum tank (ref. Fig. 4-40) that is mounted on a level surface. In the base of the tank, symmetrically located with respect to its centerline, are two heaters. These heaters are connected to a 110-volt, 60-cps, a-c outlet. A thermostat controls the temperature. A thermometer resting in a drilled hole in the tank should indicate a temperature of 165°F to insure a fluid temperature of

160°F. Mounted at each end of the tank at an offset distance from the centerline of the tank are two jewel assemblies, similar to the jewel assembly in the signal generator end housing. The purpose of this offset distance is to enable the floated units assembly to be driven by convection currents in the Fluorolube. End-for-end balance is attained when the floated units assembly rests horizontally when floating submerged in the Fluorolube. Any end-for-end unbalance tendency can be eliminated by means of a selection of rotor clamping screws. Rotational balance is effected with the floated units assembly supported by its pivots in the Fluorolube. It is attained when the times required for quarter revolutions of the float are made as equal as possible. Adjusting the weight of the floated units assembly so that it is floating submerged in the Fluorolube

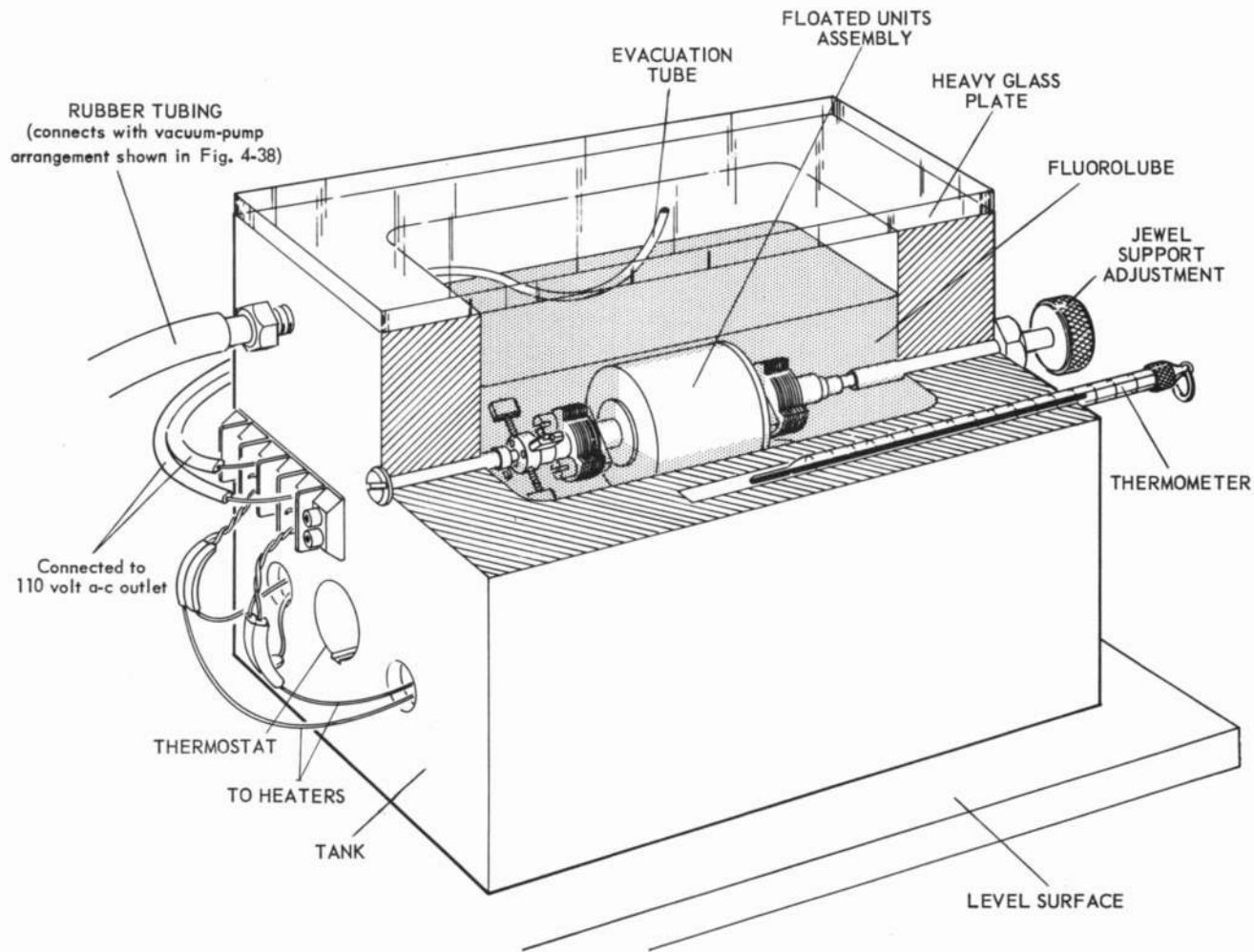


Fig. 4-40. Pictorial view of the Fluorolube-filled tank used for obtaining end-for-end and rotational balancing of the floated units assembly.

will cause it to be almost perfectly supported by buoyant forces in the assembled gyro unit. This will reduce the load on the pivots to a minimum.

4-73. The detailed steps of the balancing procedure in Fluorolube are as follows:

a. Plug the heater wires of the aluminum tank into a 110-volt a-c electrical outlet. Adjust the thermostat located in the base of the tank with a screwdriver to give a tank-thermometer reading of 165°F.

b. Wash the floated units assembly in Trichloroethylene to remove any dirt or other foreign matter. Then place the assembly in the Fluorolube-filled aluminum tank, as shown in Fig. 4-40.

c. Observe the motion of the assembly; at this point it should be heavy enough to sink. If the assembly does not sink, remove it from the tank with a pair of tongs, meanwhile allowing the Fluorolube to drain back into the tank. Wash the assembly in Trichloroethylene to remove any excess Fluorolube.

d. Select heavier Microsyn rotor clamping screws (ref. Table 4-4) so that the floated units assembly will sink in the Fluorolube. Try to select screws that will make the assembly come to rest midway between the top of the Fluorolube surface and the bottom of the tank.

e. When the floated units assembly has been made heavy enough to sink, leave it in the tank.

f. Since it is possible that the assembly has been frequently exposed to the atmosphere and washed in Trichloroethylene, it is necessary to remove the air and Trichloroethylene vapor (both soluble in Fluorolube) from the Fluorolube. This is done to obtain a homogeneous fluid, so that an accurate balance (end for end, and rotational) can be obtained.

g. To evacuate the tank, first seal the tank top with a heavy glass cover. Then connect an appropriate length of rubber tubing from the gyro unit valve of the vacuum-pump arrangement used earlier (ref. Figs. 4-38 and 4-39) to the outlet connection near the top of the tank.

h. Operate this arrangement by the procedure given in paragraph 4-70 for evacuating the gimbal shell. As soon as the bubbles have disappeared from the Fluorolube, stop the motor, open the vent valve to prevent the pump oil from being sucked up into the vacuum lines, and remove the glass cover.

Note

*The glass cover could not be lifted off if atmospheric pressure were pushing down on the top of the cover while a vacuum existed on the underside. Opening the vent valve equalizes the pressures.*

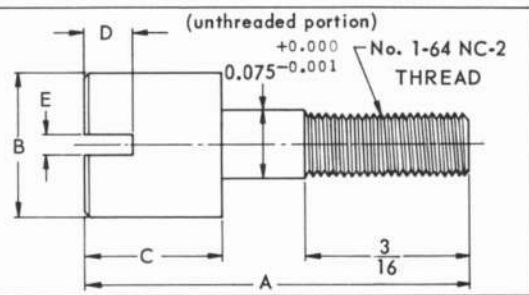
i. The next procedure is to obtain the proper weight for the floated units assembly and to effect an end-for-end balance of the assembly in Fluorolube. A pair of analytical balances (ref. Fig. 4-41) is used for this purpose. Place the Fluorolube-filled tank (ref. Fig. 4-40) inside the glass case containing the balances so that it is centered beneath the chains. Adjust the two chain lengths such that the hooks on the chain ends are midway between the top of the Fluorolube surface and the bottom of the tank when the scale pointers are at zero.

j. When the balances are adjusted, secure the beams and support the floated units assembly at each pivot by means of the hooks on the two chains. Because the assembly is heavy, the chains will lower into the Fluorolube and the pointers will swing from the zero position when the beams are released.

k. Add weights as required to both pans so that the assembly rests in a horizontal position midway

Table 4-4. Types of rotor clamping screws.

Type	Material	Dimensions (inches)					Nominal Weight (grams)
		A	B	C	$D_{-0.000}^{+0.005}$	$E_{\pm 0.003}$	
1	Aluminum 24S T4	7/16	0.165	0.125	0.080	0.022	0.155
2	Tantalum	15/32	0.165	0.156	0.055	0.022	1.140
3	No. 303 Stainless Steel	15/32	0.165	0.156	0.055	0.022	0.550
4	No. 303 Stainless Steel	0.378	0.115	0.067	0.025	0.022	0.220
5	No. 303 Stainless Steel	0.440	0.115	0.120	0.080	0.027	0.296



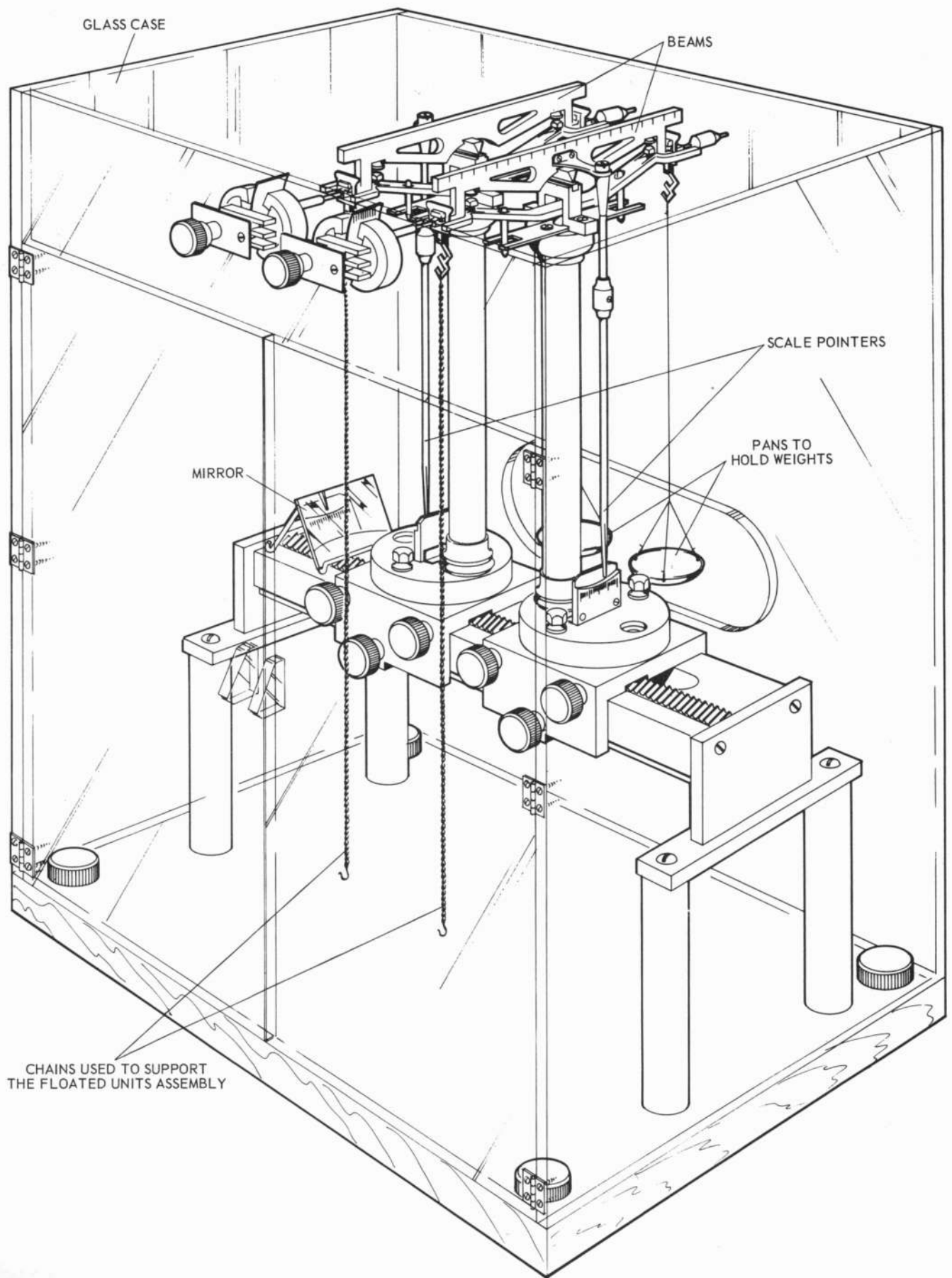


Fig. 4-41. Pair of analytical balances used for the balancing procedure in Fluorolube.

between the top of the Fluorolube and the bottom of the tank. This horizontal position is obtained when both balance pointers are at zero.

l. Observe the weights in the pans. The pan containing the larger weight indicates the heavy end of the floated units assembly. If the total weight in the pans is 75 milligrams or less, the weight of the floated units assembly is satisfactory. The 75-milligram weight is as close to an accurate zero reading as the balances will allow, because the weight of the Fluorolube collected on the chains is not a constant quantity.

m. If the total weight in the pans exceeds 75 milligrams when the floated units assembly is balanced end for end, the rotor clamping screws will have to be modified in one, or possibly more than one, of the following ways, depending on the amount of unbalance.

1) By removing metal from the rotor clamping screws (working always at the heavy end).

2) By changing the rotor clamping screws (ref. Table 4-4).

3) By making new rotor clamping screws as required.

*Note*

*In making these modifications, always attempt to reduce the weight of the heavy end of the floated units assembly. This will simplify the end-for-end adjustment to be made in the following step.*

n. Once the total weight in the pans is reduced to 75 milligrams or less, remove weight from the Microsyn rotor screws at the heavy end of the floated units assembly until end-for-end balance is obtained. This will be indicated by equal weights in the two pans.

o. To test for rotational balance, place the floated units assembly in the Fluorolube-filled tank so that its pivots are supported in the jewel assemblies in the ends of the tank. Start the check with the four adjustable balance nuts at the midpoints of their total travel.

p. As soon as the convection currents have established what seems to be a fairly constant rotation of the floated units assembly, determine with a stop watch the time durations required for a particular balance stud to rotate through each quadrant of a complete rotation. Adjust the rough balance nuts - the large balance nuts along the negative spin axis and negative input axis directions

(ref. Fig. 4-32) - so that each quarter rotation takes the same time. Leave the small balance nuts, which lie along the positive directions of these axes, in their midpositions. This will allow the maximum possible fine adjustment after final assembly is completed.

*Note*

*If balance cannot be satisfactorily achieved, a substitution may have to be made for one or both of the rough balance nuts (ref. paragraph 4-60 for the sizes available).*

q. After the desired balance is obtained, remove the floated units assembly from the tank with tongs and let the Fluorolube drain back into the tank. Once again, wash the assembly in Trichloroethylene to remove the Fluorolube and then package the assembly in a clean plastic bag pending further use in the assembly procedure (ref. paragraph 4-88).

#### 4-74. HOUSING ASSEMBLIES AND ASSOCIATED COMPONENTS.

4-75. PROCEDURE FOR ASSEMBLING THE HOUSING ASSEMBLIES AND ASSOCIATED COMPONENTS. As shown in the description of the 20IG gyro unit given in Section II, the entire housing of this gyro unit is of a three-piece construction that consists of the following:

- a. Signal generator end housing.
- b. Main housing.
- c. Torque motor end housing sleeve.

Associated with the signal generator end housing are various other parts, which when assembled together form the signal generator end housing assembly (ref. paragraphs 2-38 through 2-43). Similarly, the main housing and its associated parts form the main housing assembly (ref. paragraph 2-25). The torque motor end housing sleeve (ref. paragraph 2-21) is a self-contained part of the over-all housing and has no associated parts.

4-76. Associated with the aforementioned housing assemblies are the remaining "fixed" components of the 20IG gyro unit, that is, those components that do not rotate with respect to the gyro unit housing as the floated unit assembly does. These include the following (ref. paragraph 2-14):

- a. Outer case cap.
- b. Outer case assembly.
- c. Diaphragm assembly.

- d. Four torque motor tie rods.
- e. Torque motor end housing cap assembly.
- f. Power lead baffle assembly.
- g. Two Microsyn filler blocks.
- h. Microsyn torque motor stator assembly.
- i. Four signal generator tie rods.
- j. Shield No. 1.
- k. Shield No. 2.
- l. Microsyn signal generator stator assembly.
- m. Two balance fork plugs.

The "fixed" components together with the floated units assembly, whose assembly is described in preceding paragraphs of Section IV, comprise the entire 20IG unit.

4-77. Some of the "fixed" components, such as the outer case cap for example, come as a complete unit and need no assembly procedure. Other "fixed" components, such as the Microsyn torque motor stator assembly and the Microsyn signal generator stator assembly have their assembly procedure covered under the section entitled "Microsyn Units" (ref. paragraphs 4-41 through 4-50). The remainder of Section IV is given over as follows to those components of the 20IG unit that still require assembly procedures:

- a. Assembling the signal generator end housing assembly (ref. paragraphs 4-78 through 4-93).
- b. Assembling the main housing assembly (ref. paragraphs 4-94 through 4-99).
- c. Assembling the power lead baffle assembly (ref. paragraph 4-100).
- d. Assembling the torque motor end housing cap assembly (ref. paragraph 4-101).

4-78. **ASSEMBLING THE SIGNAL GENERATOR END HOUSING ASSEMBLY.** As described in Section II (ref. paragraphs 2-38 through 2-43), the signal generator end housing assembly comprises the following component parts:

- a. Signal generator end housing.
- b. Two balance adjustment forks.
- c. Signal generator end jewel assembly.
- d. Four fork retaining pins.
- e. 20-pin connector.
- f. Two O-rings.
- g. Wire leads.
- h. Jewel holder extractor.

- i. Two O-ring pressure washers.
- j. Two O-ring pressure screws.
- k. Wire-mesh strainer.

4-79. The procedure for assembling these component parts individually and then together to form the complete signal generator end housing assembly comprises the following steps:

- a. Preparing the 20-pin connector for assembly to the signal generator end housing (ref. paragraphs 4-80 and 4-81).
- b. Preparing the signal generator end housing for assembly to the 20-pin connector (ref. paragraphs 4-82 through 4-84).
- c. Assembling the 20-pin connector to the signal generator end housing (ref. paragraphs 4-85 and 4-86).
- d. Assembling the signal generator end jewel assembly in the signal generator end housing (ref. paragraphs 4-87 through 4-89).
- e. Assembling the two balance forks in the signal generator end housing assembly (ref. paragraphs 4-90 and 4-91).
- f. Cleaning the assembled signal generator end housing assembly (ref. paragraphs 4-92 and 4-93).

4-80. **PREPARING THE 20-PIN CONNECTOR FOR ASSEMBLY TO THE SIGNAL GENERATOR END HOUSING.** The 20-pin connector - or the "fusite" as it is sometimes called - is received for assembly in the form described in paragraph 2-42. That is, it is comprised of a disc, 20 electrode pins and a key. To ready the connector for assembly to the signal generator end housing, it is necessary to solder the various power and signal leads to the connector pins. Only 19 leads are required since one of the 20 pins is used for filling the gyro with flotation fluid (ref. Section VII). The wire gauge of the power leads used in wiring the connector is A.W.G. No. 28 wire, and is received from the manufacturer on spools.

4-81. The detailed procedure for wiring the connector is as follows:

- a. Cut 19 lengths of wire, each approximately 5 inches long, from the wire spools.
- b. Strip about one-quarter inch of booting from each end of the 19 wires.

**Note**

Check to see that none of the original seven strands that make up the No. 28 wire has been cut off or nicked during the stripping process.

c. Flux each end of the 19 wires with a noncorrosive soldering flux and tin them with 50/50 solder (50 percent tin, 50 percent lead).

d. Feed the 19 wires through the connector pins from the back side of the connector (this is the

side opposite the projecting pins). The location of the filling-connection pin, which is the only pin not to receive a wire, is shown with respect to the key on Fig. 4-42.

e. Insert each wire until about one inch of wire projects beyond the end of the pin.

f. Then bend the protruding tinned portion of the wire so as to form an eyelet or loop. A pair of

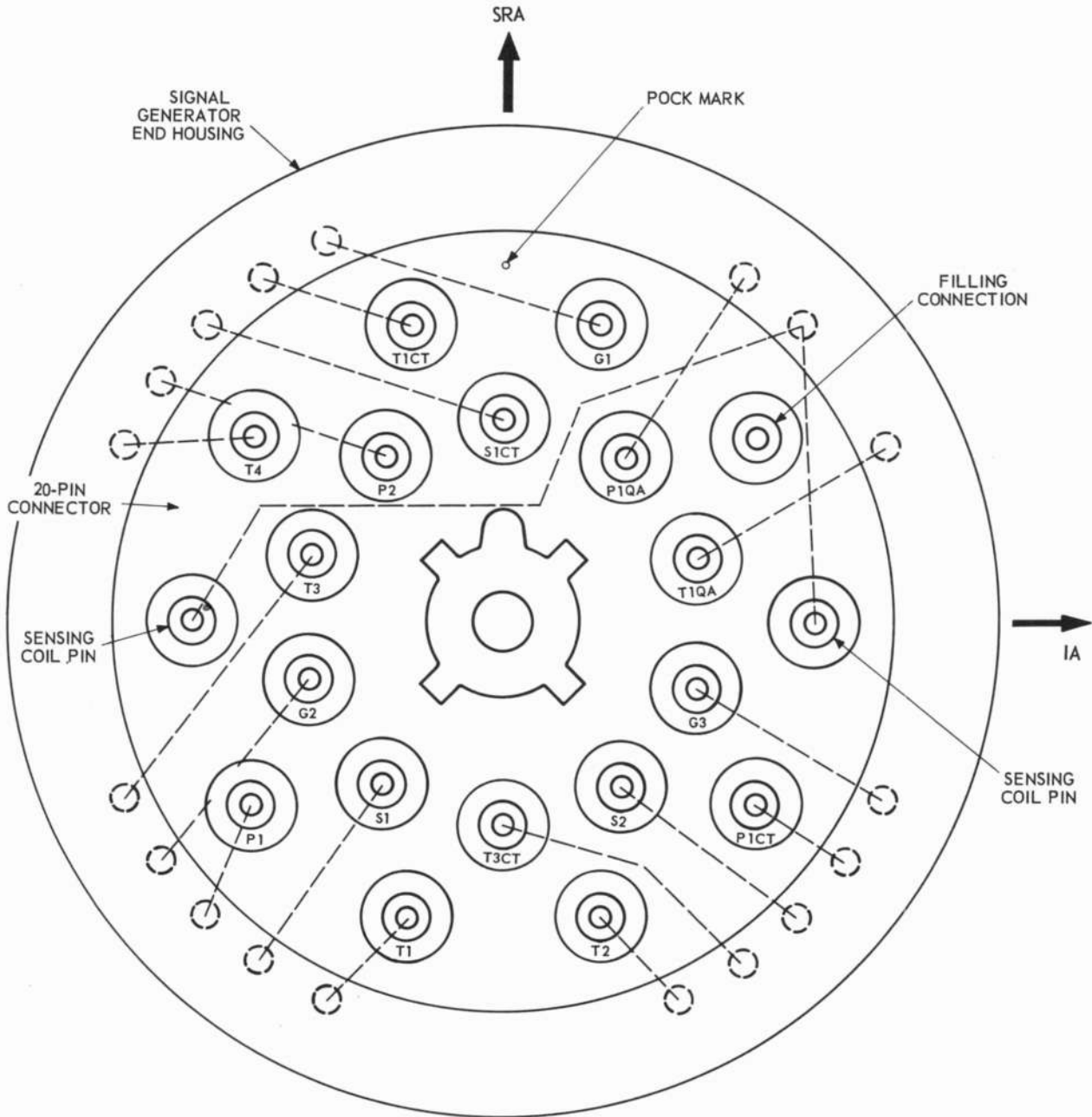


Fig. 4-42. Wiring diagram identifying the terminal pins of the 20-pin connector and showing the manner in which the power and signal leads are threaded through the signal generator end housing.

tweezers is an ideal tool to use in forming the eyelet. See Fig. 4-43a for the shape of this eyelet or loop.

g. After all the 19 loops have been formed, retract the wires so that only a small portion of each loop is visible above its pin (ref. Fig. 4-43b).

h. Apply solder flux with a piece of peg wood to each of the 19 holes that contain wire leads, and then fill these holes with solder (ref. Fig. 4-43c).

*Note*

*Be sure not to use too much solder as the pins will then be too large to fit into the matching female receptacle used with the gyro unit.*

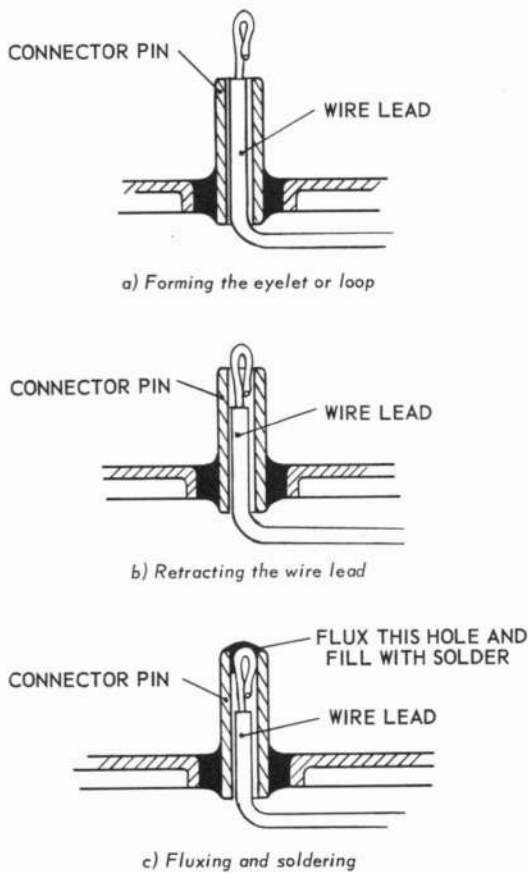


Fig. 4-43. Pictorial views showing the procedure for soldering the power and signal leads to the 20-pin connector.

i. For the time being, screw a small set screw (No. 0-80 NF-2  $\times$  1/4 inch, brass, fillister head, machine screw) tightly into the filling-connection pin to plug it up. This screw will be removed later (ref. Section VII) for the purpose of

filling the gyro with flotation fluid, after which it will be replaced and soldered to the connection pin.

j. As the final step in preparing the 20-pin connector for assembly, put insulating booting over all the 19 leads except the two sensing-coil leads.

*Note*

*This insulating booting is in addition to the booting already on the wire as it comes off the spool.*

4-82. PREPARING THE SIGNAL GENERATOR END HOUSING FOR ASSEMBLY TO THE 20-PIN CONNECTOR. Prior to assembling the 20-pin connector and the signal generator end housing together, a wire screen is soldered to the end housing at the connector end. This is to prevent any excess solder, or any other foreign matter, from entering the gyro unit during the filling procedure (ref. Section VII). The wire screen is a 270-mesh (the number of openings per linear inch), copper-gauze, filter screen. The screen is 1-1/2 inches in diameter, with a center hole about 1/2 inch in diameter so that the screen can be slipped over the boss on the end of the signal generator end housing. There are two crescent-shaped cutouts, ninety degrees apart, around the outer circumference of the screen. These cutouts should be aligned respectively with the positive directions of the spin reference axis and the input axis, as these two directions are defined for the signal generator end housing by Fig. 4-42. Note that there are four groups of wire-lead holes near the outer circumference of the signal generator end housing: 3 groups of 5 holes each and one group with only 3 holes. As indicated, the two sensing-coil leads pass through the same hole. The 3-hole group lies between the positive directions of the spin reference axis and the input axis. In addition, on the outer circumference of the signal generator end housing, in line with the directions specified for the spin reference axis and the input axis are the balance fork holes for the spin-reference-axis balance fork and the input-axis balance fork, respectively. Before soldering the wire screen to the end housing, it should be tinned for 1/16 inch on all edges. While this tinning can be done with a soldering iron, the actual soldering procedure (that is, securing the screen to the housing) must be done with an induction soldering machine since a soldering iron does not provide enough heat.

4-83. The detailed procedure for tinning the wire screen is as follows:

a. Place the screen on a clean sheet of white paper.

b. With a piece of peg wood, spread a non-corrosive soldering flux around the edges (both inner and outer), and then apply 50/50 solder with a soldering iron.

c. Turn the screen over with a pair of long-nose pliers and repeat the procedure of steps a and b.

4-84. The detailed procedure for soldering the wire screen to the signal generator end housing is as follows:

a. Screw the signal generator end housing into a discarded gyro outer case and mount the combination in a specially constructed positioning device, as shown in Fig. 4-44.

b. Place the positioning device beneath a soldering machine (ref. Fig. 3-18), in which an appropriate-size induction soldering coil is used, so that the coil fits around the signal generator end housing as shown in Fig. 4-44.

c. Turn the handle of the positioning device to raise or lower the signal generator end housing so that the coil wraps around the top of housing.

d. Mount the wire screen over the boss of the signal generator end housing so that the cutouts line up with the positive directions of the spin reference and input axes as specified in paragraph 4-82.

e. Obtain permission to use the soldering machine, and then insert the pronged plug on the cord from the foot pedal into the female outlet on the lower left-hand side of the machine and turn the ON-OFF switch to the ON position.

#### Note

*Because the high frequencies generated by the induction soldering machine could easily interfere with any gyro testing procedure, permission must be obtained from the head of the gyro testing group before operating this machine.*

f. On the wall by the soldering machine are two water-control knobs for controlling the flow of water in and out of the machine. Turn both of these knobs completely counterclockwise. This will prevent the induction coil from overheating and burning out.

g. In the center of the induction soldering machine is an ammeter whose indication is controlled by a circular knob located on the lower right-hand side of the machine. By turning this knob and using a dummy equivalent load, obtain the maximum reading on the ammeter. The dummy equivalent load should consist of a discarded gyro outer case and discarded signal generator base threaded together and placed in the positioning device as for the actual soldering operation. The reason for such a dummy equivalent load is that the machine might possibly be tuned to generate a heat that would be damaging to the actual case and signal generator base if they were initially used in the soldering operation.

h. To introduce heat through the induction coil - and hence to the signal generator end housing - depress the foot pedal on the floor.

i. At the same time, press down on the edges of the wire screen with a heat-resistant rod to insure a uniform solder flow, which is necessary for a good joint.

j. When the soldering operation is complete, shut the machine off by 1) releasing the foot pedal,

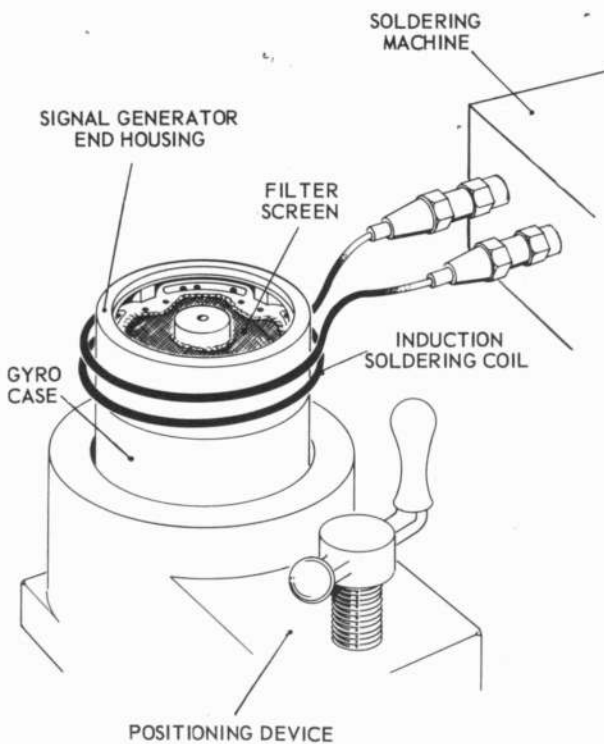


Fig. 4-44. Pictorial view showing the procedure for soldering the filter screen to the signal generator end housing.



2) turning the circular current-control knob completely counterclockwise, 3) turning both of the water control knobs completely clockwise, 4) turning the ON-OFF switch to the OFF position, and 5) removing the plug from the outlet on the lower left-hand side of the machine.

**4-85. ASSEMBLING THE 20-PIN CONNECTOR TO THE SIGNAL GENERATOR END HOUSING ASSEMBLY.** In this assembly procedure, the 19 wire leads soldered to the 20-pin connector are threaded through the signal generator end housing. Then, with the connector aligned with the end housing, these two parts are induction soldered together. To provide a means for obtaining correct alignment, the manufacturer of the connector has been instructed to stamp a pock mark on the disc in the position shown on Fig. 4-42. This pock mark should be aligned with the positive direction of the spin reference axis. Refer to paragraph 4-82 for the specification of this direction with respect to the signal generator end housing.

**4-86.** The detailed procedure for assembling the connector to the end housing is as follows:

a. Thread the wire leads of the connector, together with the extra insulating bushing for all except the two sensing-coil leads, through the holes of the signal generator end housing assembly in accordance with the wiring diagram of Fig. 4-42.

*Note*

*Make sure that the small pock mark on the connector is in alignment with the spin reference axis.*

b. It is not an easy job to thread the two sensing coil leads – even though they have no extra booting – through the single hole designed for them (ref. Fig. 4-42); hence, patience and skill must be exercised.

c. Place the 20-pin connector in place on the end housing, with the pock mark lined up with the positive direction of the spin reference axis.

d. Screw the signal generator end housing in a discarded gyro case and mount the combination in the positioning device as before (ref. paragraph 4-84a).

e. Place a ring of 50/50 solder around the outer circumference of the connector in the space left between it and the end housing.

f. Solder the connector to the end housing by use of the same procedure used to solder the filter screen to the end housing (ref. paragraph 4-84, steps b through j). The same induction soldering coil is used here as in the earlier procedure.

*Note*

*The joint obtained will be stronger if some of the molten solder is allowed to flow underneath the connector. In order to accomplish this, raise and lower the connector a few times during the soldering procedure by pushing it up and down with a heat-resistant rod.*

**4-87. ASSEMBLING THE SIGNAL GENERATOR END JEWEL ASSEMBLY IN THE SIGNAL GENERATOR END HOUSING.** Figure 4-45 is a cross-sectional view showing the signal generator end jewel assembly inserted in the jewel holder extractor and the signal generator end housing. The jewel assembly consists of an aluminum jewel holder inside of which is a tungsten carbide ball and a sapphire jewel bearing. As received for assembly from the manufacturer, the ball is pressed into the holder, with the holder spun over the jewel bearing. The inside and outside diameters of the jewel bearing are concentric within 0.0005 inch total indicator reading. All jewel surfaces are smooth and the jewel, itself, is free from flaws. The jewel inside diameter is a polished surface. The 0.0939-inch and 0.0599-inch diameters of the jewel holder are concentric within 0.0002 inch total indicator reading. It is obviously important to protect this precision-manufactured assembly against the entry of dirt or foreign matter. Hence, the jewel assembly should be carefully checked and then packaged in an individual dust proof container until ready for assembly in the signal generator end housing.

**4-88.** The following detail checks should be made on the jewel assembly prior to assembling it in the signal generator end housing:

a. Check that there are no dirt deposits on the sapphire jewel bearing.

b. Check that there is no sloppiness, that is, looseness, of the sapphire jewel bearing with respect to the jewel holder.

c. Remove the assembled floated units assembly from its plastic container (ref. paragraph 4-73q) and check the positioning of the pivot inside the jewel bearing. The cone of the pivot holder must

not rub against the inside diameter of the jewel bearing. Replace the jewel assembly if required. Return the floated units assembly to its container until further required in the assembly procedure (ref. paragraph 4-101d).

d. Clean the inside of the jewel assembly with ether, injecting the ether inside the jewel by means of a hypodermic needle (ref. Fig. 3-37). Any other solvent will leave a film deposit on the jewel bearing, which is undesirable.

**Note**

*Do not use ether near flame or sparks, as it is highly flammable.*

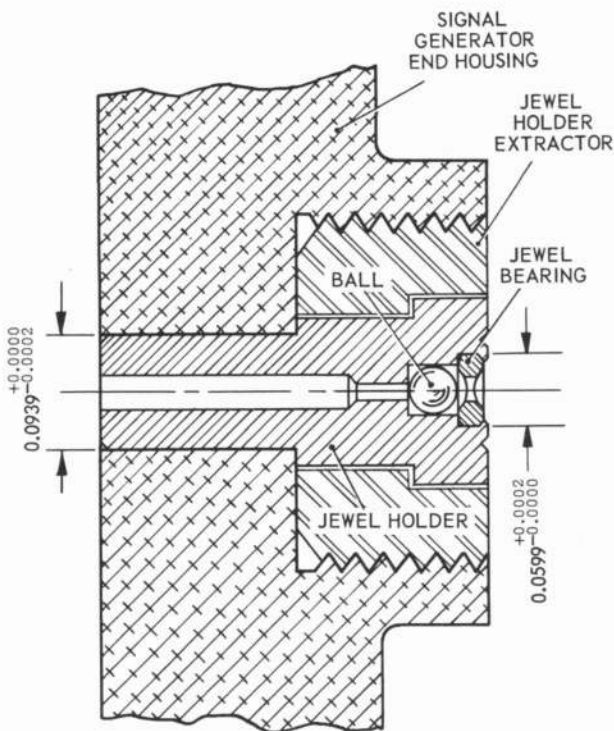


Fig. 4-45. Cross-sectional view showing the signal generator end jewel assembly inserted in the jewel holder extractor and the signal generator end housing.

4-89. The detailed procedure for assembling the jewel holder in the signal generator end housing is as follows:

- a. Screw the jewel holder extractor into the signal generator end housing so that it bottoms.
- b. Push-fit the jewel holder into the signal generator base through the jewel holder extractor. Make sure that the jewel holder also bottoms.

**Note**

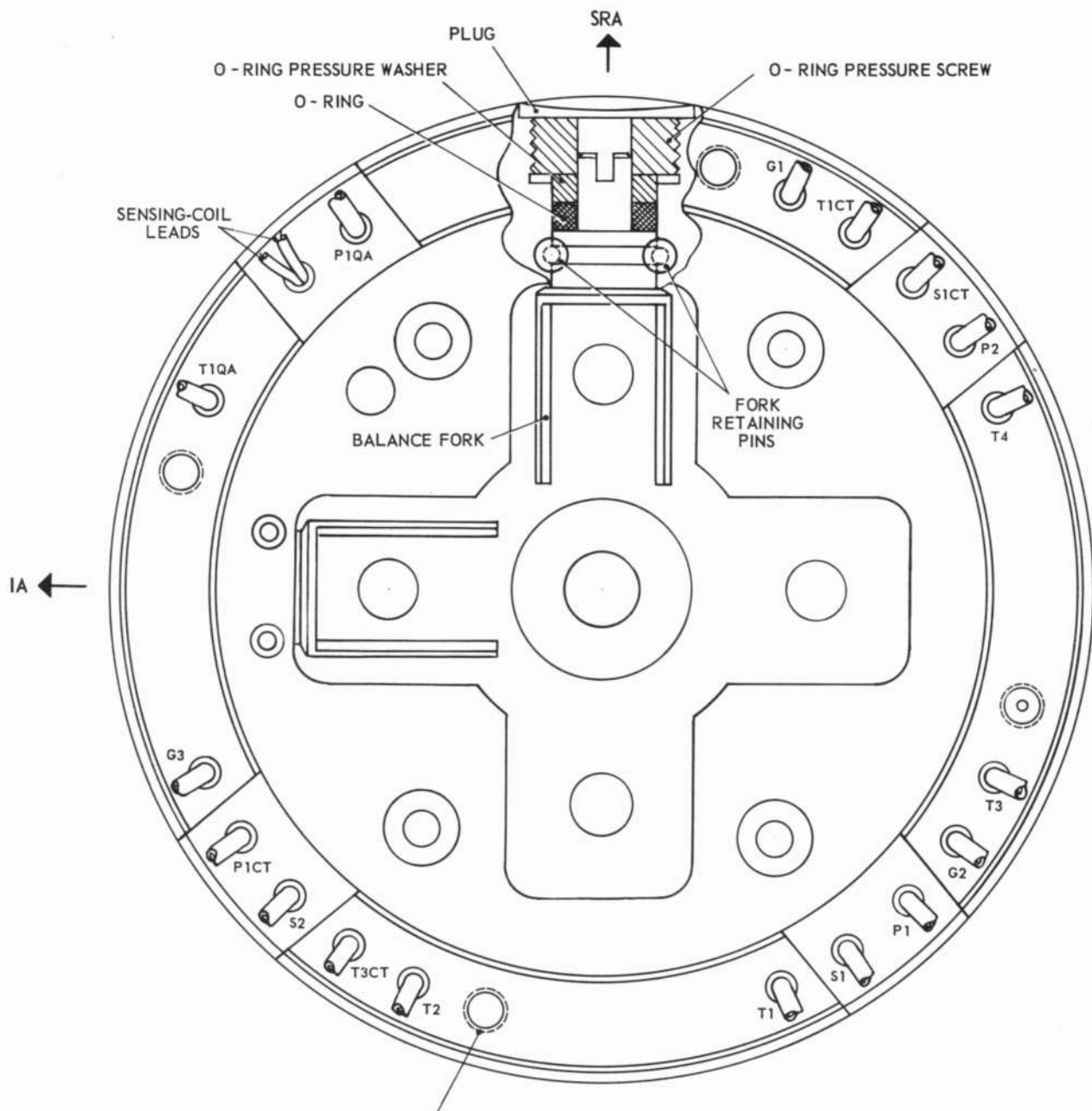
*The jewel holder is a loose fit in the extractor, but it is a push fit in the signal generator base. Thus, the extractor is not used as a clamping device for the jewel holder, but rather as a means for removing the jewel holder in the event of a mishap to the jewel bearing. It is not necessary that the extractor be flush with the jewel holder at their exposed surfaces.*

**4-90. ASSEMBLING THE TWO BALANCE FORKS IN THE SIGNAL GENERATOR END HOUSING.**

The purpose of the balance forks is to translate the fine balance nuts in and out along the positive directions of the spin reference axis and the input axis, so as to adjust the rotational balance of the floated units assembly after the gyro unit is completely assembled. Since this procedure occurs during the testing of the assembled unit, it is no concern of the assembler. Figure 4-46 is an end view of the signal generator end housing in which a portion of the housing has been broken away to reveal the manner whereby balance forks are secured in position. As shown, each fork is held in place by two pins that are push-fitted into holes drilled in the signal generator end housing. The top of each fork stem is chamfered so that an O-ring can be more readily slipped over it. A stainless-steel pressure washer fits over the O-ring. The O-ring and pressure washer are prevented from working loose by the 5/16 - 40 N.S. - 3 pressure screw that is inserted in each balance-fork opening. After the gyro unit has been tested and approved, the holes are capped with the balance fork plugs, which are cemented to the signal generator end housing with an adhesive.

4-91. The detailed procedure for assembling each balance fork in the signal generator end housing is as follows:

- a. Make sure that the hole through which the fork stem protrudes is clean.
- b. Examine the 5/16 - 40 thread for the presence of any dirt. Dirt can be removed by running a 5/16 - 40 tap through the hole, after which any metal chips can be removed easily with a vacuum hose.
- c. Insert the balance fork, stem first, from the inside of the end housing, and secure it in place by push-fitting two fork retaining pins into their



Note: The tapped holes are for the signal generator tie rods.

Fig. 4-46. Cutaway view of the signal generator end housing showing how the balance forks are secured in position.

holes. If any interference is encountered when the two fork retaining pins are inserted, remove the pins and investigate the obstruction, as the balance forks should turn freely.

d. Slip the O-ring and the O-ring pressure washer over the top of the balance fork stem, after coating the stem with a silicone lubricant to ease this procedure.

e. Insert the 5/16 - 40 O-ring pressure screw and apply pressure to the O-ring by inserting a 1/8-inch Allen wrench in the hexagonal-shaped opening in the screw and turning as required.

4-92. CLEANING THE ASSEMBLED SIGNAL GENERATOR END HOUSING ASSEMBLY. When the balance forks have been placed in position, the signal generator end housing assembly is complete

and ready for further use except for removing any dirt or other foreign substances that may have accumulated during the assembly procedure. An industrial washing machine (ref. Fig. 4-47) has been found to be a most satisfactory device for cleaning this gyro component. Four distinct cleaning operations are performed: 1) washing in a special cleaning fluid, 2) rinsing in a special rinsing solution, 3) another rinsing in an acetone

solution, and 4) drying. Each succeeding solution is compatible with the previous solution, that is, leaves no fluid film on the washed part.

4-93. The detailed procedure for cleaning the signal generator end housing (or any other part) in the industrial washing machine is as follows:

a. Make sure that the fluid levels are sufficient to cover the part, and that the fluids are clean.

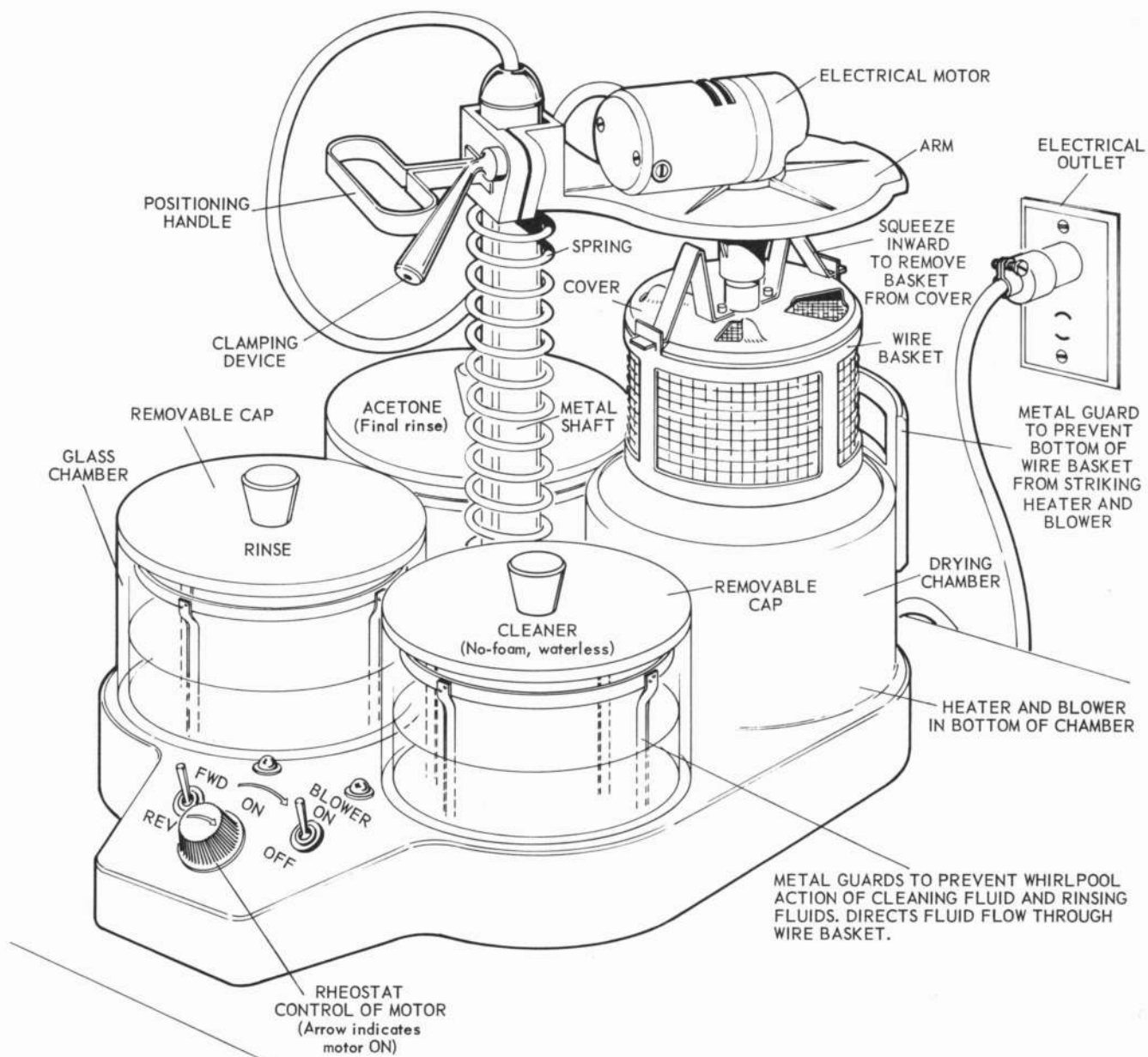


Fig. 4-47. Pictorial view of the industrial washing machine.

b. Place the part in the wire-mesh basket of the machine and clamp the basket to the cover attached to the rotatable arm.

c. Rotate the arm and lower the arm so that the part is completely covered with the cleaning fluid.

d. Start the machine and allow it to run a few minutes before reversing the direction of rotation of the basket.

e. Stop the machine before transferring the basket to the rinsing solution.

f. Repeat step d.

g. Stop the machine before transferring the basket to the acetone solution.

h. Repeat step d.

i. Stop the machine and transfer the basket to the drying chamber.

j. Start the blower and leave it on until the part is completely dry.

k. Turn off the blower when the part is dry.

l. Remove the part and package it in a plastic bag unless part is to be used shortly.

#### Note

*The operation of the washing machine depends on the whirling action of the fluids through the wire-mesh basket, which is rotated in each fluid in succession. It is good practice to reverse the direction of the rotation of the basket to obtain the best results. However, do not at any time rotate the basket at a high speed, as the foam that is created does not clean too well.*

*Acetone is a solvent that is extremely flammable, and should therefore be kept away from heat, sparks and open flame. When stored, it should be kept in a sealed container. Avoid any prolonged or repeated contact with the skin.*

4-94. **ASSEMBLING THE MAIN HOUSING ASSEMBLY.** As described in Section II (ref. paragraph 2-25), the main housing assembly is comprised of the main housing and a sensing coil assembly that fits inside it. In the assembled gyro unit, the main housing assembly surrounds the gimbal shell so that there is a small annular clearance between the inside diameter of the sensing coil and the outside diameter of the gimbal shell. In a typical 20IG gyro unit, this clearance, or damping gap, is 0.010 inch.

4-95. The procedure for assembling the main housing assembly involves the following steps:

a. Checking the main housing (ref. paragraph 4-96).

b. Winding the sensing coil assembly (ref. paragraphs 4-97 and 4-98).

c. Assembling the sensing coil in the main housing (ref. paragraph 4-99).

4-96. **CHECKING THE MAIN HOUSING.** The main housing consists of a piece of machined aluminum with a stop pin projecting from the inner side of the closed end, as shown in Fig. 4-48. As received for assembly, this stop pin is already inserted in place. No further assembly is required. It is good practice, however, to clean the housing by means of the washing procedure given in paragraph 4-93.

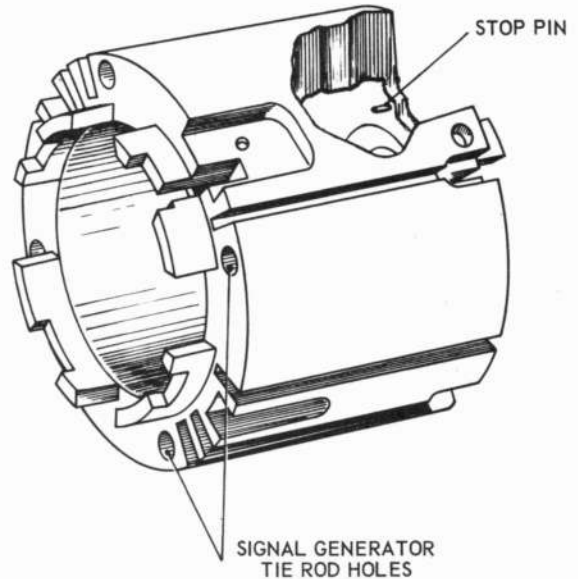


Fig. 4-48. Cutaway view of the main housing showing the stop pin.

4-97. **WINDING THE SENSING COIL ASSEMBLY.** The sensing coil assembly consists of an aluminum sensing-coil form, which has a hard coat finish on the outside, and a length of sensing-coil wire that is wrapped in a single layer around the outer circumference of the coil form. As received from the manufacturer, the wire used for the sensing coil is wound on a spool. The resistance of the wire is 11.83 ohms per foot. Figure 4-49 shows the apparatus used for winding a sensing coil. The left-hand spool is the original spool; the right-hand

spool contains approximately 27 turns or 13.5 feet of sensing coil wire that was unwrapped from the original spool onto the blank right-hand spool. Two spools are used so that the wire can be wound around the coil form noninductively and in a single layer.

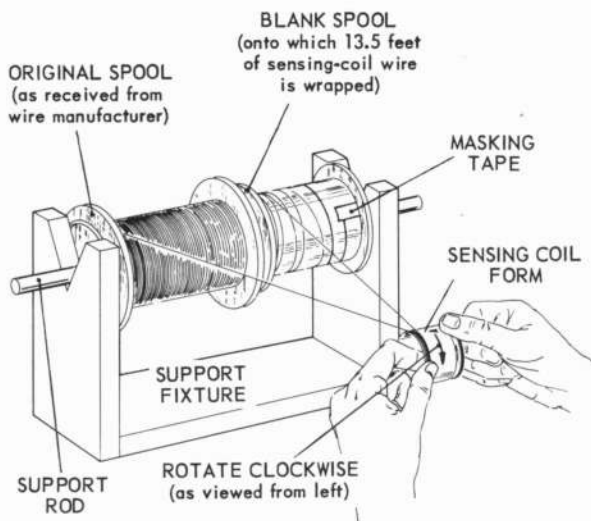


Fig. 4-49. Pictorial view showing the procedure used to wind the sensing coil assembly.

4-98. The detailed procedure for winding the sensing coil assembly is as follows:

a. Mount the original spool and the blank spool on a support rod.

b. Place the support rod in the V-cutouts of a simply constructed fixture such as shown in Fig. 4-49.

c. With a piece of masking tape, tape the end of the wire from the original spool to the extreme right-hand side of the blank spool.

d. Rotate the blank spool counterclockwise (as viewed from the left in Fig. 4-49) in order to unwrap the wire from the original spool and wrap the wire around the blank spool.

e. Stop rotating the spool when approximately 13.5 feet, or 27 turns are wrapped around the blank spool.

f. While holding the sensing-coil form so that the flange with a slot cut through it is on your right, press a 0.0150-inch diameter steel pin through the left-hand flange of the sensing-coil form.

g. Holding the coil in one hand, grasp the midpoint of the sensing-coil wire with the other and loop it over the pin.

h. Press the pin across the channel in the coil form to prevent the wire from working loose.

i. Wrap the sensing-coil wire around the coil form by rotating the coil form clockwise (as viewed from the left in Fig. 4-49).

*Note*

*Be careful to keep the wire taut. Also, do not twist the wire nor wind over a previously wound coil when wrapping it around the form.*

j. As a suggestion to facilitate the wrapping, turn the coil form with one hand and guide the oncoming wires with the other hand, that is, with the thumb on top of the coil and the index and forefinger inside the coil form (ref. Fig. 4-49).

*Note*

*The last full coil should run in the channel at the right-hand end of the coil form.*

k. Temporarily fasten the loose ends of the wire to the other wrapped wires with a small piece of masking tape. In addition, fasten all the wire together with a strip of masking tape running the length of sensing-coil form.

l. Make one of the loose wires approximately 1/2 inch longer than the other when the wires are cut from the spools.

m. Strip about 1/4 of an inch of the insulation off each end of the coil wires and connect the two exposed wires to a Wheatstone bridge (ref. Fig. 3-40) in order to measure the resistance of the sensing coil. The resistance of the coil should be between 300 and 310 ohms at room temperature.

*Note*

*The final resistance is more important than the number of turns or length of wire.*

n. Next, cut two lengths of Tensolite No. 30001-A1 No. 30 gauge Teflon-covered lead wire. Strip off about 1/4 inch of booting from both ends of each lead wire.

o. Form each lead wire to a smaller radius than the sensing-coil form. This may be done by holding the lead wire between the thumb and forefinger of one hand and drawing the thumb and forefinger of the other hand over the wire with a downward motion. Repeat this operation until the desired radius is obtained.

*Note*

*The lead wires must lie flat in the channel after the solder joint between the sensing coil wires and the lead wires has been made.*

p. Remove the small piece of masking tape that is holding the ends of the coil in place, so as to leave enough freedom to solder on the Tensolite leads.

q. Wrap the coil wires around the lead wires a few times and then solder them together. Then slip Teflon booting over the soldered joint.

r. Bring the lead wires out midway between the sides of the slot cut in the right-hand flange.

s. Fasten the lead wires to the coil form with a drop of C-8 liquid resin. Allow the resin to harden. Make sure that the top surface of the lead wires is not higher than the sensing-coil wires.

*Note*

*Liquid C-8 resin consists of 4 parts by weight of Bakelite Co. clear C-8 resin, Spec. 6020A, that has been well mixed with 1 part of C-8 hardener, Spec. 6022.*

t. Pour a small amount of liquid C-8 resin in the channel on the right-hand side of the sensing-coil form.

u. Rotate the form to allow the resin to flow around the circumference of the channel. Allow the resin to harden.

v. Remove the long piece of masking tape.

w. Bond the winding to the coil form with liquid C-8 resin, using a two-part mold (ref. Fig. 3-41) as follows.

x. Coat the inside walls of the mold with a thin film of Dow Corning 7 Compound - Silicone release agent.

y. Mix thoroughly 4 parts by weight of Bakelite Co. clear C-8 resin, Spec. 6020A, with 1 part of C-8 hardener, Spec. 6022.

z. Place the coil form in the mold and fill the mold cavity with the mixture. Heat for 3 hours at 160° F and then air cool.

aa. Separate the two parts of the mold, remove the bonded coil, and pull out the pin that was inserted in step f.

ab. Inspect the bond. Make sure that the top surface of the lead wire does not protrude above the bonding surface.

**4-99. ASSEMBLING THE SENSING COIL IN THE MAIN HOUSING.** The detailed steps of this assembly procedure are as follows:

a. Send to a machinist the bonded sensing coil, a main housing, the dimension of the damping

gap desired (ref. paragraph 4-94), and the outside diameter of the floated units assembly to be used.

b. Instruct the machinist to 1) turn down the outside diameter of the sensing coil, 2) push-fit it inside the main housing, and 3) bore the inside diameter of the sensing coil between 0.0003 inch and 0.0004 inch undersize.

c. When the parts are received back from the machinist, check the inside diameter of the sensing coil with an air gauge (ref. Fig. 3-5) and hone it (ref. Fig. 3-7) down to the diameter that will yield the required damping gap. Refer to paragraphs 4-22 through 4-31 for a description of the honing operation.

*Note*

*By this honing operation, it is possible to hold the required damping gap to a precision of 0.0001 inch.*

d. Package the main housing assembly thus obtained in a clean plastic bag until further required in the assembly procedure (ref. paragraph 5-9c).

**4-100. ASSEMBLING THE POWER LEAD BAFFLE ASSEMBLY.** The power lead baffle assembly (ref. paragraph 2-20) consists of a circular baffle plate machined from a piece of plastic resin material and three brass power-lead terminals, to which the ends of the three flex leads are subsequently attached in the assembly procedure (ref. paragraph 5-24). These terminals are assembled to the baffle plate as follows (ref. Fig. 4-50):

a. Temporarily fasten each terminal to the baffle plate by two 1/32-inch-diameter pins.

b. Permanently bond the terminals to the baffle plate by filling the circumferential slots with liquid C-8 resin.

c. Allow this liquid to solidify for 30 minutes.

d. Then place the baffle plate, with the terminals in place, inside an oven (set at 150° F) for a period of 3 hours.

e. After this period, remove the 1/32-inch-diameter pins that temporarily held the terminals in place.

**4-101. ASSEMBLING THE TORQUE MOTOR END HOUSING CAP ASSEMBLY.** As noted in Section II (ref. paragraph 2-19), the torque motor end housing cap assembly consists of an end housing cap, a jewel assembly, a power lead baffle cam, a Tru-arc retaining ring, a jewel ball retainer, a tungsten-carbide ball 1 millimeter in diameter, and three

fillister-head machine screws. The detailed procedure for assembling the parts is as follows:

- a. Check the jewel bearing inside the jewel holder for looseness, flaws or the presence of dirt.
- b. Remove any dirt or foreign matter by injecting ether inside the bearing by using a hypodermic needle (ref. paragraph 4-88d).
- c. Lightly push the jewel holder into the end cap.

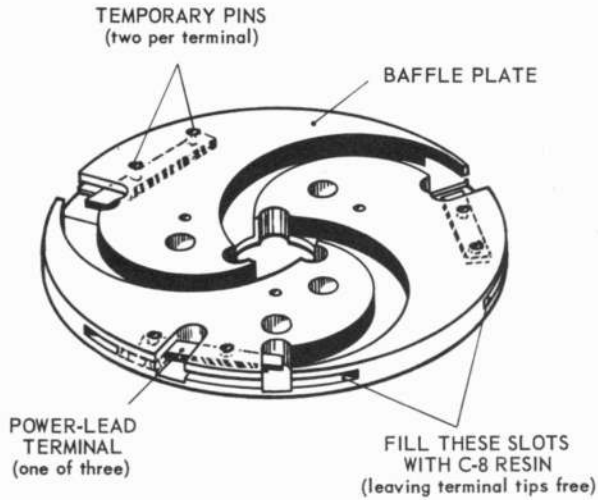


Fig. 4-50. Pictorial view of the power lead baffle assembly showing how the terminals are secured to the baffle plate.

- d. Check the positioning of the appropriate pivot of the floated units assembly inside the jewel bearing (ref. paragraph 4-88c). Replace the jewel assembly if required. Return the floated units assembly to its container until further required in the assembly procedure (ref. paragraph 5-9a).

- e. To hold the eccentric power lead baffle cam in place on the end housing cap, insert the Tru-arc retaining ring, using appropriate Tru-arc pliers provided for this purpose. Make sure that the cam turns easily.

- f. Temporarily assemble the tungsten-carbide ball and the jewel ball retainer to the torque motor end housing cap, using 3 fillister-head machine screws.

*Note*

*This is a temporary assembly because the determination of end shake, that is, the distance the floated units assembly is allowed to move between bearing seats, is a later step in the over-all assembly of the gyro unit (see Section V) and involves modification of the jewel ball retainer.*

- g. Package the assembled torque motor end housing cap assembly in a plastic bag, pending further use in the assembly procedure (ref. paragraph 5-17j).



## SECTION V

### OVER-ALL ASSEMBLY

#### 5-1. INTRODUCTION.

5-2. A complete 20IG gyro unit is comprised of various component assemblies and parts, such as the floated units assembly, the housing assemblies, the Microsyn stator assemblies, etc. The assembly of these individual components is described in Section IV. The present section - Section V - describes how these components are combined to form an assembled gyro unit.

5-3. The assembly procedure starts off by placing the signal generator end housing assembly on a special assembly test stand (ref. Fig. 3-42). From this first step, the gyro unit is built up step-by-step until the torque motor end housing cap assembly is secured in position. At this stage, the Microsyn centering procedure - covered in Section VI - takes place. Completion of the gyro unit assembly is covered in Section VII, which describes 1) the filling of the gyro unit with its flotation fluid and 2) the final electrical check.

5-4. The build-up of the gyro unit to the extent covered in this section is represented pictorially in Fig. 5-1. The associated assembly description falls under six sideheads:

a. Mounting the signal generator end housing assembly on the special assembly test stand (ref. paragraphs 5-5 through 5-7).

b. Assembling the main housing assembly and the floated units assembly onto the signal generator end housing assembly (ref. paragraphs 5-8 and 5-9).

c. Assembling the torque motor end housing sleeve and associated components onto the main housing assembly (ref. paragraphs 5-10 and 5-11).

d. Adjusting the end shake (ref. paragraphs 5-12 through 5-21).

e. Adding the power lead baffle assembly and the associated flex leads (ref. paragraphs 5-22 through 5-24).

f. Securing the torque motor end housing cap assembly (ref. paragraphs 5-25 through 5-27).

#### 5-5. MOUNTING THE SIGNAL GENERATOR END HOUSING ASSEMBLY ON THE SPECIAL ASSEMBLY TEST STAND.

5-6. Figure 5-2 is a pictorial view of the assembly stand used for assembling the 20IG gyro unit. In the center is a 20-hole receptacle that accepts the 20-pin connector of the signal generator end housing assembly. Around the circumference of the stand are 20 test jacks that are connected to the 20-pin receptacle by wiring inside the stand. The resistances of both Microsyn units and the gyro motor (ref. Tables 4-2 and 4-3) can be checked at various stages of the assembly by inserting the probes of a Simpson multimeter (ref. Fig. 3-10) into the appropriate test jacks. Each test jack is identified on the assembly stand and is also called out on Fig. 5-2.

5-7. By virtue of the key-type plug on the 20-pin connector, there is only one way to insert the signal generator end housing assembly in the assembly stand. Figure 5-3 shows the signal generator end housing assembly mounted on the assembly stand, with the stand so oriented that the positive direction of the spin reference axis is toward the reader. The positive direction of the input axis is toward the right of the reader. Each lead is identified in the illustration as a further aid to the gyro assembler. Before proceeding with the next step of the over-all assembly, it is advisable to make the following checks:

a. Check for any dirt or foreign matter inside the housing and in the jewel assembly.

b. Check for any dirt or foreign matter on the threads that engage the mating threads of the outer case.

c. Check to see that no bare wires are in evidence as the leads come out of the signal generator end housing. If bare wires are in evidence, unsolder the 20-pin connector and replace the defective wire.

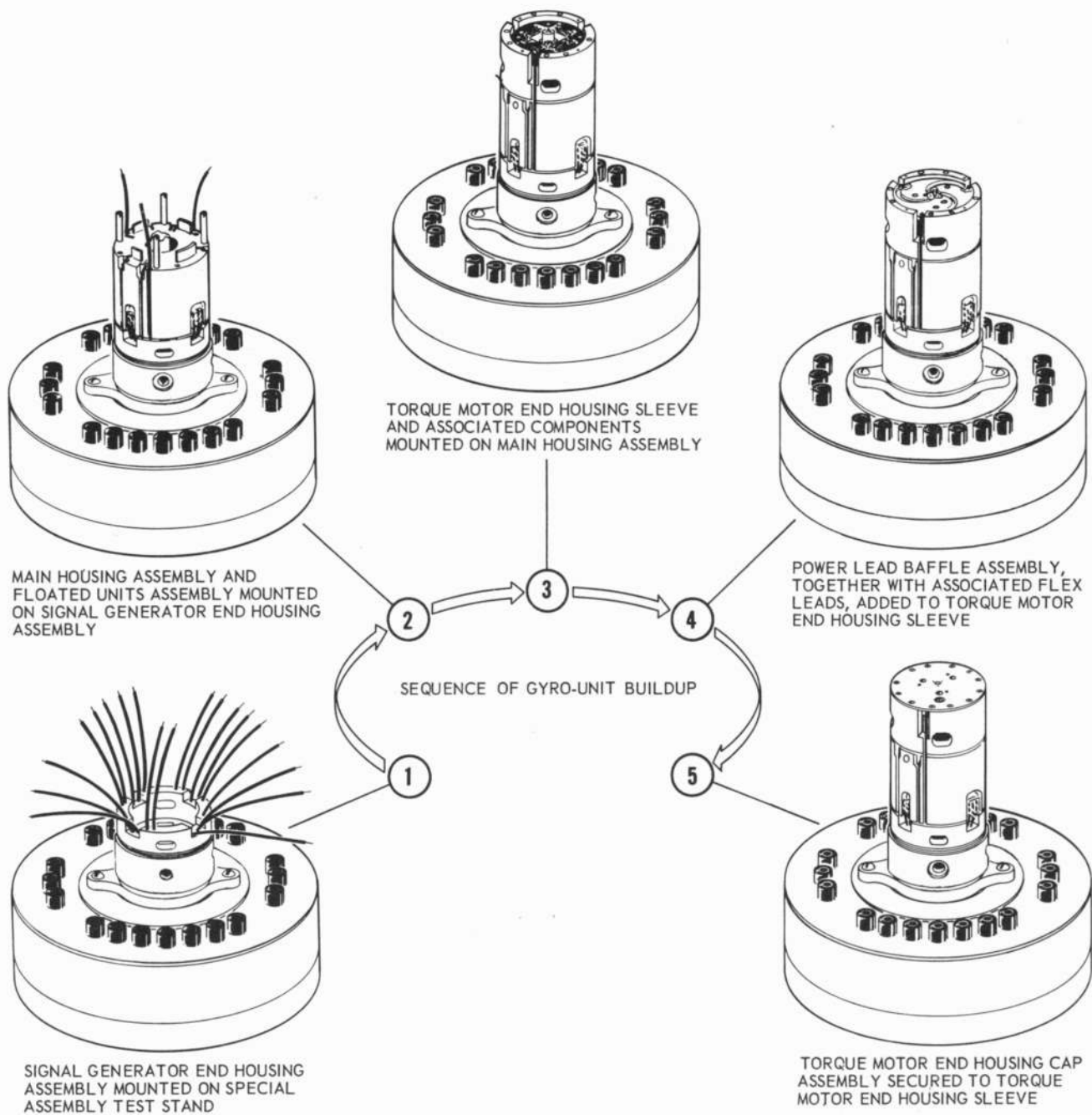


Fig. 5-1. Buildup of the 20IG gyro unit by the over-all assembly procedure covered in Section V.

5-8. ASSEMBLING THE MAIN HOUSING ASSEMBLY AND THE FLOATED UNITS ASSEMBLY ONTO THE SIGNAL GENERATOR END HOUSING ASSEMBLY.

5-9. Figure 5-4 shows the main housing assembly and the floated units assembly assembled on top of the signal generator end housing assembly. The signal generator stator leads have been connected to their mating leads from the 20-pin connector, as have the sensing-coil leads also. The detailed

procedure for carrying out this assembly is as follows:

- Remove the assembled floated units assembly from its plastic bag (ref. paragraph 4-101d).
- Carefully remove the balance assembly from the float shaft by unscrewing the three No. 000-120 flat-head machine screws, and return it and the 3 screws to the plastic bag.

**Note**

Be careful not to damage either of the two pivots in the shafts of the floated units assembly. If a pivot is damaged, replace it with a pivot that will yield a runout less than 0.0002 inch total indicator reading at its end of the gimbal shell (ref. paragraphs 4-57 and 4-58).

c. Remove the assembled main housing assembly from its plastic bag (ref. paragraph 4-99d), and make the 2 sensing-coil leads project radially from the main housing, clear of the end of the housing that will engage the signal generator end housing.

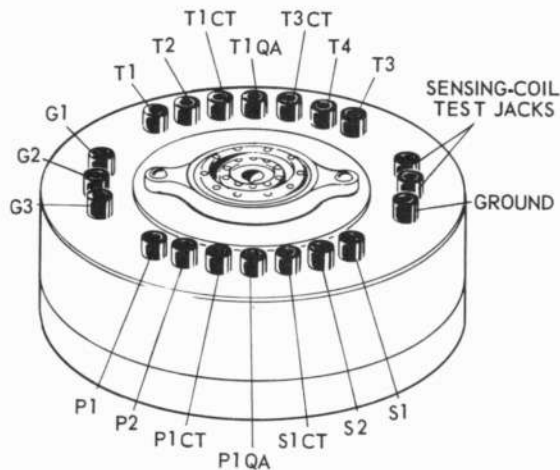


Fig. 5-2. Pictorial view of the assembly stand used for assembling the 20IG gyro unit.

d. Locate the stop pin inside the main housing. The stop pin is along the positive direction of the spin reference axis. Since the end of the stop pin is visible from the outside of the main housing, it serves as a convenient means of locating the positive direction of the spin reference axis after the pin inside is no longer visible.

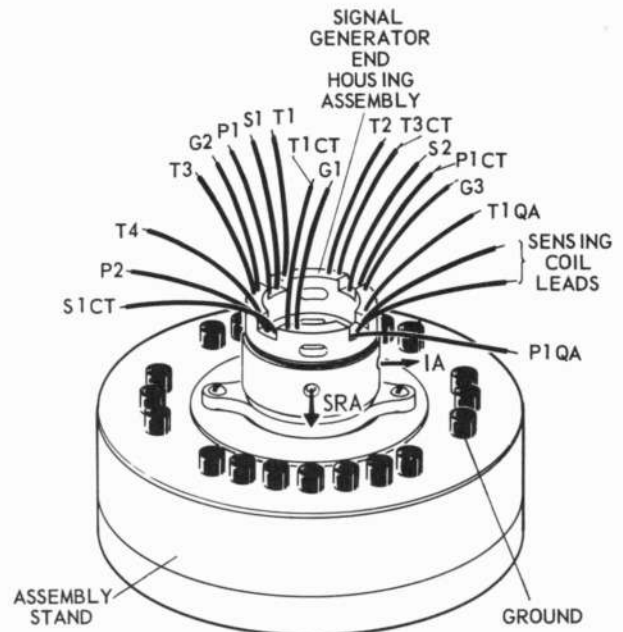
e. Locate the stop-pin hole in the float. This hole is along the positive direction of the spin axis.

**Note**

As noted in paragraph 2-8 of Section II, the spin axis of the gyro rotor and the spin reference axis of the gyro unit are in alignment when the floated units assembly is in its zero-rotation position.

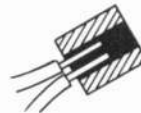
f. Carefully lower the float inside the main housing, making sure that the stop pin engages the stop-pin hole. Check the engagement by turning the floated units assembly.

g. Slip shield No. 1 over the float shaft at the signal generator end. It is unimportant which side of this shield faces the main housing.

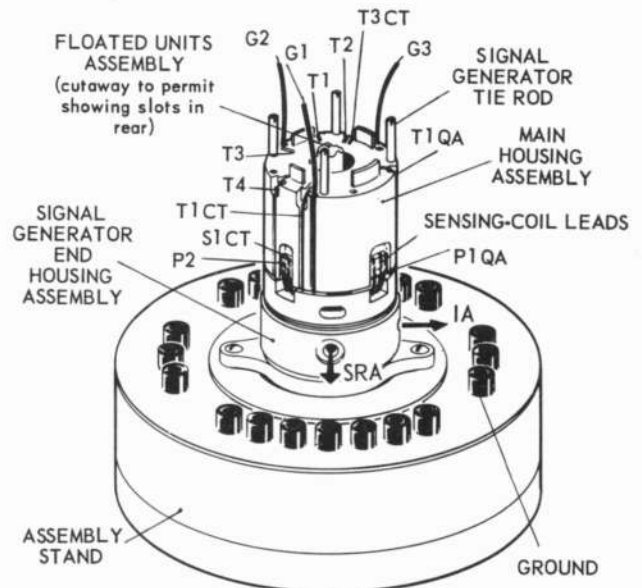


Note: For identification of the other test jacks, see Fig. 5-2.

Fig. 5-3. Pictorial view showing the signal generator end housing assembly mounted on the assembly stand.



Soldering sleeves are used, as shown, to join mating leads to main housing assembly and signal generator stator assembly.



Note: For identification of the other test jacks, see Fig. 5-2.

Fig. 5-4. Pictorial view showing the main housing assembly and the floated units assembly assembled on top of the signal generator end housing assembly.

h. Slip shield No. 2 over the float shaft – feet last – and push it up against shield No. 1. Turn shield No. 2 slightly so that the feet on the shield fit under the lips projecting from the main housing.

i. Remove the assembled Microsyn signal generator stator assembly from its plastic bag (ref. paragraph 4-50d).

j. Locate the positive direction of the spin reference axis on the Microsyn signal generator stator assembly with the aid of Fig. 4-20, which shows the relationship of the spin reference axis to the split quadrature pin.

k. Slip the stator assembly – feet first – over the float shaft, alongside shield No. 2. Make sure that the positive spin reference axis directions of both the stator assembly and the main housing assembly are in alignment.

l. Place the Microsyn signal generator leads – radially outward – in the cutouts of the projecting lips of the main housing, making sure the leads do not cross one another (ref. Fig. 5-5).

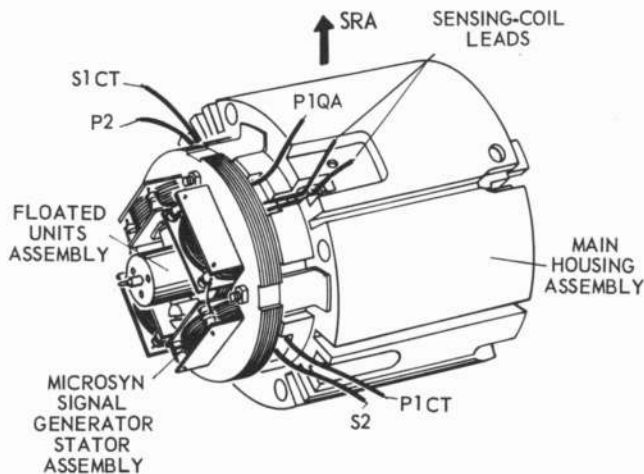


Fig. 5-5. Pictorial view showing the location of the Microsyn signal generator leads in the cutouts of the lips that project from the main housing assembly.

m. Slip a Microsyn filler block – smooth surface first – over the float shaft, alongside the Microsyn stator assembly. Turn the filler block so that the drilled holes in the block fit over the nuts and screws that secure the Microsyn stator mount to the Microsyn stator core (ref. Fig. 4-18).

n. Remove the balance assembly and the 3 attaching screws from the plastic bag (ref. step b of this procedure), and locate the positive direc-

tion of the spin axis on it. This direction is found by locating the only tapped hole that is exactly in line with a balance stud. The balance stud opposite this tapped hole is along the positive direction of the spin axis (ref. Fig. 4-21). The positive direction of the spin axis with respect to the gimbal shell shaft is shown on Fig. 4-26.

o. Replace the balance assembly on the float shaft with the positive directions of the spin axis in alignment, and secure with the three No. 000-120 flat-head machine screws. When this is done, the combination of the floated units assembly and the main housing assembly is ready for assembly onto the signal generator end housing assembly.

p. Locate the positive direction of the spin reference axis on the signal generator end housing with the aid of Fig. 4-46. This should check also with the positive direction for this axis noted on Fig. 5-3.

q. Spread radially outward the leads coming from the signal generator end housing, as the lips projecting from the main housing must fit inside the signal generator end housing. Make sure these leads do not cross one another. In addition, turn the two balance forks in the signal generator end housing so that the balance nuts along the positive spin-axis and input-axis directions will go between the prongs.

r. While holding the main housing assembly in one hand, with the balance assembly at the top, invert the signal generator end housing assembly and lower it gently onto the main housing assembly. Align the positive directions of the spin reference axes of the two assemblies, and be careful not to damage the pivot. Firmly press the two housings together by using the thumb and index finger of both hands as a vise.

s. Insert the 4 signal generator tie rods through the clearance holes in the main housing and thread them into the tapped holes in the signal generator end housing.

*Note*

*It may be necessary to turn the main housing assembly slightly in order to make the holes in the two housings line up.*

t. Locate the 7 Microsyn torque motor leads and the 3 gyro motor leads coming out of the signal generator end housing (ref. Figs. 5-3 and 2-18).

Place these 10 leads in the proper channels of the main housing (ref. Fig. 5-4). Note that the 3 motor leads (G1, G2 and G3) rest in the constant-width channels.

u. Locate the 7 Microsyn signal generator leads and the 2 sensing-coil leads coming out of the signal generator housing. These are the leads that are in the U-shaped cutouts in the signal generator end housing.

v. Locate the mating leads from the Microsyn signal generator stator assembly and the sensing coil. Slip a short brass soldering sleeve over each mating pair of leads associated with the Microsyn signal generator stator assembly and the sensing coil as indicated on the insert of Fig. 5-4. Figures 5-3 and 5-5 are helpful in finding the mating leads. Let the solder flow in from the open end of the sleeve.

**Note**

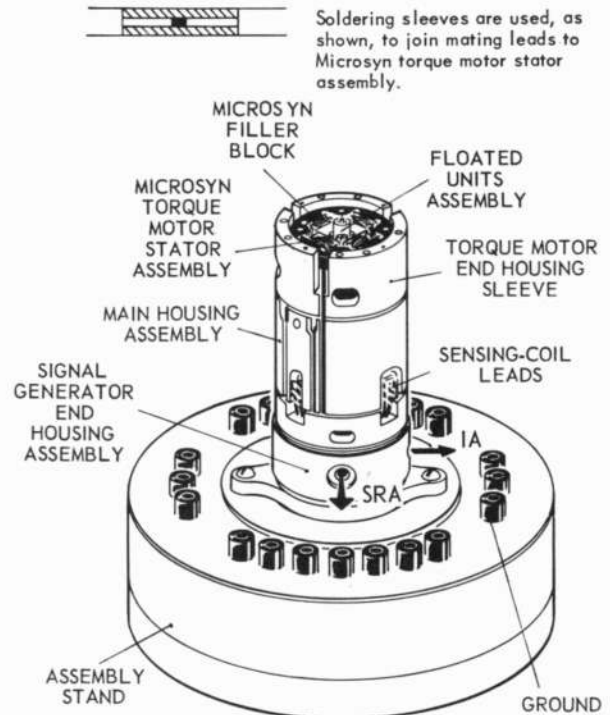
*Before soldering the mating leads, cut them back as required to avoid any excess length when step x following is carried out.*

w. Before proceeding further, check the signal generator resistances (ref. Table 4-3), using the test jacks of the assembly stand and a Simpson multimeter (ref. Fig. 3-10).

x. Insert the soldered ends of the mating leads into the 4 wire clamps (made of insulating material) used to secure these leads to the main housing. Then secure the wire clamps in the cutouts in the main housing with one No. 00-96 NF-2, 3/16-inch long, flat fillister-head machine screw for each clamp. Note that 3 of the wire clamps have 2 holes each, while the fourth has 3 holes. The latter clamp is used in the slot that contains the 2 sensing-coil leads and the signal generator quadrature adjust lead (PIQA).

**5-10. ASSEMBLING THE TORQUE MOTOR END HOUSING SLEEVE AND ASSOCIATED COMPONENTS ONTO THE MAIN HOUSING ASSEMBLY.**

5-11. Figure 5-6 shows the torque motor end housing sleeve, the Microsyn torque motor stator assembly, and the Microsyn filler block assembled on top of the main housing assembly. The torque motor stator leads have been connected to their mating leads from the 20-pin connector. The



Note: For identification of the other test jacks, see Fig. 5-2.

Fig. 5-6. Pictorial view showing the torque motor end housing sleeve with its associated components assembled onto the main housing assembly.

detailed procedure for carrying out this assembly is as follows:

a. Remove the assembled Microsyn torque motor stator assembly from its plastic bag (ref. paragraph 4-50d).

b. Locate the positive direction of the spin reference axis on the Microsyn torque motor stator assembly with the aid of Fig. 4-19, which shows the relationship of the spin reference axis to the split quadrature pin.

c. Slip the stator - feet downward - over the float shaft and onto the main housing such that the positive spin reference axis directions of both the Microsyn torque motor stator assembly and main housing assembly are in alignment.

d. Using Figs. 4-19 and 5-4 as guides, locate the Microsyn torque motor leads that mate with the torque motor leads coming from the signal generator end housing assembly.

e. Cut each of the 7 torque motor leads coming from the signal generator end housing assembly at a point slightly above the midpoint of the main housing.

f. Cut each of the 7 leads from the Microsyn torque motor stator assembly so that there is just sufficient overlap of mating leads to make a good solder joint. Then place a short length of additional booting over each of these 7 leads.

g. Strip about 1/4 inch of booting from the ends of the torque motor stator leads and their mates from the signal generator end housing assembly.

h. Tin both ends of the wires. Slip a long brass sleeve over one wire; then insert the other wire in the sleeve as indicated on the insert of Fig. 5-6. Apply heat to the sleeve with the soldering iron to effect the bond. Then, slip the short lengths of added booting over the sleeve.

i. Make sure the 7 leads rest flush in their channels, with no parts of these leads extending beyond the surface of the main housing. To accomplish this, it may be necessary to push the leads from the torque generator stator assembly back slightly.

j. Check the torque motor resistances (ref. Table 4-3), using the test jacks of the assembly stand and a Simpson multimeter (ref. Fig. 3-10).

k. Place a Microsyn filler block - smooth surface downward - onto the torque motor stator assembly. The drilled holes in the block must fit over the nuts and screws that clamp the stator mount to the stator core.

l. Place the torque motor end housing sleeve onto the main housing assembly, fitting it over the projecting ends of the 4 signal generator tie rods (ref. Fig. 5-4).

**Note**

*The 1/4 torque motor tie rods are not used to secure the end housing sleeve in position on the main housing until completion of the end-shake adjustment described in the following paragraphs. Make sure that the torque motor end housing sleeve bottoms; otherwise, end-shake measurements are meaningless.*

**5-12. ADJUSTING THE END SHAKE.**

5-13. The next task for the assembler is to adjust the amount of end shake in the gyro unit. As shown by Fig. 5-7, end shake is the distance in an assembled gyro unit mounted on an assembly stand that exists between the top of the upper pivot of the floated units assembly and the bottom of the tungsten-carbide jewel ball associated with the

upper jewel assembly. This definition assumes that the jewel ball is flush against the jewel ball retainer. The specified end shake for the 20IG gyro unit is 0.005 inch. This small amount gives sufficient axial play of the floated units assembly to allow for thermal expansion changes and to protect the pivots against shock, once the Fluorolube flotation fluid has been added (ref. Section VII).

**Note**

*In general, regardless of gyro unit orientation, end shake is the distance the floated units assembly is allowed to move between pivot seats. Of course, when the gyro unit is in an upright position and is not yet filled with Fluorolube, the power pivot will rest on top of the tungsten-carbide jewel ball in the lower jewel assembly. Hence, the distance between the top of the upper pivot and the bottom of the jewel ball in the upper jewel assembly is the end shake.*

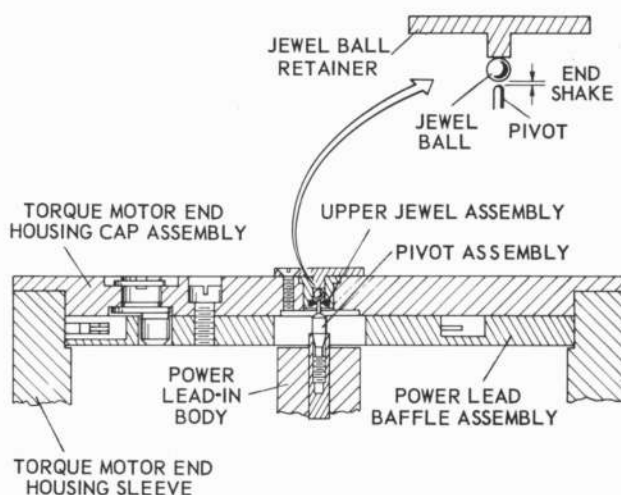


Fig. 5-7. Cross-section view showing the end shake in an assembled gyro unit mounted on an assembly stand.

5-14. The procedure used for determining the end shake involves finding the distance from the top of the torque motor end housing sleeve to the top of the upper pivot and then finding the distance from the top of the torque motor end housing sleeve to the bottom of ball in the upper jewel assembly. The difference between these two distances is the actual end shake present in the gyro unit. As an aid in visualizing this situation, remember that in a completed gyro unit the top of the upper pivot and the bottom of the ball are both below the top of the torque motor end housing sleeve (ref. Fig. 5-7).

5-15. The procedure used to acquire the specified end shake of 0.005 inch involves two steps:

a. Machining an amount equal to the *actual* end shake off the top of the torque motor end housing sleeve, thus leaving the unit with zero end shake.

b. Machining 0.005 inch off the shaft protruding from the ball retainer in order to obtain the specified end shake.

5-16. DETAILED PROCEDURE FOR DETERMINING THE ACTUAL END SHAKE. An adapter ring, a surface plate, and a special-type micrometer gauge, which has an ordinary micrometer scale, constitute the special equipment used during the procedure for determining the actual amount of end shake. Figure 5-8 shows the gauge mounted

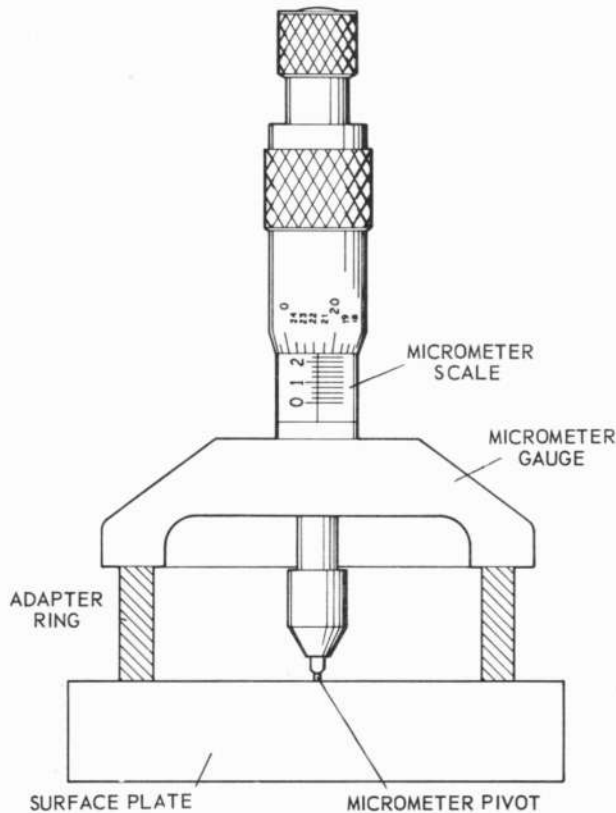


Fig. 5-8. Cross-section view showing the special equipment used for determining the actual amount of end shake in a gyro unit.

on the adapter ring, which in turn rests on the surface plate. The gauge does not measure depth directly because it uses the spindle of an ordinary micrometer. As the micrometer pivot mounted on the spindle is lowered, the micrometer scale readings become smaller. Three readings are

taken with this special equipment. The first reading, during which the adapter ring is placed on the surface plate (ref. Fig. 5-8), establishes the height of the bottom of the adapter ring *above* the micrometer zero. The second reading, during which the adapter ring is placed on the torque motor end housing sleeve (ref. Fig. 5-9) when

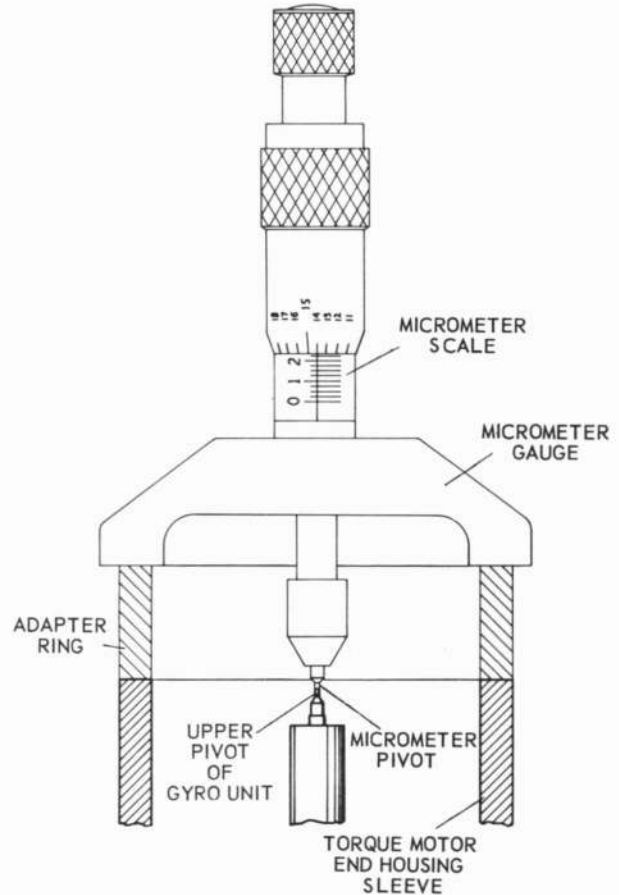
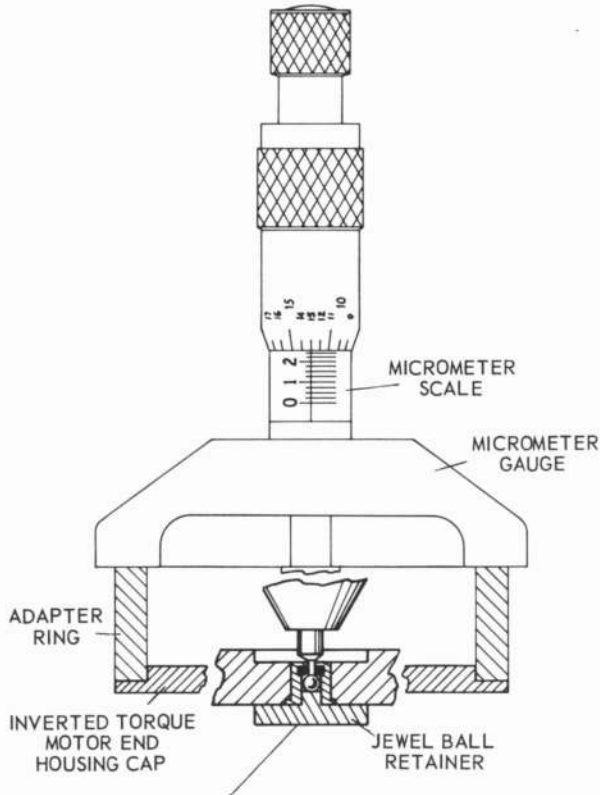


Fig. 5-9. Cross-section view showing the special end-shake equipment mounted on the torque motor end housing sleeve.

this sleeve is mounted as shown in Fig. 5-6, establishes the height of the top of the upper pivot *above* the micrometer zero. The difference between these two readings gives the distance that the top of the upper pivot lies below the top of the torque motor end housing sleeve. The third reading, during which the adapter ring is placed on the inverted torque motor end housing cap (ref. Fig. 5-10), establishes the height of the top of the ball *above* the micrometer zero. The difference between the first and third readings gives the distance the top of the ball lies above the part of the endhousing cap on which the adapter rests. This is equal to

the distance that the bottom of the ball would lie below the top of the torque motor end housing sleeve in the gyro unit when mounted on the assembly stand. To obtain the actual end shake, subtract



Note: This portion of the illustration has been enlarged for clarity.

Fig. 5-10. Cross-section view showing the special end-shake equipment mounted on the torque motor end housing cap.

the number representing the distance from the top of the torque motor end housing sleeve to the top of the upper pivot from the number representing the distance from the top of the torque motor end housing sleeve to the bottom of the ball.

5-17. The following is the step-by-step procedure used for determining the actual end shake:

- a. Place the adapter ring on the surface plate (ref. Fig. 5-8).
- b. Set the micrometer gauge on the top of the adapter ring.
- c. Advance the micrometer pivot until it touches the surface plate.
- d. Read the micrometer and record the number. Call this number  $D_{(ref)}$ .
- e. Place the adapter ring on top of the torque motor end housing sleeve (ref. Fig. 5-9).

f. Set the micrometer gauge on top of the adapter ring.

g. Advance the micrometer pivot until it touches the upper pivot of the gyro unit.

h. Read the micrometer and record the number. Call this number  $D_1$ .

Note

The number  $D_1$  should always be less than the number  $D_{(ref)}$ .

i. Subtract the number  $D_1$  from the number  $D_{(ref)}$  and record the difference. Call this number  $D_2$ .  $D_2$  is the distance from the top of the torque motor end housing sleeve to the top of the upper pivot.

j. Remove the assembled torque motor end housing cap from its plastic bag (ref. paragraph 4-101g). Then place the adapter ring on the inverted torque motor end housing cap as shown in Fig. 5-10.

k. Set the micrometer gauge on top of the adapter ring.

l. Advance the micrometer pivot until it touches the top of the jewel ball.

m. Read the micrometer and record the number. Call this number  $D_3$ .

Note

The number  $D_3$  should always be greater than the number  $D_{(ref)}$ .

n. Subtract the number  $D_{(ref)}$  from the number  $D_3$  and record the difference. Call this difference  $D_4$ .  $D_4$  is the distance from the top of the torque motor end housing sleeve to the bottom of the ball in the gyro unit when mounted on the assembly stand.

Note

The number  $D_2$  should always be greater than the number  $D_4$ .

o. Subtract the number  $D_4$  from the number  $D_2$ . Record the difference. This number is the actual end shake, that is, the clearance that would exist between the top of the upper pivot and the bottom of the jewel ball in the gyro unit when mounted on the assembly stand.



5-18. The following illustrative tabulation shows typical readings and the calculations necessary to find the actual end shake.

Height of bottom of adapter ring above micrometer zero	$D_{(ref)}$	0.2535 in.
Height of top of upper pivot above micrometer zero	$D_1$	0.2335 in.
Distance from top of torque motor end housing sleeve to top of upper pivot	$D_2$	0.0200 in.
	$(D_2 = D_{(ref)} - D_1)$	
Height of top of ball above micrometer zero	$D_3$	0.2680 in.
Distance from top of torque motor end housing sleeve to bottom of ball in gyro unit mounted on assembly test stand	$D_4$	0.0145 in.
	$(D_4 = D_3 - D_{(ref)})$	
Clearance between top of pivot and bottom of ball in gyro unit mounted on assembly test stand	$D_5$	0.0055 in.
	$(D_5 = D_2 - D_4)$	

5-19. DETAILED PROCEDURE FOR OBTAINING THE SPECIFIED END SHAKE. The actual end shake for the preceding illustrative example is 0.0055 inch, which is 0.0005 inch greater than the specified end shake of 0.005 inch. This means the ball must be moved 0.0005 inch closer to the upper pivot. To do this, it is necessary to first machine 0.0055 inch off the top of the torque motor end housing sleeve, thus giving the gyro unit zero end shake. The number  $D_1$  will now be 0.2390 inch, which is an increase of 0.0055 inch. The distance from the top of the torque motor end housing sleeve to the top of the upper pivot ( $D_2 = D_{(ref)} - D_1$ ) is now 0.0145 inch, which is identical with the distance in the gyro unit mounted on the assembly stand from the top of the torque motor end housing sleeve to the bottom of the ball ( $D_4 = D_3 - D_{(ref)}$ ). Since  $D_2 = D_4$ , the end shake ( $D_5 = D_2 - D_4$ ) is zero.

5-20. To acquire the necessary 0.005 inch end shake, it is now necessary to machine 0.005 inch off the protruding shaft of the jewel ball retainer. The new numbers obtained after 0.0055 inch and 0.005 inch are respectively machined off the torque motor end housing sleeve and the jewel ball retainer shaft are given in the following tabulation.

Height of bottom of adapter ring above micrometer zero	$D_{(ref)}$	0.2535 in.
Height of top of upper pivot above micrometer zero	$D_1$	0.2390 in.
Distance from top of torque motor end housing sleeve to top of upper pivot	$D_2$	0.0145 in.
	$(D_2 = D_{(ref)} - D_1)$	

Height of top of ball above micrometer zero	$D_3$	0.2630 in.
Distance from top of torque motor end housing sleeve to bottom of ball in gyro unit mounted on assembly test stand	$D_4$	0.0095 in.
	$(D_4 = D_3 - D_{(ref)})$	
Clearance between top of pivot and bottom of ball in gyro unit mounted on the assembly stand	$D_5$	0.0050 in.
	$(D_5 = D_2 - D_4)$	

5-21. For the purpose of illustration, suppose 0.0056 inch were machined off the torque motor end housing sleeve through error, instead of the desired 0.0055 inch. Also, assume that no material has yet been machined from the jewel ball retainer. Under this circumstance, the tabulation would be as follows:

Height of bottom of adapter ring above micrometer zero	$D_{(ref)}$	0.2535 in.
Height of top of upper pivot above micrometer zero	$D_1$	0.2391 in.
Distance from top of torque motor end housing sleeve to top of upper pivot	$D_2$	0.0144 in.
	$(D_2 = D_{(ref)} - D_1)$	
Height of top of ball above micrometer zero	$D_3$	0.2680 in.
Distance from top of torque motor end housing sleeve to bottom of ball in gyro unit mounted on assembly test stand	$D_4$	0.0145 in.
	$(D_4 = D_3 - D_{(ref)})$	
Clearance between top of pivot and bottom of ball in gyro unit mounted on assembly test stand	$D_5$	-0.0001 in.
	$(D_5 = D_2 - D_4)$	

The negative number indicates that too much material has been machined from the torque motor end housing sleeve. To offset this error, 0.0051 inch would have to be machined off the ball retainer shaft.

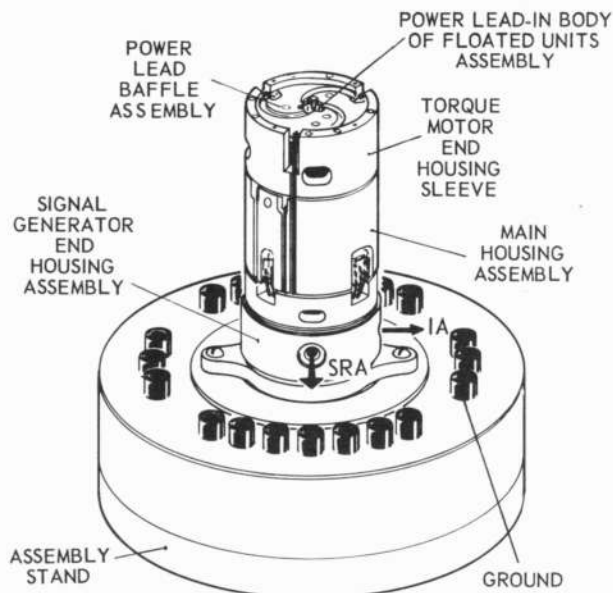
#### Note

*Once the proper end shake has been obtained by machining, the torque motor end housing sleeve should be replaced onto the main housing assembly, fitting it over the projecting ends of the ¼ signal generator tie rods (ref. Fig. 5-4). It should then be secured in position by inserting the ¼ torque motor tie rods through the clearance holes in the torque motor end housing sleeve and threading them into the tapped holes in the main housing. In addition, the modified torque motor end housing cap assembly should be reassembled and repackaged in its plastic bag, pending further use in the assembly procedure (ref. paragraph 5-27a).*

5-22. ADDING THE POWER LEAD BAFFLE ASSEMBLY AND THE ASSOCIATED FLEX LEADS.

5-23. Figure 5-11 shows the power lead baffle assembly, together with the three gyro motor flex

leads, assembled to the arrangement shown in Fig. 5-6 and described in preceding paragraphs. When properly assembled, the flex leads will rest midway between the sides of the curved channels milled in the baffle plate. In addition, they will rest midway between the top of the baffle plate and



Note: For identification of the other test jacks, see Fig. 5-2.

Fig. 5-11. Pictorial view showing the power lead baffle assembly, together with three gyro motor flex leads, added to the torque motor end housing sleeve.

the bottom of the channels. The three flex leads, which carry power to the gyro motor, have a composition of 85 percent silver and 15 percent copper. Each is a flat ribbon wire, 0.001 inch by 0.009 inch in cross section, and has an electrical resistance of 10.44 ohms per foot.

5-24. The detailed procedure for adding the power lead baffle assembly and the associated flex leads is as follows:

a. Remove the assembled power lead baffle assembly from its plastic bag (ref. paragraph 4-100).

b. Cut 3 strips – each about 3 inches long – from the spool of flat ribbon wire used for flex leads.

c. Form the 3 flat-ribbon leads into circular arcs by using an approximately 1/4-inch-diameter cylindrical rod as a forming tool. To form a lead, place it crosswise on top of the forming tool, underneath the thumb of the hand holding the tool. With

a downward motion of the other hand, slowly draw the length of the lead over the forming tool. It may be necessary to repeat this procedure a few times in order to obtain the desired radius of curvature.

d. After forming, anneal the flex leads on the annealing fixture (ref. Fig. 3-44) for 8 hours at 220° F.

e. Solder the annealed leads in the slots of the brass terminals on the baffle plate.

f. Slip the power lead baffle assembly over the float shaft, with the hole for the eccentric cam along the positive direction of the spin reference axis (ref. Fig. 5-12).

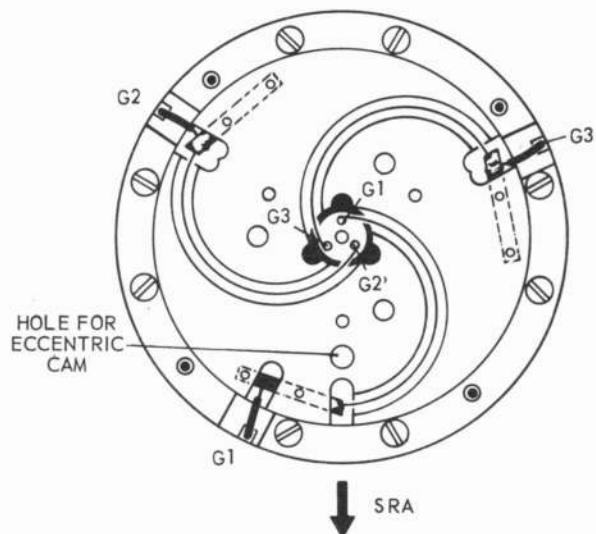


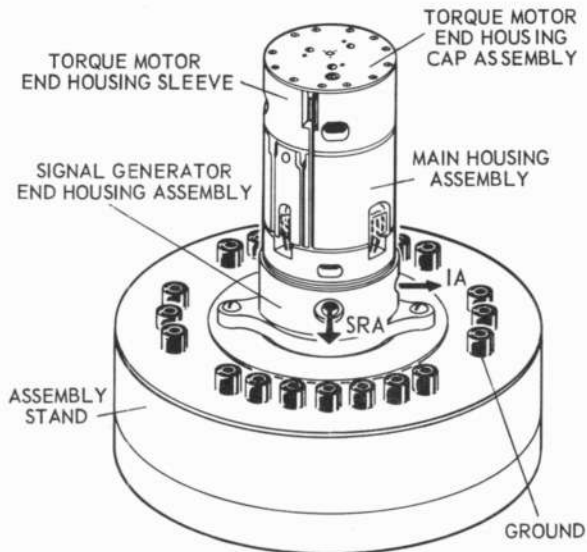
Fig. 5-12. Top view of the power lead baffle assembly, identifying the end connections of the three gyro motor flex leads.

g. Insert each of the 3 gyro motor leads from the 20-pin connector in the hole of the associated brass terminal on the baffle plate and then solder the leads in place.

h. Solder the loose ends of the flex leads to the outboard sides of the three power lead rods projecting from the power lead baffle assembly. Before soldering, position each flex lead with respect to its power lead rod so that, when the soldering procedure is completed, the flex leads do not touch the baffle plate (ref. paragraph 5-23). Match each flex lead to the appropriate power lead rod with the aid of Fig. 5-12.

5-25. SECURING THE TORQUE MOTOR END HOUSING CAP ASSEMBLY.

5-26. Figure 5-13 shows the torque motor end housing cap assembly secured in position on top of the arrangement shown in Fig. 5-11. Extreme care must be exercised in placing the end housing cap assembly in position to be certain that the top pivot will not be damaged. Refer to the note in paragraph 5-9b for the action required when a pivot becomes damaged.



Note: For identification of the other test jacks, see Fig. 5-2.

Fig. 5-13. Pictorial view showing the torque motor end housing cap assembly secured to the torque motor end housing sleeve.

5-27. The detailed procedure for securing the torque motor end housing cap assembly is as follows:

a. Remove the assembled torque motor end housing cap assembly from its plastic bag (ref. paragraph 5-21).

b. With the end housing cap assembly oriented so that the baffle cam is along the positive direction of the spin reference axis, carefully fit this assembly over the top pivot onto the torque motor end housing sleeve.

c. Fasten the baffle plate to the end cap by means of 3 No. 0-80 N.F. -2, 1/8 inch long, flat fillister-head machine screws.

d. Secure the end housing cap assembly to the torque motor end housing sleeve by means of 4 No. 1-72 N.F. -2, 1/4 inch long, flat-head screws.

Note

A special removing tool (ref. Fig. 3-45) is used to lift the end housing cap assembly off the torque motor end housing sleeve should this become necessary. The tool is similar to a pair of long-nosed pliers except that the jaws of the pliers open up when the handles are squeezed together. To lift the end housing cap assembly, insert the jaws in turn in the 3 U-shaped cutouts of the torque motor end housing sleeve and squeeze the handles together. Do not lift the end cap off with the pliers applied in only one cutout, but rather move from one cutout to the next in order to lift the cap off gently, so that the upper pivot will not be damaged.

## SECTION VI

### MICROSYN CENTERING

#### 6-1. GENERAL.

6-2. For optimum performance of the assembled 20IG gyro unit, the Microsyn signal generator and the Microsyn torque motor must be exactly centered. The Microsyn units are centered after the gyro unit has been assembled to the point described in Section V - that is, before it has been filled with liquid and before the outer case assembly has been attached. Centering a Microsyn unit means adjusting the stator and rotor of the unit both rotationally and radially with respect to one another as required to obtain optimum input-output relationships. Centering a Microsyn signal generator a) centers the rotor angular displacement input - voltage signal output relationship (ref. Fig. 6-1) so that the null voltage signal occurs at the zero-rotor-displacement angle of the gyro unit, b) minimizes the null voltage, with a resultant increase in accuracy at extremely small values of rotor displacement, and c) reduces the reaction torque and the uncertainty torque acting on the floated units assembly. Centering a Microsyn torque motor reduces the reaction torque, which provides better linearity between current input signals and the torque output, and also reduces the uncertainty acting on the floated units assembly.

6-3. In the centering procedure, both the signal generator and the torque motor are treated as signal generators. Microsyn centering consists of three main divisions: (1) rotational centering, (2) radial centering along the short axis of the rotor, and (3) radial centering along the long axis of the rotor. The Microsyn unit is centered rotationally when its null voltage occurs with the rotor midway between the mechanical stop positions (this is the zero-angular-displacement position of the rotor). This rotational centering is obtained when the voltage output signals at the two rotor-stop positions are equal. The Microsyn unit is centered radially when, with zero rotor angle displacement, the stator is adjusted along both the short axis

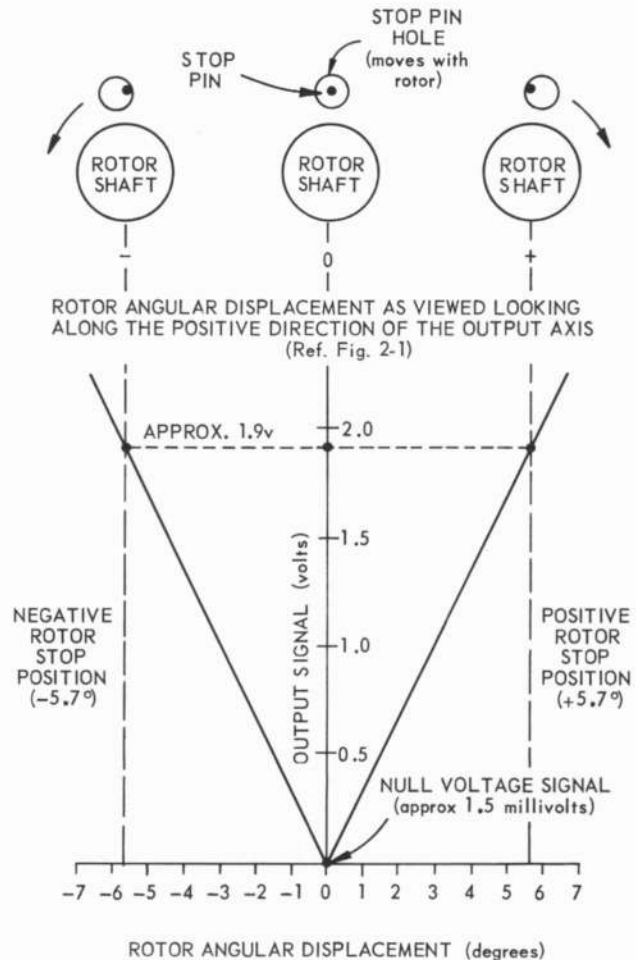


Fig. 6-1. Signal generator performance plot; voltage output signal as a function of rotor angular displacement.

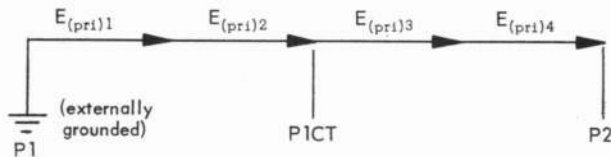
(x-axis, Fig. 6-2) and the long axis (y-axis, Fig. 6-2) of the rotor so that the flux distribution is the same in all four poles. Therefore, the induced voltages in the individual coils of the secondary winding will be equal.

6-4. **SIGNAL GENERATOR ROTATIONAL CENTERING.** Rotational centering for either Microsyn unit is accomplished by exciting the Microsyn primary winding and measuring the output voltage from the secondary winding.

**Note**

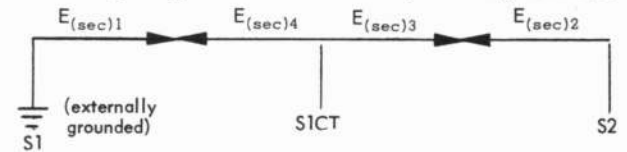
The two windings of the torque motor do not actually operate like the primary and secondary of a transformer, as do the two windings of the signal generator. However, since the winding arrangement of the torque motor is basically that of the signal generator, the winding between terminals T1 and T2 of the torque motor is referred to, for convenience, as the primary winding. Similarly, the winding between terminals T3 and T4 of the torque motor is called the secondary winding.

For the Microsyn signal generator, the primary winding is the one with P designations; and the secondary winding is the one with S designations (ref. Fig. 6-2a). The excitation voltages applied to the individual coils of the signal generator primary winding may be shown by the following voltage diagram:



The symbols  $E_{(pri)1}$ ,  $E_{(pri)2}$ ,  $E_{(pri)3}$ , and  $E_{(pri)4}$  represent the excitation voltages applied to the coils of poles 1, 2, 3, and 4, respectively. The lengths of the arrows correspond to the magnitudes of the voltages concerned. The voltages in these and the following diagrams are represented as being in

phase or 180 degrees out of phase. Although they may depart somewhat from this ideal condition because of variations in resistance and reactance from coil to coil, the representation shown is satisfactory for the purposes of this discussion. Any substantial departures from the ideal phase relationships are compensated by the use of a quadrature adjustment. The excitation voltages to the coils of the signal generator primary winding are all equal. When the rotor is centered rotationally, the voltages induced in the individual coils of the signal generator secondary winding will be:



These induced voltages are also all equal. However, the coils of the secondary winding on poles 2 and 4 of the signal generator are connected so as to oppose the coils of the primary winding on poles 2 and 4, and the coils of the secondary winding on poles 1 and 3 are connected so as to aid the coils of the primary winding on poles 1 and 3. Therefore, the resultant induced voltage in the secondary winding of the signal generator between terminals S1 and S2 is zero. If the rotor is moved a few degrees in the clockwise direction, the resultant induced

Note: See Fig 2-18 for the over-all wiring diagram of the 20IG gyro unit.

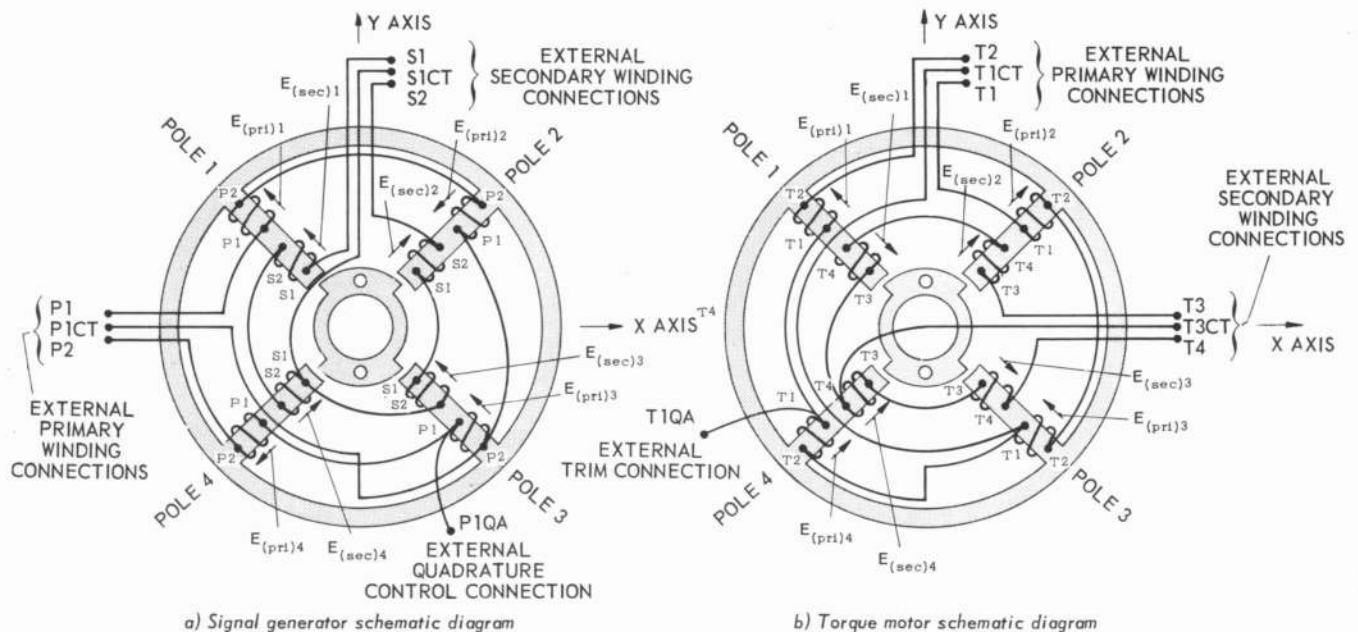
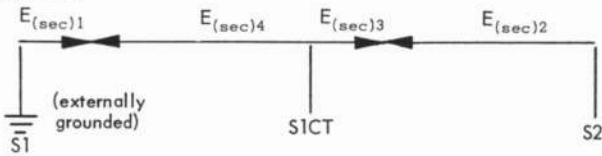


Fig. 6-2. Wiring diagrams for the Microsyn centering procedure of the 20IG gyro unit.

voltages in the signal generator secondary winding will be:



The clockwise rotation of the signal generator rotor decreases the reluctance of the magnetic path between the rotor and poles 2 and 4, with a resultant increase in the induced voltages  $E_{(sec)2}$  and  $E_{(sec)4}$ . Similarly, the clockwise rotation of the rotor increases the reluctance of the magnetic path to poles 1 and 3, with a resultant decrease in the induced voltages  $E_{(sec)1}$  and  $E_{(sec)3}$ . The summation of these voltages shows a net resultant induced voltage in the secondary winding between terminals S1 and S2. With the excitation voltage across the primary winding (P1-P2) applied to the horizontal input of an oscilloscope and the induced voltage across the secondary winding (S1-S2) applied to the vertical input of the oscilloscope, the oscilloscope trace will go downward-to-the-right  $\searrow$  because the induced secondary voltage is 180 degrees out of phase with the excitation voltage.

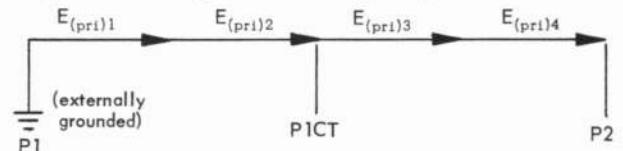
Note

The  $\searrow$  symbol and similar symbols used in the text of this section do not represent the actual shape of the oscilloscope trace, but only its orientation. The actual trace seen should be an ellipse of the orientation indicated in each particular instance.

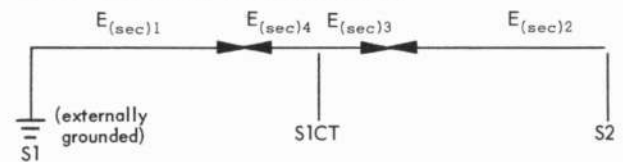
If the signal generator rotor were turned in a counterclockwise direction, the reverse would be true: the voltages  $E_{(sec)1}$  and  $E_{(sec)3}$  would be the larger induced voltages and the resultant induced secondary voltage would be in phase with the excitation voltage. This would be indicated by an upward-to-the-right slope of the oscilloscope trace  $\nearrow$ . The rotor is electrically centered rotationally with respect to the stators when the induced secondary voltage is a minimum as indicated by a vacuum tube voltmeter and a horizontal trace on the oscilloscope  $\ominus$ .

**6-5. SIGNAL GENERATOR RADIAL CENTERING ALONG ROTOR LONG AXIS.** Radial centering of the signal generator along the long axis (y-axis, Fig. 6-2a) of the rotor is accomplished by exciting the primary winding (P1-P2) and measuring the induced voltage across one-half of the secondary

winding (S1-S1CT) when the rotor is at the rotational electrical-zero position. The excitation voltages applied to the individual coils of the primary winding may be shown by the following diagram:

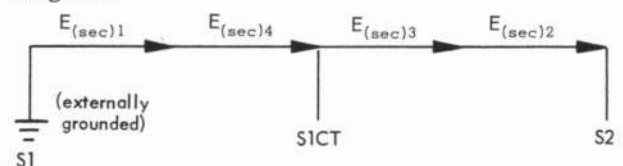


These excitation voltages are all equal. When the rotor is moved radially from its center along the long axis of the rotor (y-axis) toward the poles 1 and 2, the voltages induced in the individual coils of the secondary winding will be:

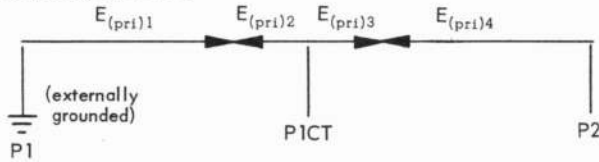


The resultant induced voltage in one-half the secondary winding (S1-S1CT) will be in phase with the excitation voltage. Therefore, the oscilloscope trace will be upward-to-the-right  $\nearrow$ . Radial motion of the rotor away from center toward poles 3 and 4 will induce a voltage 180 degrees out of phase with the excitation voltage in one-half the secondary winding, yielding a downward-to-the-right trace on the oscilloscope  $\searrow$ . The rotor is centered radially along the y-axis when the voltage induced in one-half the secondary winding is a minimum ( $E_{(sec)1} \cong E_{(sec)4}$ ), as indicated by a vacuum tube voltmeter and a horizontal trace on the oscilloscope  $\ominus$ .

**6-6. SIGNAL GENERATOR RADIAL CENTERING ALONG ROTOR SHORT AXIS.** Radial centering of the signal generator along the short axis of the rotor (x-axis, Fig. 6-2a) is accomplished by exciting the secondary winding (S1-S2) and measuring the induced voltage across one-half the primary winding (P1-P1CT) when the rotor is at the rotational electrical-zero position. The excitation voltages applied to the individual coils of the secondary winding may be shown by the following diagram:

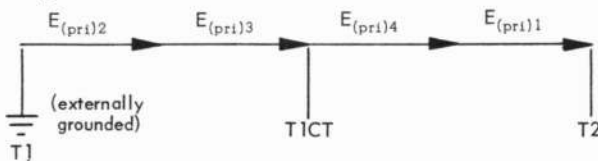


These excitation voltages are all equal. When the rotor is moved radially from its center along the x-axis (Fig. 6-2a) toward poles 1 and 4, the voltage induced in the individual coils of the primary winding will be:

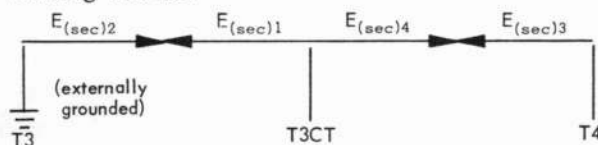


The resultant induced voltage in one-half the primary winding (P1-P1CT) will be in phase with the excitation voltage. Therefore, the oscilloscope trace will be upward-to-the-right  $\nearrow$ . Radial motion of the rotor away from the center toward poles 2 and 3 will induce an out-of-phase voltage, which would be indicated by a downward-to-the-right trace on the oscilloscope  $\searrow$ . The signal generator rotor is centered radially along the x-axis when the voltage induced in one-half the primary winding is a minimum ( $E_{(pri)1} \cong E_{(pri)2}$ ), as indicated by a vacuum tube voltmeter and a horizontal trace on the oscilloscope  $\rightarrow$ .

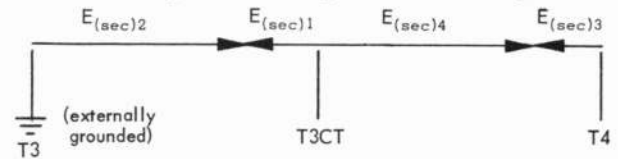
**6-7. TORQUE MOTOR ROTATIONAL CENTERING.** Rotational centering of the torque motor is accomplished by exciting the primary winding and measuring the output voltage from the secondary winding. The torque motor primary winding is the one with the T1, T2 designations; the secondary winding is the one with the T3, T4 designations (ref. Fig. 6-2b). The excitation voltage applied to the individual coils of the torque motor primary winding may be shown by the following voltage diagram:



These excitation voltages to the coils of the torque motor primary winding are all equal. When the rotor is centered rotationally, the voltages induced in the individual coils of the torque motor secondary winding will be:



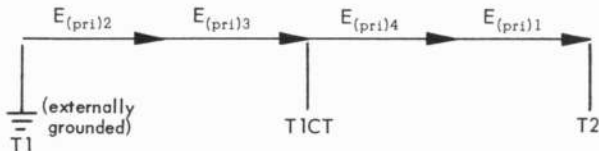
These induced voltages are also all equal. However, the coils of the secondary winding on poles 1 and 3 of the torque motor oppose the coils of the primary winding and the coils of the secondary winding on poles 2 and 4 aid the coils of the primary winding, so that the resultant induced voltage in the torque motor secondary winding between terminals T3 and T4 is zero. If the rotor is moved a few degrees in the clockwise direction, the resultant induced voltages in the torque motor winding will be:



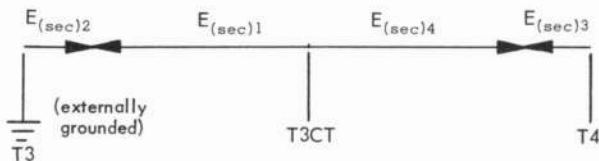
The clockwise rotation of the torque motor rotor decreases the reluctance of the magnetic path between the rotor and poles 2 and 4, with a resultant increase in the induced voltages  $E_{(sec)2}$  and  $E_{(sec)4}$ . Similarly, the clockwise rotation of the rotor increases the reluctance of the magnetic path to poles 1 and 3, with a resultant decrease in the induced voltages  $E_{(sec)1}$  and  $E_{(sec)3}$ . The summation of these voltages shows a net resultant induced voltage in the secondary winding between terminals T3 and T4. With the excitation voltage across the primary winding (T1-T2) applied to the horizontal input of an oscilloscope and the induced voltage across the secondary winding (T3-T4) applied to the vertical input of the oscilloscope, the oscilloscope trace will go upward to the right  $\nearrow$  because the induced secondary voltage is in phase with the excitation voltage. If the torque motor rotor were turned in a counterclockwise direction, the reverse would be true: the voltages  $E_{(sec)1}$  and  $E_{(sec)3}$  would be the larger induced voltages and the resultant induced secondary voltage would be 180 degrees out of phase with the excitation voltage. This would be indicated by a downward-to-the-right slope of the oscilloscope trace  $\searrow$ . The rotor is electrically centered rotationally with respect to the stator when the induced secondary voltage is a minimum, as indicated by a vacuum tube voltmeter and a horizontal trace on the oscilloscope  $\rightarrow$ .

**6-8. TORQUE MOTOR RADIAL CENTERING ALONG ROTOR SHORT AXIS.** Radial centering of the torque motor along the short axis (x-axis,

Fig. 6-2b) of the rotor is accomplished by exciting the primary winding (T1-T2) and measuring the induced voltage across one-half of the secondary winding (T3-T3CT) when the rotor is at the rotational electrical-zero position. The excitation voltages applied to the individual coils of the primary winding may be shown by the following diagram:



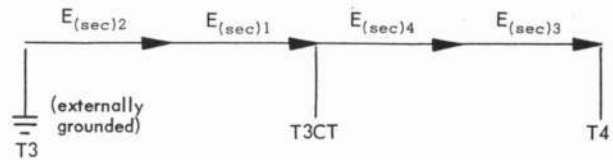
These excitation voltages are all equal. When the rotor is moved radially from its center along the short axis of the rotor (x-axis) toward poles 1 and 4 (Fig. 6-2b), the voltages induced in the individual coils of the secondary winding will be:



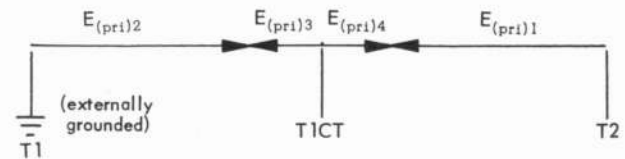
The resultant induced voltage in one-half the secondary winding (T3-T3CT) is 180 degrees out of phase with the excitation voltage. Therefore, the oscilloscope trace will be downward-to-the-right  $\searrow$ . Radial motion of the rotor away from center toward poles 2 and 3 will induce an in-phase voltage in one-half the secondary winding, as indicated by an upward-to-the-right trace on the oscilloscope  $\nearrow$ . The rotor is centered radially along the x-axis when the voltage induced in one-half the secondary winding is a minimum ( $E_{(sec)2} \cong E_{(sec)1}$ ), as indicated by a vacuum tube voltmeter and a horizontal trace on the oscilloscope  $\ominus$ .

**6-9. TORQUE MOTOR RADIAL CENTERING ALONG ROTOR LONG AXIS.** Radial centering of the torque motor along the long axis of the rotor (y-axis, Fig. 6-2b) is accomplished by exciting the secondary winding (T3-T4) and measuring the induced voltage across one-half the primary winding (T1-T1CT) when the rotor is at the rotational electrical-zero position. The excitation voltages

applied to the individual coils of the secondary winding may be shown by the following diagram:



These excitation voltages are all equal. When the rotor is moved radially from its center along the y-axis (Fig. 6-2b) toward poles 1 and 2, the voltages induced in the individual coils of the primary winding will be:



The resultant induced voltage in one-half the primary winding (T1-T1CT) will be in phase with the excitation voltage. Therefore, the oscilloscope trace will be upward-to-the-right  $\nearrow$ . Radial motion of the rotor away from center toward poles 3 and 4 will induce an out-of-phase voltage that would be indicated by a downward-to-the-right trace on the oscilloscope  $\searrow$ . The torque motor rotor is centered radially along the y-axis when the voltage induced in one-half the primary winding is a minimum ( $E_{(pri)2} \cong E_{(pri)3}$ ), as indicated by a vacuum tube voltmeter and a horizontal trace on the oscilloscope  $\ominus$ .

#### 6-10. EQUIPMENT REQUIRED.

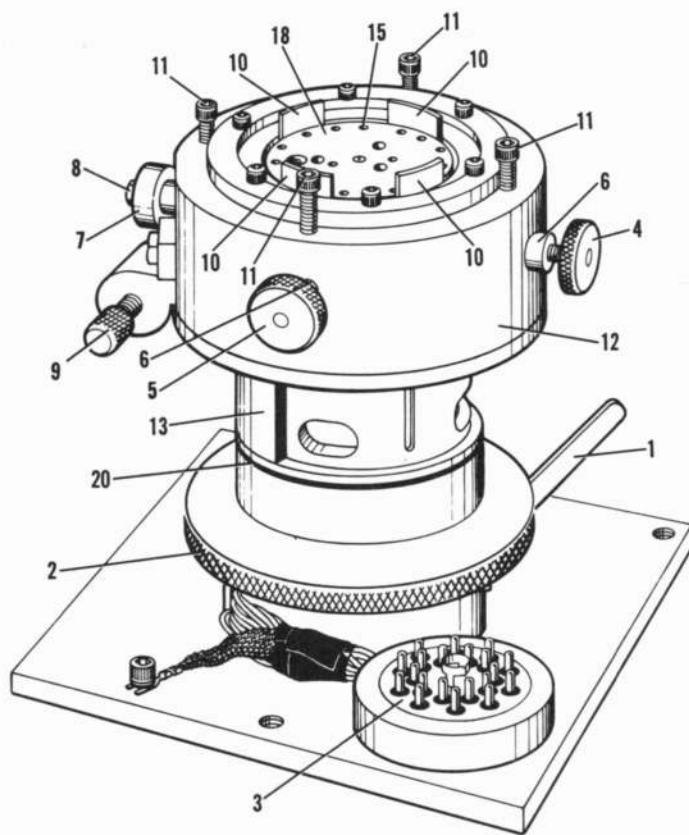
6-11. The various items of equipment required for the Microsyn centering procedure are (ref. Figs. 6-3 and 6-4):

- a. Microsyn centering fixture.
- b. Test console and equipment mounted therein.
- c. Two oscilloscopes.
- d. Two vacuum-tube voltmeters.

#### 6-12. PROCEDURE FOR PLACING GYRO UNIT IN CENTERING FIXTURE.

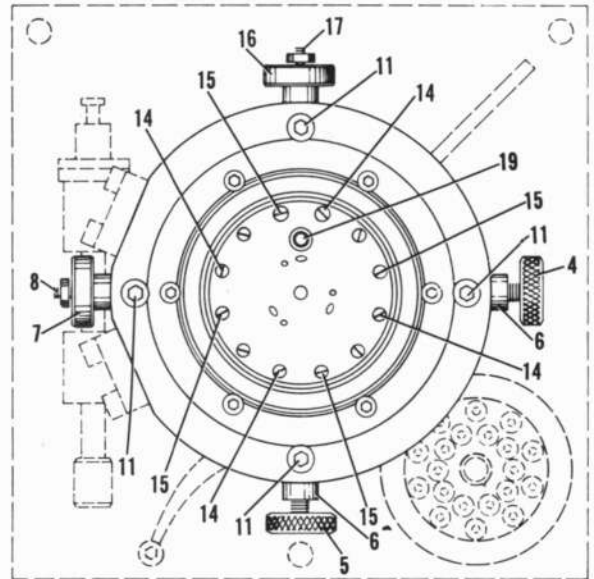
6-13. The purpose of the centering fixture (ref. Fig. 6-3) is to hold the gyro unit and to permit easy adjustment of each Microsyn stator with respect to the associated rotor. The detailed





ROTOR LONG  
AXIS  
(Y-axis, Fig. 6-2)  
SPIN  
REFERENCE  
AXIS

ROTOR SHORT AXIS  
(X-axis, Fig. 6-2)



1. Ejector lever
2. Collet draw-in nut
3. 20-pin connector
4. Radial adjusting screw knob
5. Radial adjusting screw knob
6. Adjusting rod housing
7. Pressure rod housing
8. Pressure rod
9. Angular adjustment screw
10. Wedges
11. Set screws
12. Adjustment sleeve
13. Spacer
14. Signal generator tie rods
15. Torque motor tie rods
16. Pressure rod housing
17. Pressure rod
18. Gyro unit
19. Flex lead adjustment screw
20. Collet jaws
21. Adjusting rod

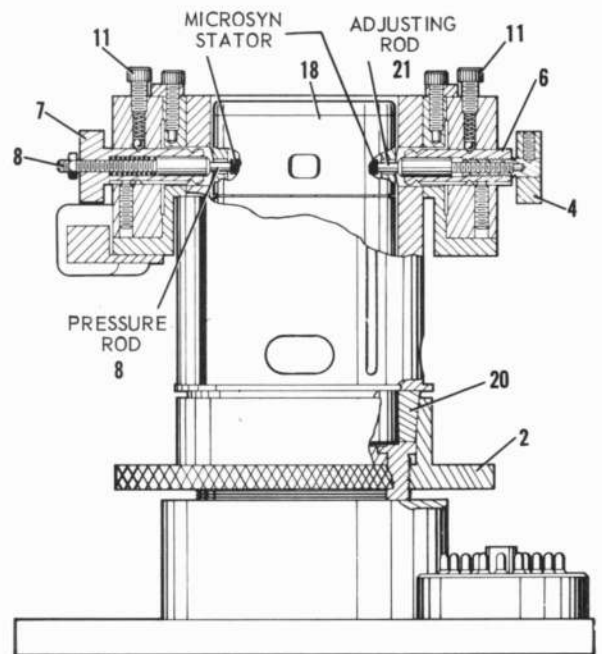
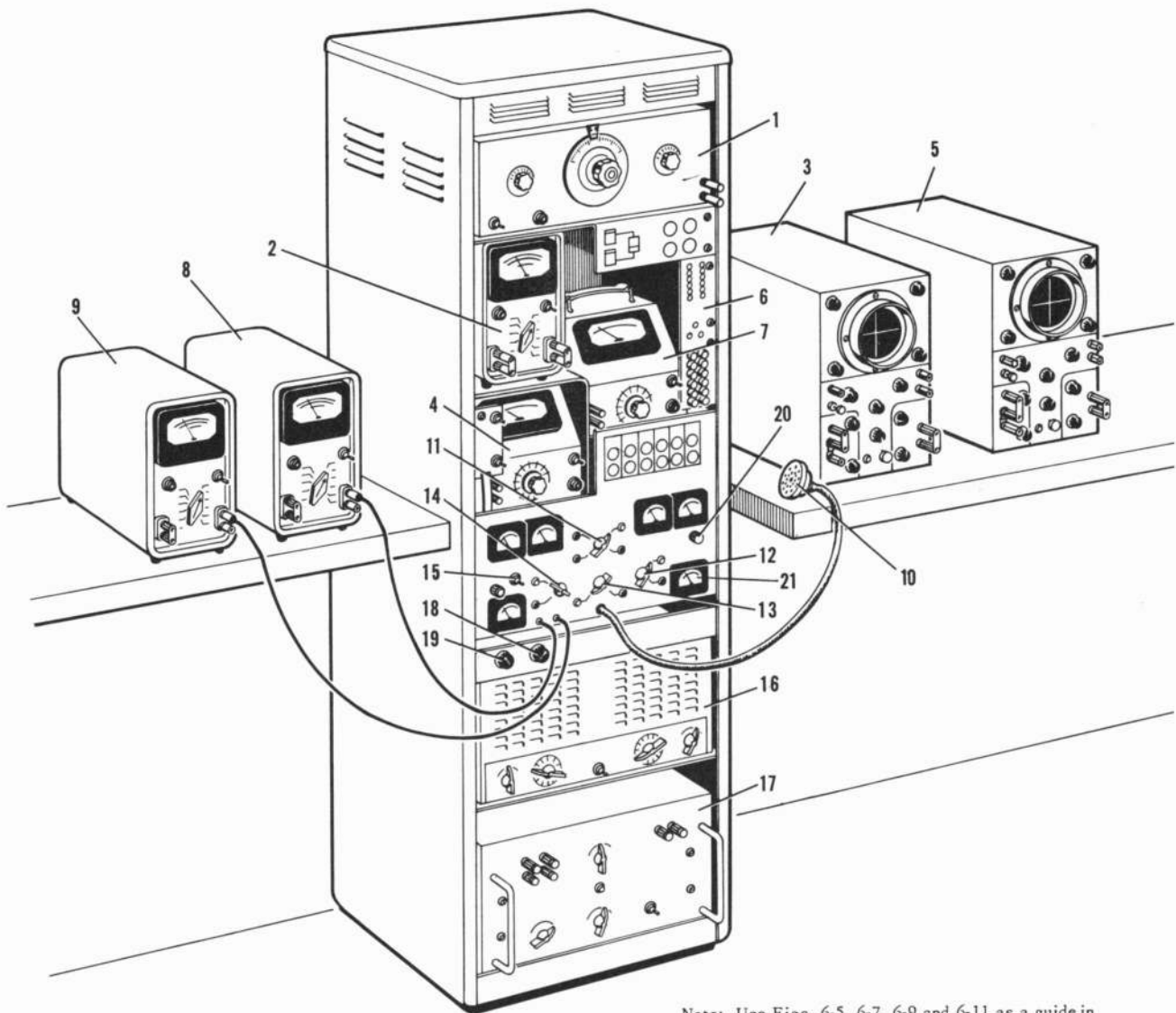


Fig. 6-3. Pictorial views of the Microsyn centering fixture.



Note: Use Figs. 6-5, 6-7, 6-9 and 6-11 as a guide in making connections to the two oscilloscopes.

- |  |  |   |
|--|--|---|
| 1. Audio oscillator  | 9. Secondary input voltmeter – Microsyn used as a torque motor | 16. Excitation amplifier – for Microsyn being centered                          |
| 2. Angular voltmeter                                       | 10. 20-pin receptacle  | 17. Driving amplifier – for Microsyn used as torque motor                       |
| 3. Angular oscilloscope                                    | 11. Selector switch  | 18. Primary torque current rheostat – for Microsyn being used as torque motor   |
| 4. Radial voltmeter  | 12. Circuit excited switch – primary or secondary              | 19. Secondary torque current rheostat – for Microsyn being used as torque motor |
| 5. Radial oscilloscope                                     | 13. Type of unit switch – rate or integrating or pendulous     | 20. Quadrature adjust rheostat  |
| 6. Impedance matching panel                                | 14. Torque-off-restraint switch                                | 21. Torque motor excitation ammeter   |
| 7. Excitation voltmeter – Microsyn being centered          | 15. Torque direction switch – CW, CCW                          |   |
| 8. Primary input voltmeter – Microsyn used as torque motor |  |   |

Fig. 6-4. Pictorial view of the Microsyn centering test equipment.

procedure for placing the assembled gyro unit into the centering fixture is as follows:

a. Rotate the collet draw-in nut (2, Fig. 6-3) in a clockwise direction (as viewed from the top of centering fixture) as far as it will go, so that the nut lowers and loosens the collet jaws (20). Push back the collet jaws from the inside of the fixture so that they do not protrude within the inside diameter of the fixture.

b. Loosen the set screw (11) on each of the two adjusting rod housings (6) and on each of the two pressure rod housings (7 and 16).

c. Pull out each of the two adjusting rod housings (6) and each of the pressure rod housings (7 and 16) as far as it will go, by pulling on the radial adjusting screw knobs (4 and 5) and the pressure rod housings (7 and 16), so that the adjusting rods and pressure rods on the inside clear the inside diameter of the fixture.

d. Plug the gyro unit (18) into the centering fixture, making sure that the plug on the gyro unit fits firmly into the socket at the bottom of the fixture.

e. Clamp the bottom of the gyro unit in position by rotating the collet draw-in nut (2) in a counterclockwise direction. Tighten firmly.

f. Set the four wedges (10) symmetrically about the gyro unit in order to hold it firmly within the fixture.

g. Lower the adjustment sleeve (12) by removing the spacer (13) and lowering the assembly as far as it will go on the fixture.

h. Push the pressure rod housing (7), into position and tighten its associated locking set screw (11). The pressure rod housing contains a V-slot and the locking set screw seats against a spring and ball. The pressure rod housing is located in its proper position when the locking set screw takes up on the ball so that the ball seats into the V-slot in the pressure rod housing. Once the pressure rod housing is locked into position, be sure the retaining nut on the pressure rod (8) is backed away from the pressure rod housing.

**Note**

*There is a possibility that the pressure rod, which is spring-loaded, will not be held in position against the Microsyn stator with sufficient force if the retaining nut is not backed away from the pressure rod housing.*

i. Repeat the previous step h to position the other pressure rod housing (16).

j. Back off the radial adjusting screw knob (4). Then push in the adjusting rod housing (6) by pushing on the knob. Lock the housing in position by tightening the locking set screw (11) so that its ball seats in the V-slot in the adjusting rod housing. Turn in the radial adjusting screw knob until it seats lightly against the Microsyn stator.

k. Repeat the previous step j to position the other radial adjusting screw knob (5).

l. Plug the 20-pin receptacle (10, Fig. 6-4) on the end of the cord from the test console into the 20-pin connector (3, Fig. 6-3) mounted on the base of the centering fixture. Ground the centering fixture by connecting it to the frame of the test console.

**6-14. SIGNAL GENERATOR CENTERING PROCEDURE.**

**6-15. SIGNAL GENERATOR ROTATIONAL CENTERING PROCEDURE.** Figure 6-5 is a functional block diagram showing how the test equipment of Fig. 6-4 is used during signal generator rotational centering and radial centering along the rotor long axis. The signal generator primary winding is excited by the oscillator through one of the amplifiers, and the signal generator secondary voltage is measured for rotational centering and one-half the secondary voltage is measured for radial centering along the rotor long axis. The torque motor is energized by the oscillator and a second amplifier when it is required to drive the rotor from one angular position to another. Center the rotor of the signal generator rotationally by the following procedure:

a. Turn on the test console by plugging its power cord into an electrical outlet.

**Note**

*This test procedure assumes that a) all test units have been previously interconnected by a qualified technician in accordance with the functional diagram of Fig. 6-5 and b) the on-off switches on the individual test equipments have been previously turned on.*

b. Make the following patch-cord connections on the impedance matching panel (6, Fig. 6-4) of the test console, as shown in Fig. 6-6:

(1) Connect the left-hand terminal designated 15 to the EXCITE terminal designated P1-P2.

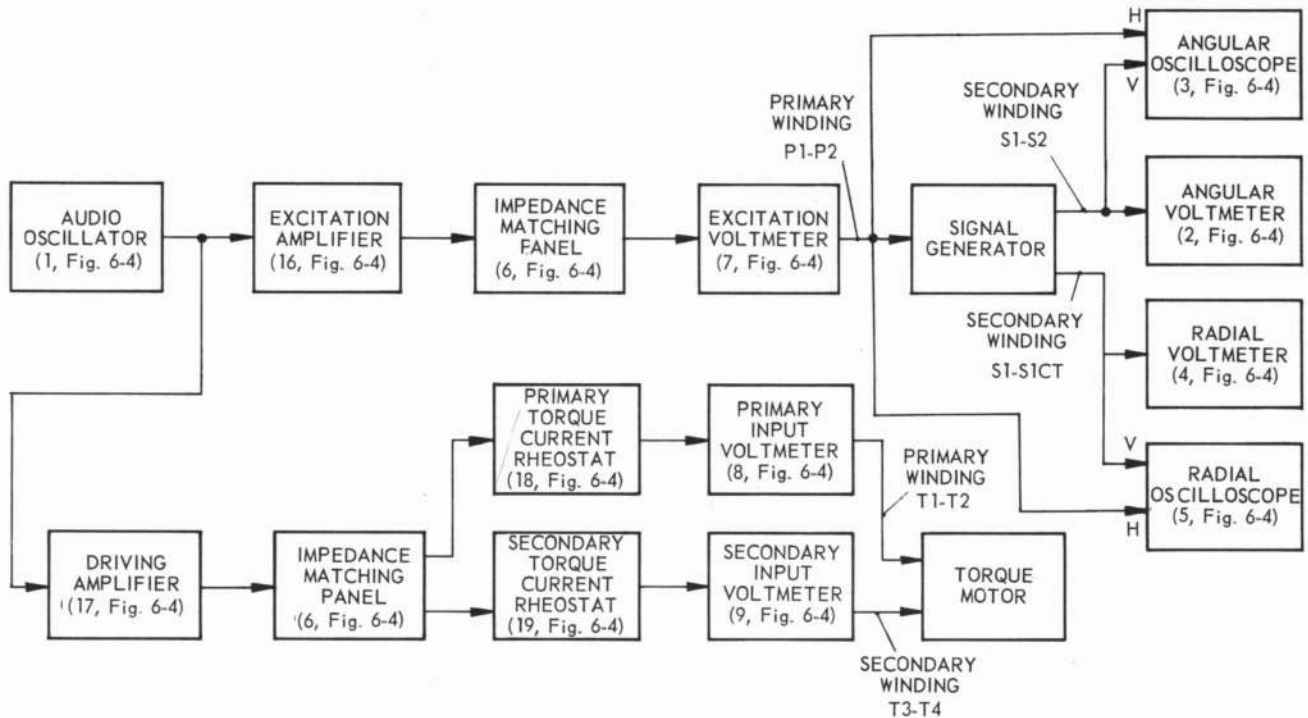


Fig. 6-5. Functional block diagram of test equipment when used during signal generator rotational centering and radial centering along rotor long axis.

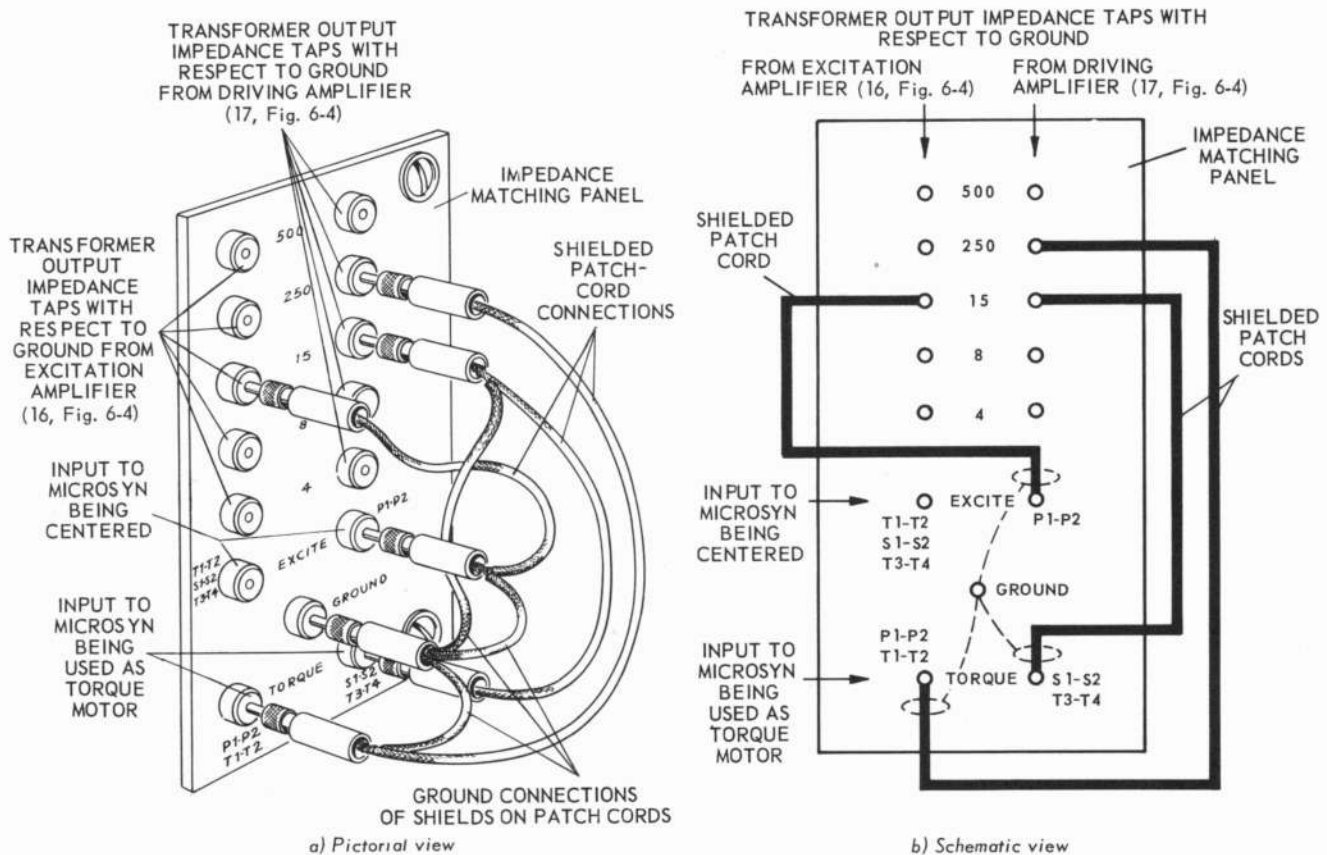


Fig. 6-6. Patch-cord connections required on impedance matching panel of test console when signal generator primary winding is excited and torque motor is connected so as to drive rotor.

(2) Connect the right-hand terminal designated 15 to the TORQUE terminal designated T3-T4.

(3) Connect the right-hand terminal designated 250 to the TORQUE terminal designated T1-T2.

*Note*

*The patch cords used with the impedance matching panel are shielded cords with the shields connected to the ground terminal.*

c. Place the TORQUE-OFF-RESTRAINT switch (14, Fig. 6-4) in the OFF position.

d. Place the TYPE OF UNIT switch (13, Fig. 6-4) in the INTEGRATING position.

e. Place the CIRCUIT EXCITED switch (12, Fig. 6-4) in the PRIMARY position.

f. Place the selector switch (11, Fig. 6-4) in the right-hand position, so that proper connections will be made for centering the signal generator and using the torque motor to drive the floated units assembly from one stop position to another.

g. Set the frequency of the oscillator (1, Fig. 6-4) at 400 cycles per second.

h. Adjust the excitation current to the Microsyn signal generator primary winding to 125 ma by adjusting the output level control on the oscillator (1, Fig. 6-4) and the output level control of the excitation amplifier (16, Fig. 6-4). This current is adjusted to 125 ma when the vacuum tube voltmeter (7, Fig. 6-4) reads 1.25 volts.

i. Loosen the four signal generator tie rods (14, Fig. 6-3).

j. Place the TORQUE DIRECTION switch (15, Fig. 6-4) in the CW position.

k. Place the TORQUE-OFF-RESTRAINT switch (14, Fig. 6-4) in the TORQUE position. The torque motor is now excited. Adjust the excitation to the primary and secondary windings of the torque motor by the torque-current rheostats (18 and 19, Fig. 6-4) so that the torque motor will drive the rotor against one of the stops. This rotation can be noted by the change in angular voltage on the angular voltmeter (2, Fig. 6-4). The voltage will reach a maximum when the rotor is against the stop. Read this voltage.

l. Place the TORQUE DIRECTION switch (15, Fig. 6-4) in the CCW position. The torque motor will drive the rotor in the opposite direction against the opposite stop. As the rotor is driven in this manner, from one stop to the other, the

voltage on the angular voltmeter (2, Fig. 6-4) will decrease to the null voltage and then increase to a maximum when the rotor reaches the stop. The short axis of the elliptical trace on the angular oscilloscope (3) will increase or decrease proportionately to the voltage.

*Note*

*The trace on the oscilloscope should be an ellipse. The short axis of the ellipse will increase or decrease as the induced voltage in the secondary winding increases or decreases. If the oscilloscope cannot be adjusted to give an ellipse, it is an indication that the quadrature adjustment is not correct. Rotate the quadrature rheostat (20, Fig. 6-4) so that a) the oscilloscope trace can be adjusted to an ellipse and b) the short axis of the ellipse is at a minimum.*

m. The rotor is properly centered rotationally within the stator when the voltages with the rotor at the stop positions are as nearly equal as possible. If they are unequal, rotate the stator by moving the angular adjustment screw (9, Fig. 6-3) so that the voltages at the stops increase or decrease as required. Move the rotor between its stops by placing the TORQUE DIRECTION switch (15, Fig. 6-4) in first one position and then the other position. This adjustment of the voltages at the stops is called splitting the stops.

n. Rotate the rotor to the null position (point of lowest voltage on angular voltmeter). Place the TORQUE-OFF-RESTRAINT switch (14, Fig. 6-4) in the OFF position when the rotor is in the null position.

6-16. SIGNAL GENERATOR RADIAL CENTERING PROCEDURE. Refer to Fig. 6-5 and paragraph 6-15 for a description of the test setup when used for the radial centering of the signal generator along the long axis of the rotor. Center the rotor of the signal generator radially by the following procedure:

*Note*

*This procedure should follow the rotational centering procedure described in the previous paragraph. The initial conditions here are the terminal conditions for that procedure. That is, the rotor is in the null voltage position (point of lowest voltage on angular voltmeter) and the TORQUE-OFF-RESTRAINT switch (14, Fig. 6-4) is in the OFF position.*

a. Center the stator radially by rotating the radial adjusting screw knob (5, Fig. 6-3) on the centering fixture. As the center position is approached, the short axis of the ellipse on the radial

oscilloscope will decrease and the trace will approach a horizontal position. Adjust the radial adjusting screw knob (5, Fig. 6-3) until the short axis of the ellipse on the radial oscilloscope is a minimum and the trace is horizontal. Read the minimum voltage on the radial voltmeter (4, Fig. 6-4).

**Note**

*Radial centering can not be more accurate than the bearing side shake (clearance between pivot and jewel bearing inside the gyro unit). To determine bearing side shake, measure the change in radial voltage as you tip the centering fixture approximately 30 degrees, first in one direction and then in the opposite direction about the x-axis (ref. Fig. 6-3). A change in voltage greater than about 50 millivolts is an indication of a defective jewel bearing component.*

b. This radial centering has taken place along the long axis of the rotor, with the primary winding of the signal generator excited. To provide radial centering along the short axis, the secondary winding of the signal generator is excited. Figure 6-7 is a functional block diagram of the test equipment when used during the radial centering along the rotor short axis of the signal generator. Note that the secondary winding of the signal generator is excited and the output voltage from one-half the primary winding is measured. Center the signal generator along this short axis by proceeding with the following steps.

c. Change the patch cord connections on the

impedance matching panel (6, Fig. 6-4) of the test console by removing the patch cord that is connected between the left-hand terminal designated 15 and the EXCITE terminal P1-P2 and connecting it between the left-hand terminal designated 500 and the EXCITE terminal designated S1-S2 (ref. Fig. 6-8). Be sure to connect the shields of the patch cords to ground.

d. Place the CIRCUIT EXCITED switch (12, Fig. 6-4) in the SECONDARY position.

e. Adjust the secondary excitation voltage to 20 volts. This is read directly on the excitation voltmeter (7, Fig. 6-4). This voltage is adjusted by rotating the output level control on the oscillator (1, Fig. 6-4) and the level control on the excitation amplifier (16, Fig. 6-4).

f. Center the stator radially by rotating the radial adjusting screw knob (4, Fig. 6-3) on the centering fixture. As described in step a, adjust this screw until the short axis of the ellipse on the radial oscilloscope is at a minimum and the trace on the radial oscilloscope is horizontal. Read the minimum voltage on the radial vacuum tube voltmeter (4, Fig. 6-4).

g. These centering procedures for the signal generator should now be repeated, starting with paragraph 6-13, because of the interaction of the flux linkages involved. Record the voltage with the rotor at each stop, the angular null voltage, the radial voltage with the primary excited and the

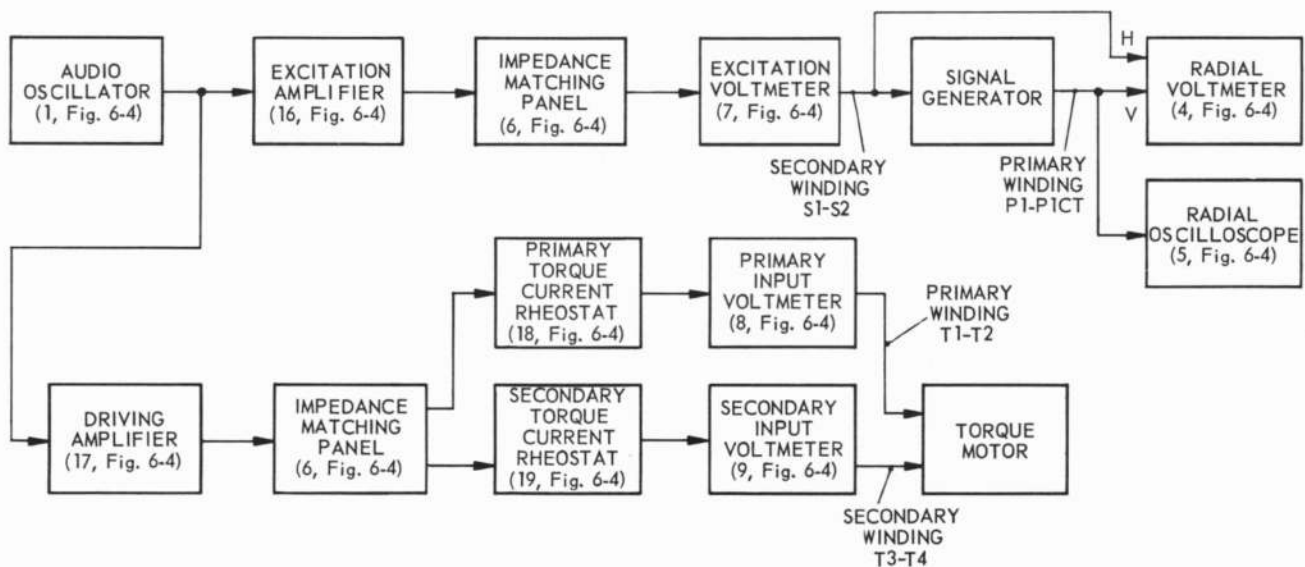


Fig. 6-7. Functional block diagram of test equipment when used during signal generator radial centering along rotor short axis.

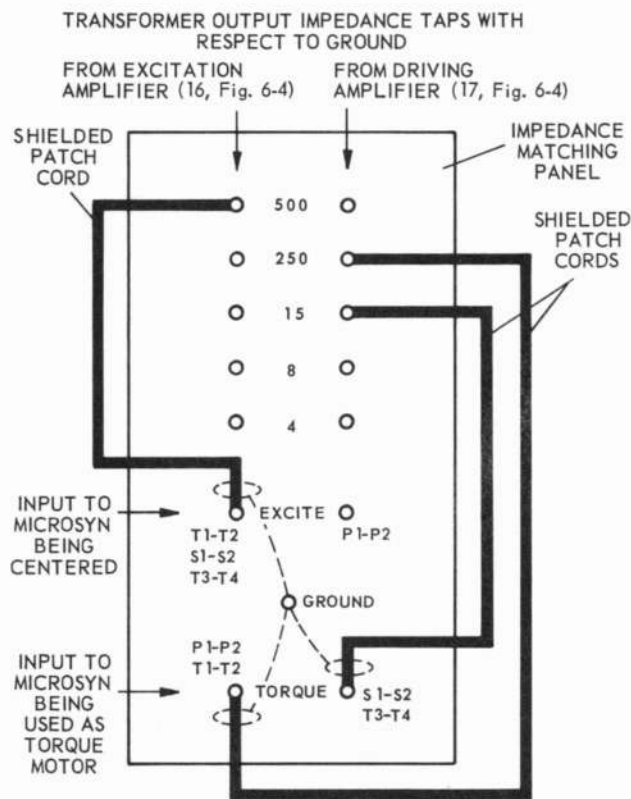


Fig. 6-8. Patch-cord connections required on impedance matching panel of test console when signal generator secondary winding is excited and torque motor is connected so as to drive rotor.

radial voltage with the secondary excited. Enter this data on the Microsyn Centering Data Sheet in the Microsyn Assembly Record Book. A typical example of a Microsyn Centering Data Sheet is shown in Appendix A. When these adjustments have been repeated so that optimum centering has been obtained, tighten the signal generator tie rods (14, Fig. 6-3).

h. Loosen the locking set screws (11, Fig. 6-3) on each of the two adjusting rod housings (6, Fig. 6-3) and each of the two pressure rod housings (7 and 16). Pull out the two adjusting rod housings and the two pressure rod housings as far as they will go, so that the adjusting rods and pressure rods on the inside will clear the gyro unit.

i. Repeat the centering tests without making adjustments and record the voltages with the rotor at each stop, the angular null voltage, the radial voltage with the primary excited, and the radial voltage with the secondary excited. There should be little difference between these readings and the

readings taken before the Microsyn tie rods were clamped and the adjusting rods and pressure rods of the centering fixture were backed off.

#### 6-17. TORQUE MOTOR CENTERING PROCEDURE.

6-18. TORQUE MOTOR ROTATIONAL CENTERING PROCEDURE. Figure 6-9 is a functional block diagram of the test equipment when used during torque motor rotational centering and radial centering along the rotor short axis. With the torque motor primary winding excited by the oscillator through one of the amplifiers, the total torque motor secondary voltage is measured for rotational centering, and one-half the secondary voltage is measured for radial centering along the rotor short axis. The signal generator is energized by the oscillator and a second amplifier when it is required to drive the rotor from one angular position to another. Center the rotor of the torque motor rotationally by the following procedure:

- a. Mount the gyro unit in the centering fixture as described in paragraph 6-13, steps a through f.
- b. Raise the adjustment sleeve (12, Fig. 6-3), insert the spacer (13, Fig. 6-3), and let the adjustment sleeve rest on the spacer.
- c. Locate the stator centering components on the adjustment sleeve (12, Fig. 6-3) and plug in the 20-contact connector as described in paragraph 6-13, steps h through l.
- d. Turn on the test console by plugging its power cord into an electrical outlet.
- e. Make the following patch cord connections on the impedance matching panel (6, Fig. 6-4) of the test console, as shown in Fig. 6-10:

- (1) Connect the left-hand terminal designated 15 to the EXCITE terminal designated T1-T2.
- (2) Connect the right-hand terminal designated 15 to the TORQUE terminal designated P1-P2.
- (3) Connect the right-hand terminal designated 500 to the TORQUE terminal designated S1-S2.

#### Note

Be sure to connect the shields of the patch cords to the ground terminal.

f. Follow the steps given in paragraph 6-15 steps c through n with the following exceptions:

- (1) In place of step f, place the selector switch (11, Fig. 6-4) in the left-hand position, so that proper connections will be made for centering the

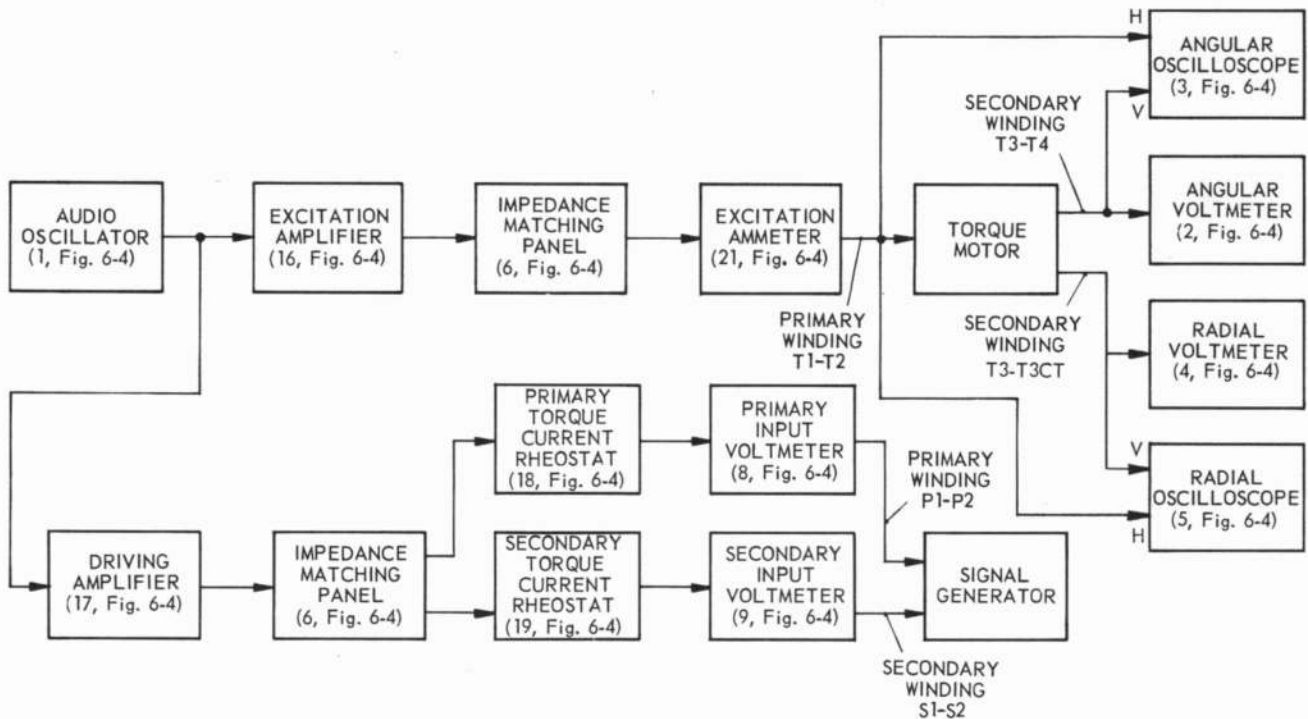


Fig. 6-9. Functional block diagram of test equipment when used during torque motor rotational centering and radial centering along rotor short axis.

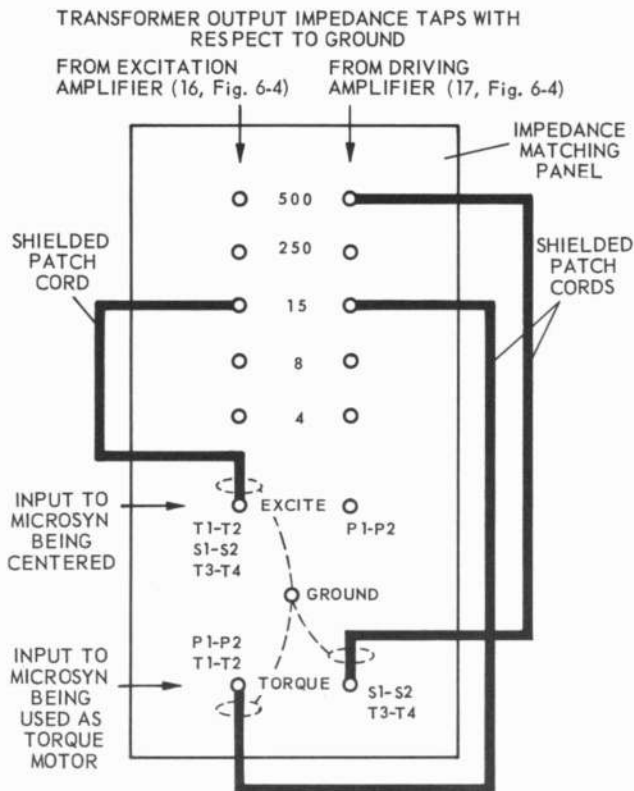


Fig. 6-10. Patch-cord connections required on impedance matching panel of test console when torque motor primary winding is excited and signal generator is connected so as to drive rotor.

torque motor and using the signal generator to drive the floated units assembly from one stop position to another.

(2) In step h, adjust the current to the torque motor primary winding to 100 ma by adjusting the output level control on the oscillator (1, Fig. 6-4) and the level control of the excitation amplifier (16, Fig. 6-4). This current can be read directly on the excitation ammeter (21, Fig. 6-4).

(3) In place of step i, loosen the four torque motor tie rods (15, Fig. 6-3).

(4) In step k, when the TORQUE-OFF-RESTRAINT switch (14, Fig. 6-4) is in the TORQUE position, the signal generator is excited and will drive the rotor between the stops.

**6-19. TORQUE MOTOR RADIAL CENTERING PROCEDURE.** Refer to Fig. 6-9 and paragraph 6-18 for a description of the test setup when used for the radial centering of the torque motor along the short axis of the rotor. Center the rotor of the torque motor radially by the following procedure:

a. Follow the procedure given in paragraph 6-16 with the following exceptions:

(1) In step a, rotate the radial adjusting screw knob (4, Fig. 6-3).



(2) In step b, reference to the signal generator now applies to the torque motor. Figure 6-11 is a functional block diagram of the test equipment when used during the radial centering along the long axis of the torque motor. Note that the secondary winding of the torque motor is excited and the output voltage from one-half the primary winding is measured.

(3) In step c, change the patch-cord connections on the impedance matching panel (6, Fig. 6-4) of the test console by connecting the patch cord from the EXCITE terminal designated T3-T4 to the left-hand terminal designated 250 instead of terminal 15 (ref. Fig. 6-12).

(4) In step e, adjust the current to the torque motor secondary winding to 100 ma by the adjustments noted. This current can be read directly on the excitation ammeter (21, Fig. 6-4).

(5) In step f, center the stator radially by the radial adjusting screw knob (5, Fig. 6-3).

b. Once the signal generator and torque motor have been centered, it is desirable to adjust the gyro motor flex leads for minimum torque at the zero-angular-displacement position of the floated units assembly, and to measure the friction level at this position, before removing the gyro unit from the centering fixture. Refer to paragraphs 6-20 through 6-23 for the methods of making these adjustments and measurements.

#### 6-20. FLEX-LEAD NULL.

6-21. The torque applied to the floated units assembly by the gyro motor flex leads should have its minimum value at the zero-angular-displacement position of the floated units assembly. That is, the flex-lead torque null should coincide with the signal-generator voltage null. This can be accomplished by the following procedure:

a. Set up the test equipment the same as for rotational centering of the signal generator (ref. paragraph 6-15).

b. By means of the TORQUE-OFF-RESTRAINT switch, the TORQUE DIRECTION switch and the torque-current rheostats (ref. paragraph 6-15, steps j, k and l), place the floated units assembly in the zero-angular-displacement position. This will be indicated by a minimum reading on the angular voltmeter (2, Fig. 6-4).

c. Place the TORQUE-OFF-RESTRAINT switch in the OFF position.

d. Adjust the flex-lead adjustment screw (19, Fig. 6-3) so that a minimum reading is obtained on the angular voltmeter (2, Fig. 6-4). The minimum flex-lead torque now occurs at the zero-angular-displacement position of the floated units assembly.

#### 6-22. GYRO UNIT FRICTION LEVEL.

6-23. The gyro unit friction level is the amount of

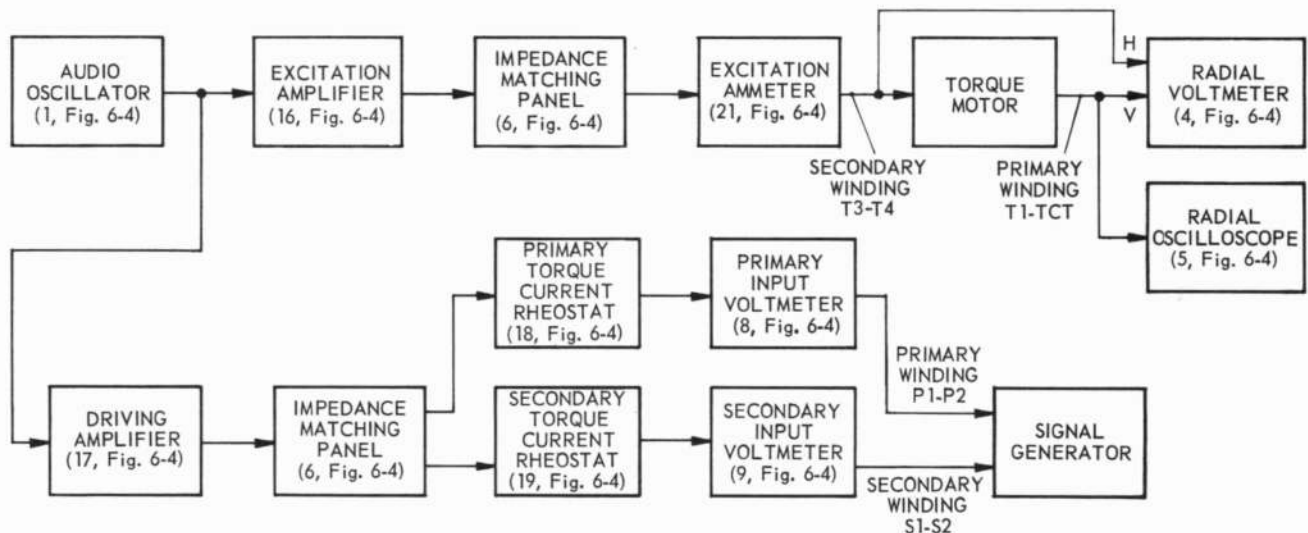


Fig. 6-11. Functional block diagram of test equipment when used during torque motor radial centering along rotor long axis.

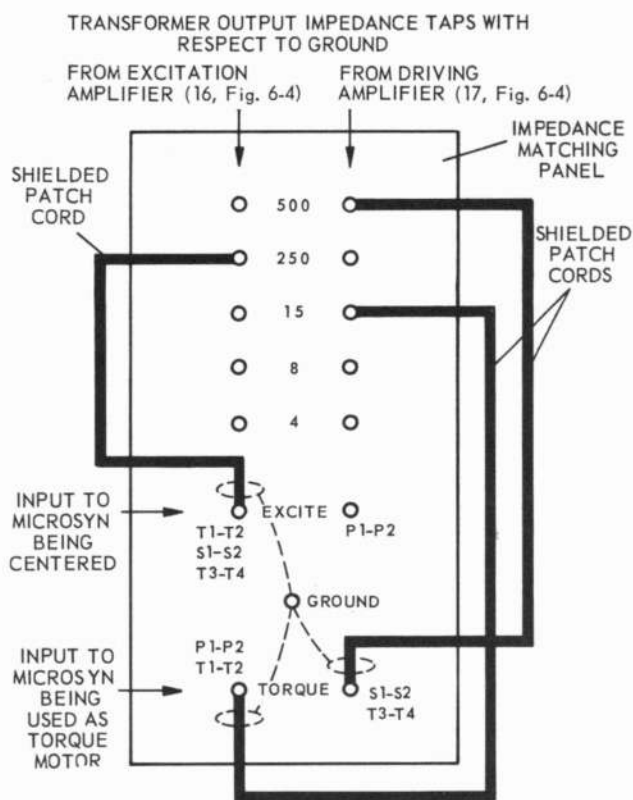


Fig. 6-12. Patch-cord connections required on impedance matching panel of test console when torque motor secondary winding is excited and signal generator is connected so as to drive rotor.

torque required to overcome the stationary friction level of the floated units assembly from its zero-angular-displacement position. The friction level is determined by measuring the minimum inputs to the torque motor that are required to move the floated units assembly from its zero-angular-displacement position. The torque output from the torque motor can then be calculated, using the known sensitivity of the Microsyn unit. The detailed procedure is as follows:

a. Set up the test equipment the same as for rotational centering of the signal generator null (that is, with no change from the setup used in obtaining the flex-lead null).

b. By means of the **TORQUE-OFF-RESTRAINT** switch, the **TORQUE DIRECTION** switch and the torque-current rheostats, place the floated units assembly in the zero-angular-displacement position. This will be indicated by a minimum reading on the angular voltmeter (2, Fig. 6-4).

c. With the **TORQUE DIRECTION** switch in the CW position, move the floated units assembly away from the zero-angular-displacement position. Observe the voltage readings of the primary input voltmeter and the secondary input voltmeter (8 and 9, Figs. 6-4 and 6-5) at the instant the minimum reading on the angular voltmeter (2, Fig. 6-4) starts to increase.

d. Repeat the procedure of steps b and c with the **TORQUE DIRECTION** switch in the CCW position.

e. The primary input voltmeter and the secondary input voltmeter are each set up to read the voltage across a 10-ohm resistor. Therefore, to determine the current inputs (in milliamperes) into the primary and secondary circuits of the torque motor, divide the voltage readings (in millivolts) by ten. Obtain the corresponding torque output of the torque motor (in dyne-centimeters) by multiplying the product of the two currents by the torque motor sensitivity (obtained from the appropriate production test data sheet; ref. paragraph 4-44). The friction-level torque obtained should not exceed 0.4 dyne-centimeter.

6-24. When the centering and testing of the gyro unit in the centering fixture have been completed, remove the gyro unit from the centering fixture by removing the four wedges (10, Fig. 6-3), loosening the collet draw-in nut (2, Fig. 6-3) by rotating it clockwise, pressing down the ejection lever (1, Fig. 6-3), and lifting out the gyro unit.

**Note**

Be sure the two adjusting rod housings (6, Fig. 6-3) and the two pressure rod housings (7 and 16) have been pulled out as described in paragraph 6-16, step h.

## SECTION VII

### FILLING AND FINAL ELECTRICAL CHECK

#### 7-1. INTRODUCTION.

7-2. Once the Microsyn units have been centered (ref. Section VI), the outer case assembly is attached and hermetically sealed. The void between the floated units assembly and the outer case assembly is then filled with a fluid of relatively high viscosity. The purpose of filling the gyro unit is to float the floated units assembly in order to reduce bearing friction and to apply the desired integrating damping action. The viscosity of the fluid - and hence the damping action - is determined by the operating temperature of the gyro unit. The main housing assembly of the gyro unit contains a non-inductively wound temperature-sensitive coil of wire (ref. paragraph 4-97) that may be used for determining, and also controlling, the operating temperature of the gyro unit (for example, see paragraphs 8-21 through 8-23).

7-3. The 20IG gyro units built by the Instrumentation Laboratory are filled with Fluorolube, a product manufactured by the Hooker Electrochemical Co., Niagara Falls, N. Y. Fluorolube, which is almost colorless, has a soft, sticky feeling at room temperature. At the operating temperature of the gyro unit (160° F), the viscosity decreases, so that the fluid has the properties required to provide the functions noted in the preceding paragraph.

7-4. The gyro unit is filled by forcing the filling fluid through a fritted glass filter, heating the fluid to operating temperature, and forcing the filling fluid up through one of the pins in the 20-pin connector into the gyro unit and out through the copper tubing on the top of the outer case assembly. When the filling is complete, the filling pin on the 20-pin connector and the copper tubing on the top of the outer case assembly are sealed. A final electrical check is then made of the completed gyro unit.

7-5. The following paragraphs of Section VII give the detailed procedures associated with the gyro filling operation under the following sideheads.

- a. Attaching the outer case assembly (ref. paragraphs 7-6 and 7-7).
- b. Testing the gyro unit for leakage (ref. paragraphs 7-8 and 7-9).
- c. Description of the filling equipment (ref. paragraphs 7-10 through 7-12).
- d. Filling the gyro unit (ref. paragraphs 7-13 and 7-14).
- e. Making the final electrical check (ref. paragraphs 7-15 and 7-16).

#### 7-6. ATTACHING THE OUTER CASE ASSEMBLY.

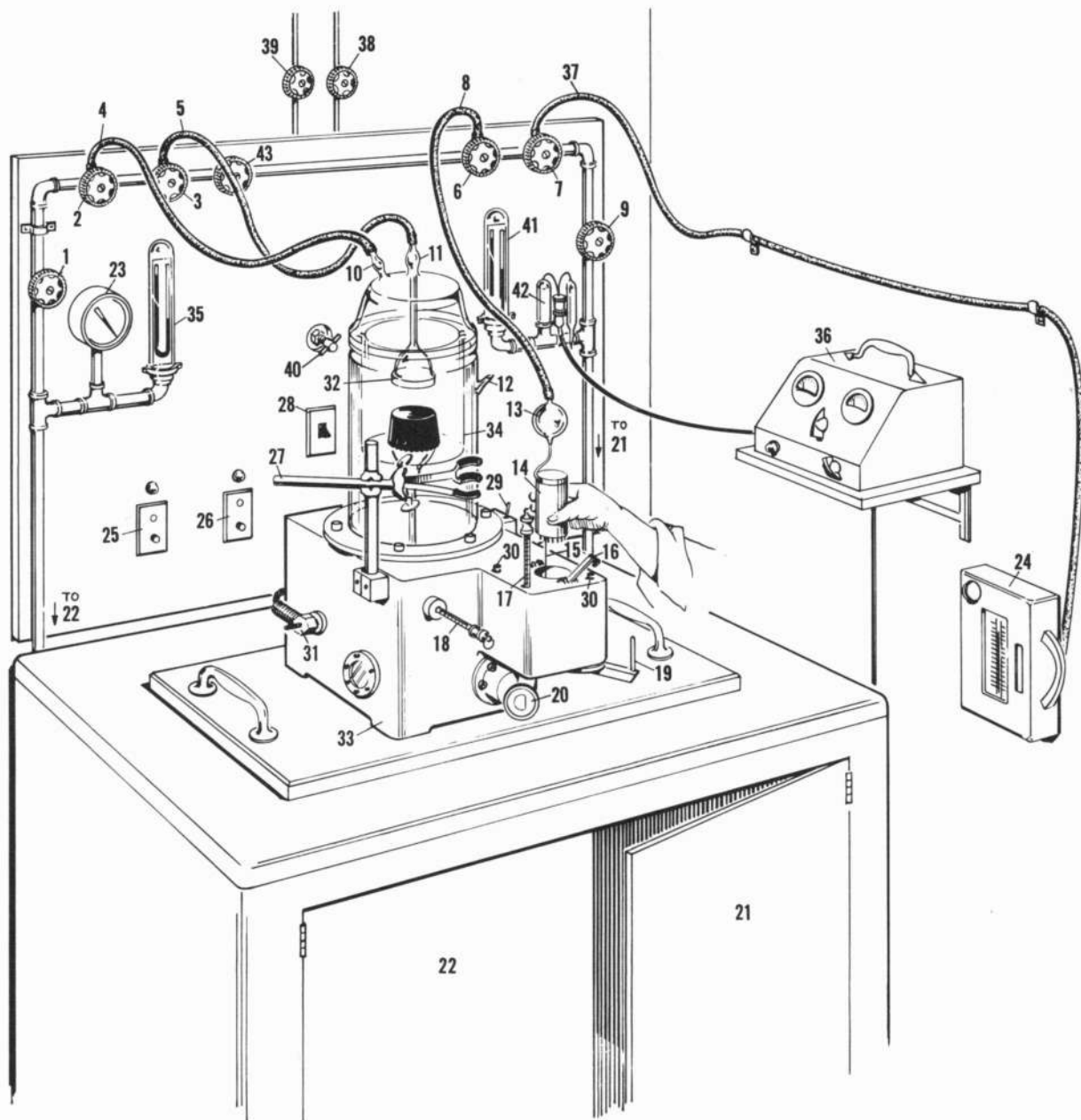
7-7. The outer case assembly is assembled to the gyro unit by attaching it to the signal generator end housing by the following detailed procedure:

- a. Inspect the threads of the signal generator end housing and also those of the outer case assembly to see that they are free from dirt.
- b. Coat the threads of the signal generator end housing with special Armstrong adhesive, which is prepared in the ratio of 25 parts (by weight) to 1 part of hardener.
- c. Drop the diaphragm in the outer case and make sure it seats correctly in the bottom. As an aid in securing the diaphragm, smear a small quantity of cold Fluorolube (same as used for filling the gyro unit) at the center of the inside face of the diaphragm.

d. Support the outer case assembly with the open end upward. Thread the signal generator end housing into the case until the case is solidly abutted against the shoulder on the end housing. Cure for 20 minutes at room temperature, then overnight in an oven set at 165° Fahrenheit.

#### 7-8. TESTING THE GYRO UNIT FOR LEAKAGE.

7-9. Before filling the gyro unit, test it for leakage by sealing the filling pin (ref. Fig. 2-18) on the 20-pin connector with the sealing screw (15, Fig. 7-1; also 1, Fig. 7-3), applying ten pounds per square inch of helium - supplied by a helium pressure flask - through the copper tubing at the top of the outer case assembly, and immersing the gyro unit in hot water.



- |                      |   |   |
|----------------------|---|---|
| 1. Control valve     | 17. Gyro heater block temperature thermometer       | 31. Water heater thermostat                               |
| 2. Control valve     | 18. Water temperature thermometer                   | 32. Fritted glass filter                                  |
| 3. Control valve     | 19. Ejection lever                                  | 33. Filling fixture                                       |
| 4. Flexible hose     | 20. Filling valve assembly                          | 34. Glass retainer  |
| 5. Flexible hose     | 21. Megovac and diffusion pumps                     | 35. Vacuum gauge (mercury manometer - alternate for (23)) |
| 6. Control valve     | 22. Kinney pump                                     | 36. Vacuum gauge (Pirani type)                            |
| 7. Control valve     | 23. Vacuum gauge (Bourdon tube type)                | 37. Flexible hose   |
| 8. Flexible hose     | 24. Vacuum gauge (McLeod type - alternate for (36)) | 38. Control valve (cooling water in)                      |
| 9. Control valve     | 25. Switch for Kinney pump                          | 39. Control valve (cooling water out)                     |
| 10. Exhaust port     | 26. Switch for Megovac pump                         | 40. Needle valve control (controls water flow)            |
| 11. Filling port     | 27. Holding fork                                    | 41. Vacuum gauge (mercury manometer - alternate for (36)) |
| 12. Water inlet port | 28. Switch for diffusion pump                       | 42. Heated filaments for (36)                             |
| 13. Glass bulb       | 29. Heater switch                                   | 43. Isolation valve                                       |
| 14. Gyro unit        | 30. Gyro heater thermostats                         |   |
| 15. Sealing screw    |   |   |
| 16. Clamp            |   |   |

Fig. 7-1. Pictorial view of the filling equipment.

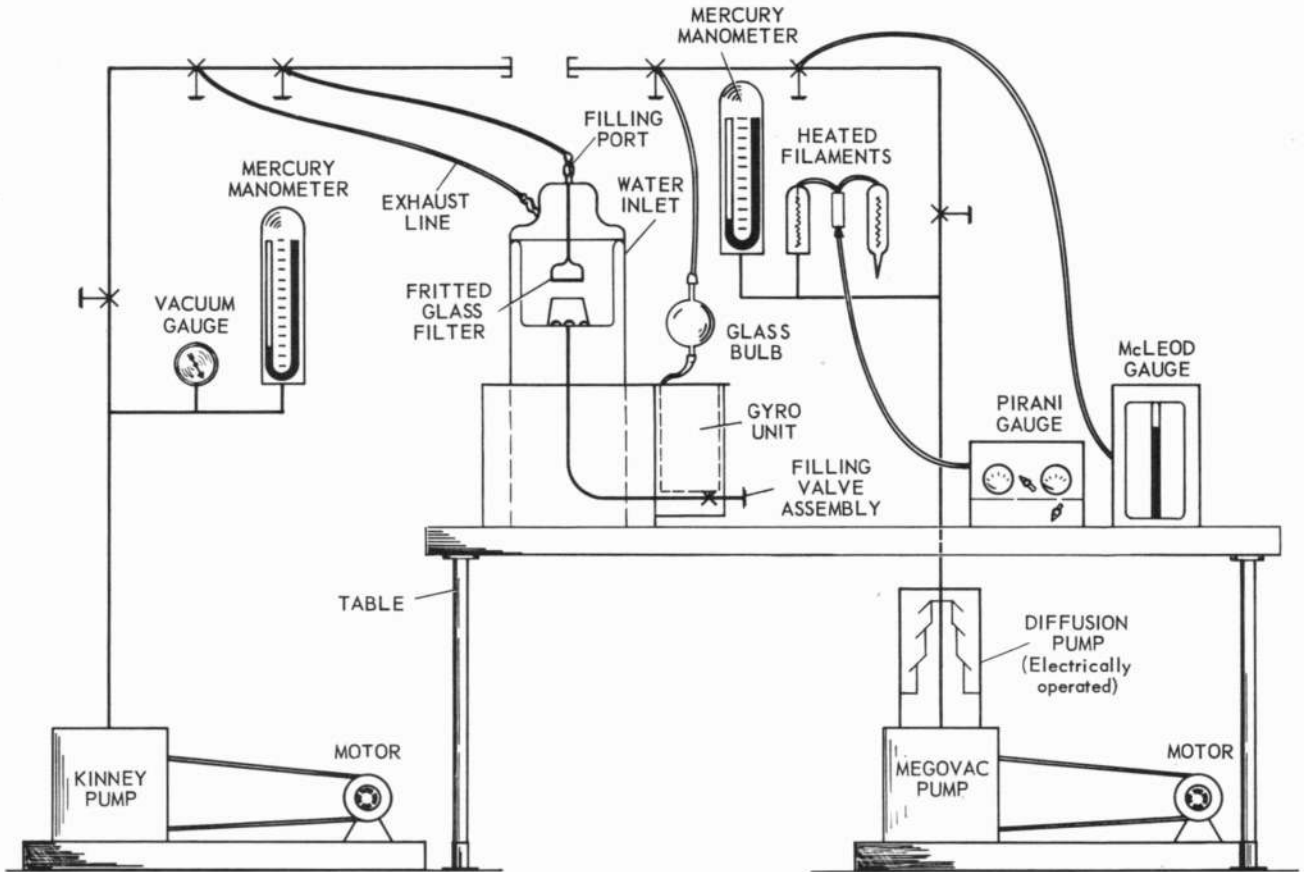


Fig. 7-2. Schematic diagram of the filling equipment.

**Note**

*Hot water is used because helium, like most gases, is less soluble in hot water than in cold. Hence, bubbles will escape to the surface if any helium is leaking from the gyro unit.*

By observing for bubbles, check for leaks at the following places:

- a. At the joint of the copper tubing to the outer case assembly.
- b. At the seal of the outer case assembly to the rest of the gyro unit.
- c. At the two balance-fork port holes.
- d. At the joints of the 20-pin connector. Fix any leaks as required, recheck, and remove the sealing screw when all is in order.

**7-10. DESCRIPTION OF THE FILLING EQUIPMENT.**

7-11. Figure 7-1 is a pictorial view of the equipment used to fill the assembled gyro unit, which is shown being placed into position. The equipment consists of a filling fixture (33, Fig. 7-1), a

Kinney pump, a Megovac pump, an oil diffusion pump, and the associated vacuum gauges, thermometers, control valves, and other equipment called out on the figure. The oil diffusion pump assists the Megovac pump in obtaining a high vacuum. There are two separate vacuum circuits, as shown by the schematic diagram of Fig. 7-2.

7-12. The filling fluid is poured onto the fritted glass filter (32) through the filling port (11), while the flexible hose (5) is temporarily removed. The fluid is then forced through the filter into the glass retainer (34) by a difference in pressure between the top of the filter and the glass retainer. This glass retainer has a water jacket, which contains water heated by an electrical heating unit in the base of the filling fixture (33). The heated water brings the filling fluid up to the operating temperature. The gyro unit is also heated to the operating temperature of the filling fluid by electric heaters in the part of the filling fixture that surrounds the

gyro unit when the unit is placed in its proper position in the filling fixture. The fluid is pushed from the glass retainer (34) through the glass tubing connecting the glass retainer with the filling valve assembly (20). When the sealing screw (1, Fig. 7-3) is lowered, and the hand wheel (7) is turned to the open position, fluid is pushed into the gyro unit by a difference in pressure between the filling valve assembly and the gyro unit (21). The flow of fluid from the glass retainer through the gyro unit is controlled by the filling valve assembly. The pictorial cutaway view of Fig. 7-3 shows the details of this assembly and the path followed by the filling fluid.

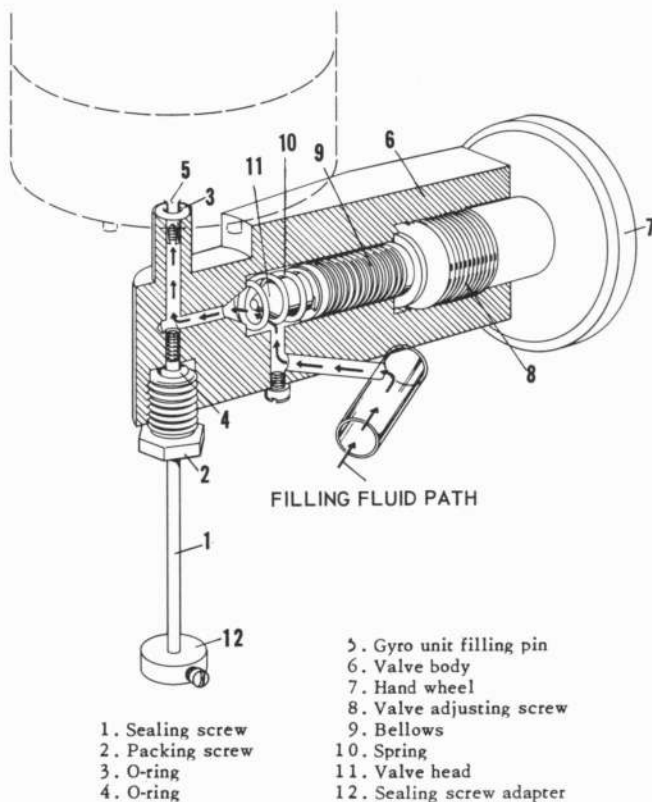


Fig. 7-3. Pictorial cutaway view of the filling valve assembly.

#### 7-13. FILLING THE GYRO UNIT.

7-14. The detailed procedure for filling the gyro unit with the filling fluid is as follows:

a. Close the control valves (1, 2, and 3, Fig. 7-1) to shut off the air connections to the glass retainer (34).

b. Be sure that the water level in the jacket around the glass retainer (34) reaches the water

inlet port (12). Add water through this port if necessary.

c. Turn on the water heater and gyro unit heaters by means of the heater switch (29). The water temperature should reach the operating temperature of the filling fluid, which is 160° Fahrenheit. The water temperature is controlled by the water heater thermostat (31) and is measured by the water temperature thermometer (18). The gyro heaters should heat the filling fixture surrounding the gyro unit to the operating temperature of the filling fluid. The gyro heater block temperature is controlled by the two gyro heater thermostats (30) and is measured by the gyro heater block temperature thermometer (17).

d. Close the filling valve assembly (20) to shut off the filling fluid line to the gyro unit. This is accomplished by turning the hand wheel (7, Fig. 7-3) completely clockwise (as viewed in Fig. 7-1).

e. Remove the flexible hose (5) from the filling port (11), pour about 75 milliliters of filling fluid into the filling port, and replace the flexible hose on the filling port.

f. Start the Kinney pump (22) by depressing the switch (25). This pump is a standard rotary pump.

g. Fully open control valves (1) and (2) in order to create a vacuum within the glass retainer (34).

h. Open and close the control valve (3) quickly several times in order to apply the vacuum on the filling fluid slowly, without permitting the filling fluid to back up through hose (5) into the air lines and into the pump. Once this danger is over, fully open the control valve (3) so that an equal vacuum is applied to both sides of the filling fluid. The result of this procedure is that any air present in the filling fluid is removed through the hose (5).

i. Place the gyro unit in a horizontal position and slip the Kovar tubing attached to the glass bulb (13) over the copper tubing from the gyro unit. Heat the joint with a soldering iron before applying solder to the joint. Leak test the joint by first sealing the gyro filling pin with the sealing screw (1, Fig. 7-3) and then applying about one pound per square inch of helium through the glass bulb while the gyro unit and joint are immersed in hot water.

j. Remove the packing screw (2, Fig. 7-3) from the bottom of the filling valve assembly (20, Fig. 7-1).

k. Place an O-ring (3, Fig. 7-3) over the filling pin (5) of the gyro unit (ref. Fig. 2-18) so that it seats tightly against the base of the 20-pin connector. Use a lubricant, such as Dow Corning 7 Compound, as required to put on the O-ring.

l. Screw the sealing screw (1, Fig. 7-3), with the sealing screw adapter (12) removed, into the filling pin of the gyro unit.

m. Place the gyro unit (14, Fig. 7-1) in the filling fixture (33), aligning the key on the 20-pin connector with the keyway in the 20-hole receptacle in the base of the filling fixture and being sure that the gyro unit seats firmly into this receptacle. Under this condition, the filling pin (5, Fig. 7-3) will engage the filling valve assembly as shown in Fig. 7-3. Clamp the gyro unit into position by means of the clamp (16, Fig. 7-1), which swings across the top of the gyro unit.

n. Place an O-ring (4, Fig. 7-3) and the packing screw (2) over the sealing screw (1), which is projecting out the bottom of the filling valve assembly (20, Fig. 7-1), and start to screw the packing screw into the filling valve assembly. Fasten the sealing screw adapter (12, Fig. 7-3) to the end of the sealing screw (1). Tighten the packing screw (2) with a wrench to the position shown in Fig. 7-3.

o. Secure the glass bulb (13, Fig. 7-1) in the holding fork (27).

p. Connect the flexible hose (8, Fig. 7-1) between the glass bulb (13) and the control valve (6).

q. Start the Megovac pump (21) by depressing the switch (26). This pump is a rotary pump.

r. Open control valves (6), (7), and (9) in order to create a vacuum within the gyro unit (14). When the pressure has been reduced by the Megovac pump to a Pirani gauge (36) reading of 100 microns, start the diffusion pump (21) by depressing switch (28), and opening valves (38) and (39).

s. After all pumps have been operating for several hours - so that good vacuums have been obtained (Pirani gauge readings of 30 microns are not unusual) - close the control valve (3) and remove the flexible hose (5) from the filling port (11).

#### Note

*The McLeod gauge is used only for checking the Pirani gauge. It shows what the pressure was, not what it is at the time of observation. The McLeod gauge gives a discontinuous reading because of the time elapsed during which a sample of air is taken and compressed to make a measurement.*

The difference in pressure created by the difference between the atmospheric pressure introduced through the filling port (11) and the vacuum within the glass retainer (34) will cause the filling fluid to flow through the glass filter (32) into the glass retainer (34).

t. When at least 25 percent of the filling fluid has been pushed through the fritted glass filter (32), start filling the gyro unit by lowering the sealing screw (1, Fig. 7-3) and turning the hand wheel (7) on the filling valve assembly (20, Fig. 7-1) counterclockwise. Then, increase the pressure in the glass retainer (34) by about 7 inches of mercury. This action - accomplished by starting and stopping the Kinney pump (22) - will keep the pressure in the glass retainer, as indicated on the vacuum gauge (23), the required amount above the pressure in the gyro unit, as indicated by the Pirani gauge (36). This difference in pressure will cause the filling fluid to flow from the glass retainer (34) into the gyro unit and up into the glass bulb (13).

#### Note

*Be careful not to exceed this differential pressure very much as the gyro unit will be filled too quickly. As a result, any dirt deposits inside the unit that during normal gyro usage would stay in place might work loose and cause the gyro unit to function improperly.*

u. Continue the filling operation until the glass bulb (13) is approximately half full. The filling operation should require about 10 minutes.

v. When the filling is complete, close the filling valve assembly (20) to shut off the filling-fluid line to the gyro unit. This is accomplished by turning the handwheel (7, Fig. 7-3) completely clockwise (as viewed in Fig. 7-1).

w. Screw in the sealing screw (1, Fig. 7-3) and then remove the sealing screw adapter (12).

x. Stop the Kinney pump (22, Fig. 7-1) by depressing switch (25).

y. Remove hose (4) at valve (2) to introduce atmospheric pressure in the line in order to prevent the Kinney pump oil from coming up the line.

z. Close valve (6).

aa. Remove hose (8) at valve (6).

ab. Turn off the heater switch (29).

ac. At a temperature of 155° Fahrenheit on the gyro heater block thermometer (17)(about one-half hour after step ab), crimp the copper tubing at the top of the gyro unit just below the point where it is soldered to the metal tube at the base of the glass bulb (13). Unsolder the metal tube on the glass bulb from the copper tubing on the gyro unit. Then solder the end of the copper tubing on the gyro unit, so that this end connection is completely sealed.

ad. Release the clamp (16, Fig. 7-1) and remove the gyro unit from the filling fixture by depressing the ejection lever (19). Wrap a towel around the gyro unit, as it is hot, and lift it out of the filling fixture.

ae. With the 20-pin connector of the gyro unit upright, remove the O-ring (3, Fig. 7-3) and the sealing screw (1) from the gyro unit.

af. Insert a filling screw into the filling pin (5, Fig. 7-3) on the gyro unit. At this time, it is not necessary to make the joint leak proof.

*Note*

*The filling screw is a standard No. 0-80 NF-2 fillister head screw that has been modified with a chamfer at the base of the head. The reason for this is that the filling pin on the gyro has a mating chamfer.*

ag. Heat the gyro unit in an oven to 165° Fahrenheit for approximately 15 to 20 minutes so that

any air or excess filling fluid will be forced out of the filling pin as the filling fluid expands. Wipe off any excess filling fluid around the filling pin and make the connection leak proof by threading the screw in as far as it will go and soldering the screw into the filling pin. The slot in the screw should be full of solder. Make sure that the top of the screw does not extend beyond the other 19 pins of the connector.

ah. Turn off the diffusion pump by means of switch (28).

ai. Depress the Megovac pump switch (26), provided about one-half hour has elapsed after step z.

aj. Quickly, open valve (6) to allow atmospheric pressure to go to the diffusion pump. This prevents the oil in the Megovac pump from being siphoned into the diffusion pump and damaging the pump.

ak. Close the cooling water valves (38) and (39).

#### 7-15. MAKING THE FINAL ELECTRICAL CHECK.

7-16. As a final electrical check, test the gyro unit in accordance with Tables 4-2 and 4-3 (ref. paragraphs 4-37 and 4-48). Enter the results in the Assembly Record Book. Then recheck the centering of the Microsyn units in accordance with the procedure of Section VI. This completes the assembly procedure for the M. I. T. 20IG Integrating Gyro Unit.



## SECTION VIII

# TESTING PROCEDURE

### 8-1. INTRODUCTION.

8-2. This section describes the series of tests and associated procedures that are made on assembled 20IG gyro units at the Instrumentation Laboratory, M.I.T. There are 16 distinct procedures in this series. Taken together, they comprise the complete testing procedure for the 20IG unit. Explanatory information, a list of equipment, initial conditions, and a step-by-step set of instructions is included for each procedure. Typical data taken during an actual testing procedure are included where applicable, in order to give test personnel an indication of results to be expected.

8-3. The information given in this section has been prepared specifically for use in carrying out the testing procedures. In general, therefore, discussions of gyro unit operation, applications of gyro units to operating systems, and theoretical analyses have been omitted. Such information, as it pertains to the testing procedure for the 20IG gyro unit, is quite adequately covered in the Institute of the Aeronautical Science's Sherman M. Fairchild Fund Paper No. FF-13 and also in Instrumentation Laboratory Report R-91 (ref. Section I).

### 8-4. TESTS TO BE PERFORMED.

8-5. The various tests and associated procedures to be performed are listed below, in the order in which they should be made:

- a. Selection of the signal generator quadrature resistor.
- b. Alignment of the input axis.
- c. Application of compensation to the torque generator prior to making mass unbalance adjustments.

#### Note

*As stated in Section II, the Microsyn torque motor is also commonly known as a torque generator. This device has been referred to as a torque motor in the preceding sections on assembling the 20IG unit in order to be consistent with the nomenclature assigned to the various components by the working drawings of the unit. For convenience in making use of related material in the publications noted in paragraph 8-3, however, the designation used in those publications - torque generator - will be used throughout Section VIII.*

d. Mass unbalance adjustments without earth-rate effect.

e. Mass unbalance adjustments with earth-rate effect.

f. Determination of the excitation current squared - reaction torque sensitivity of the signal generator.

g. Determination of the excitation current squared - reaction torque sensitivity of the torque generator.

h. Determination of the angle-torque sensitivity of the elastic-restraint-producing components.

i. Determination of the angular velocity - voltage rate sensitivity of the gyro unit.

j. Determination of the current squared - voltage rate sensitivity of the gyro unit.

k. Determination of the current squared - angular velocity sensitivity ratio of the gyro unit.

l. Determination of the base angular velocity - controlled-member angular velocity sensitivity ratio of the gyro unit.

m. Determination of the gravity-sensitive drift rate, compensated and uncompensated.

n. Determination of the nongravity-sensitive drift rate, compensated and uncompensated.

o. Final balance trim.

p. Determination of the characteristic time.

#### Note

*A tabulation of conditions for each procedure is provided by Table 8-1 for the purpose of presenting an over-all picture of the testing procedure.*

### 8-6. MINIMUM PERFORMANCE STANDARDS.

8-7. An examination of the requirements of the system in which the tested gyro unit is to be used would have to be made before minimum performance standards for the gyro unit under test could be established. Typical examples of applications of gyro units may be roughly listed as follows:

- a. Stabilization equipment.
- b. Autopilots.

Table 8-1. Tabulation of test conditions.

Test	Position of Gyro	Servo Loop Used*	Wheel Excitation (0.6 amp/phase - 400 cps)	Torque Generator Excitation (100 ma cps or 10 ma dc)	Signal Generator Excitation (125 ma 400 cps)	Dummy Director Required	Torque Generator Windings in Series	Torque Generator Compensating Resistance	Rate Table Required	Turntable Equipment Required
Selection of the signal generator quadrature resistor	Any	No	No	Yes	Yes	No	Yes	No	No	Yes
Alignment of the input axis	SA-Vert	No	Yes	Yes	Yes	No	No	No	No	Yes
Application of compensation to the torque generator prior to making mass unbalance adjustments	OA-Vert IA-EW	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Mass unbalance adjustments without earth-rate affect	SA-Vert IA-EW	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Mass unbalance adjustments with earth-rate affect	IA-Vert SA-Horiz	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Determination of the excitation current squared-reaction torque sensitivity of the signal generator	OA-Vert IA-EW	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Determination of the excitation current squared-reaction torque sensitivity of the torque generator	OA-Vert IA-EW	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Determination of the angle-torque sensitivity of the elastic-restraint producing components	OA-Vert IA-EW	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Determination of the angular velocity - voltage rate sensitivity of the gyro unit	IA-Vert	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Determination of the current squared - voltage rate sensitivity of the gyro unit	IA-Vert	No	Yes	Yes (Variable)	Yes	No	Yes	No	No	Yes
Determination of the current squared - angular velocity sensitivity ratio of the gyro unit	IA-Vert	Yes	Yes	Yes (Variable)	Yes	No	Yes	No	No	Yes
Determination of the base velocity - controlled member angular velocity sensitivity ratio of the gyro unit	IA-Vert	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Determination of the gravity-sensitive drift rate, compensated and uncompensated	SA-Vert IA-EW	Yes	Yes	Yes	Yes	No	No	Yes** No	No	Yes
Determination of the nongravity-sensitive drift rate, compensated and uncompensated	OA-Vert IA-EW	Yes	Yes	Yes	Yes	No	No	Yes** No	No	Yes
Final balance trim	SA-Vert IA-EW IA-Vert	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Determination of characteristic time	IA-Vert	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes

\* Using circuit arrangement of Fig. 8-2, except for the characteristic time test, for which Fig. 8-26 applies.

\*\* "Yes" for compensated; "No" for uncompensated.

- c. Fire control equipment.
- d. Stable verticals.

Since the minimum performance standards for gyro units vary in accordance with their application, no specifications can be set down here. However, as an example of performance standards that might be expected for a particular application, Table I of Report R-91 is included here as Table 8-2.

#### 8-8. BASIC TEST SETUP.

8-9. The servo-controlled turntable and associated equipment shown in Fig. 8-1 comprise the basic test setup used to carry out the procedures listed in paragraph 8-5. The essential components of the basic test setup are as follows:

- a. Servo-controlled turntable assembly.
- b. Gyro mounting package.

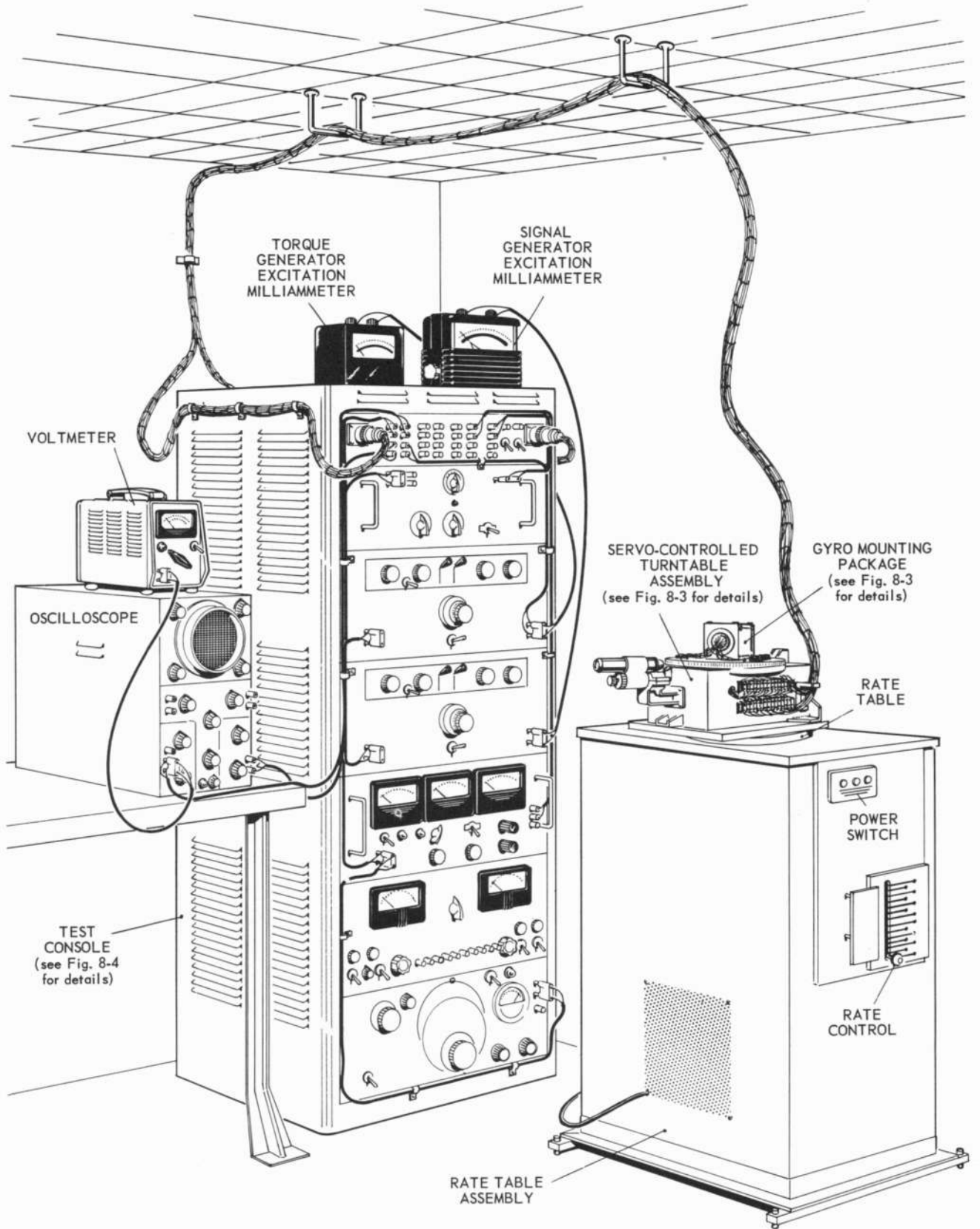


Fig. 8-1. Pictorial view of the basic test setup.

Table 8-2. Typical performance specifications for a 20IG gyro unit (Table I of M.I.T. Instrumentation Laboratory Report R-91).

SUGGESTED SPECIFICATIONS FOR BuOrd STANDARD INTEGRATING GYRO 20IG (Page 1 of 2)  
(Use MIL-F-18870 (NOrd) for specifications not listed here.)

I. PHYSICAL SPECIFICATIONS - size 20 (2-inch diameter), square-flange mounted, hermetically sealed, terminal plug on flange end. (See Fig. 14.)						
II. OPERATING SPECIFICATIONS	(1) Type	(2) Terminals at Plug (electrically independent of case) (See Fig. 6.)	(3) Insulation Check* (measured at operating temperature)	(4) Electrical Specifications (measured at operating temperature)	(5) Nominal Operation (to meet specifications under Parts III and IV)	(6) Notes
A. Gyro Spin Motor	2-phase synchronous (speed or momentum not specified)	3 terminals	Between circuit and case: No breakdown for 1 minute at 120 volts a-c Insulation to be 1 megohm or greater at 120 volts d-c	130 ± 10% ohms per phase at 400 cps Effective electrical Q per phase when running with 400 cps: $0.5 < Q < 2$	400 cps ± 0.05% 16 ± 5% volts per phase 3 ± 20% watts total 2 phase: $90^\circ \pm 20^\circ$ (for positive rotation)	1. Must reach synchronous speed within 30 sec after application of 400 cps power.* 2. Must operate synchronously over an electrical input frequency range from 200 to 800 cps.
B. Signal Generator	Microsyn (a-c signal proportional to angle, excitation current, and frequency)	Excitation Circuit: 4 (circuit terminals, center tap, and quadrature tap) Signal Circuit: 3 (circuit terminals and center tap)	Between circuits, and from each circuit to case: No breakdown for 1 minute at 500 volts a-c Insulation to be 3 megohm or greater at 500 volts d-c	Excitation Circuit: 16 ± 10% ohms at 400 cps 9 ± 10% ohms d-c* Signal Circuit: 1600 ± 10% ohms at 400 cps 530 ± 10% ohms d-c*	Excitation: 400 cps ± 0.5% 100 ma ± 1% less than 1% harmonic distortion Signal: Load impedance: 20 K or greater	1. Must give a usable signal over a frequency range from 60 to 2000 cps.* 2. Must be able to operate continuously at 400 cps over an excitation current range from 0 to 400 ma.
C(a). Torque Generator (a-c excitation, 20IGa)	Microsyn (torque proportional to product of excitation current and signal current, and independent of rotor angle)	Excitation Circuit: 4 (circuit terminals, center tap, and quadrature tap) Signal Circuit: 3 (circuit terminals and center tap)	Between circuits, and from each circuit to case: No breakdown for 1 minute at 500 volts a-c Insulation to be 3 megohm or greater at 500 volts d-c	Excitation Circuit: 150 ± 10% ohms at 400 cps 70 ± 10% ohms d-c* Signal Circuit: 140 ± 10% ohms at 400 cps 50 ± 10% ohms d-c*	Excitation and signal currents of the same frequency, 400 ± 5% cps Magnitude: see note 1. Distortion: see note 2. Phase: excitation and signal currents in phase or $180^\circ$ out of phase within ± 2.5°	1. The excitation current rms magnitude depends upon the maximum rate required by each particular application. This maximum rate is usually achieved with equal signal and excitation currents. Maximum continuous rates up to 2.5 rad/sec corresponding to 160 ma in both circuits are possible. 2. Total harmonic distortion in current waveform must be within 1% of the actual magnitude. 3. Must give usable torque output over a frequency range from 60 to 2000 cps.
C(b). Torque Generator (d-c excitation 20IGb)	Microsyn (torque proportional to product of excitation current and signal current, and independent of rotor angle)	Excitation Circuit: 4 (circuit terminals, center tap, and quadrature tap) Signal Circuit: 3 (circuit terminals and center tap)	Between circuits, and from each circuit to case: No breakdown for 1 minute at 500 volts a-c Insulation to be 3 megohm or greater at 500 volts d-c	Excitation Circuit: 1500 ± 10% ohms at 400 cps 700 ± 10% ohms d-c* Signal Circuit: 1400 ± 10% ohms at 400 cps 500 ± 10% ohms d-c*	Excitation and signal circuits direct-current operated. Magnitudes: see note 1.	1. The excitation current magnitude depends upon the maximum rate required by each particular application. This maximum rate is usually achieved with equal signal and excitation currents. Maximum continuous rates up to 2.5 rad/sec corresponding to 30 ma in both circuits are possible. 2. Must be adaptable to conventional hysteresis erasing circuits.
D. Thermal Control	Heater not part of gyro. Heater and control to be chosen by user. Temperature-sensitive resistance element to be built into each gyro near damping gap. May be used for control purposes if desired by user.	2 terminals for temperature-sensitive element	From temperature-sensitive element to case: No breakdown for 1 minute at 500 volts a-c Insulation to be 3 megohm or greater at 500 volts d-c	Temperature-sensitive element to have 780 ± 10% ohms* at 170°F and a gradient of 1.5 ± 10% ohms per degree F.	170 ± 1°F controlled either by an on-off or proportional heater controller, and measured at gyro case surface near center of unit.	1. Heat to be supplied symmetrically about the gyro. 2. Actual resistance of temperature-sensitive element within 0.2% to be supplied for each gyro for the nominal operating temperature, i.e., that temperature at which final gravity balance was undertaken.
E. Trim Adjustments	1. Gravity balance adjustments that are available to manufacturer on complete unit are optional. However, this adjustment should not normally be required during life of gyro. 2. No external padding adjustments on Microsyns should be required to meet performance specifications outlined in Part IV, although such adjustments may be made by user to improve performance.					
F. Life	1. Shelf life must be at least 3 years. 2. Gyro must meet performance specifications for at least 2000 hours of gyro-wheel operation.					
G. Environment	1. Ambient temperature range: Not specified; depends upon thermal control used. 2. Heat cycles: 3. Quick warmup: 4. Humidity: No effect 5. Ambient pressure: No effect, ± 1 atmosphere gage. 6. Vibration: 7. Acceleration:					1. Notes on temperature: (a) the gyro must not be permanently damaged by 1 hour of operation at 200°F. (b) It can be expected that the use of heaters can control the gyro at 170°F under normal operating conditions with equal torque generator currents corresponding to 2.5 radians per second in an ambient temperature as high as 140°F. This is while the gyro is mounted in the standard test block in still, open air with heat conduction from the block insulated.

\* Every gyro unit must be tested for sections or individual items marked with a single asterisk.

Table 8-2. Typical performance specifications for a 20IG gyro unit (cont.).

SUGGESTED SPECIFICATIONS FOR BuOrd STANDARD INTEGRATING GYRO 20IG (Page 2 of 2)  
(Use MIL-F-18870 (NORd) for specifications not listed here.)

III. FUNCTIONAL SPECIFICATIONS (At nominal operation conditions under Part II, Column 5)		Value	Unit to Unit Variation	Variation in One Unit over Operating Range	Notes
A. Ratio of input axis angular velocity to equivalent torque motor current product, $(SR)_{(qu)[i^2;W]}$	20IGa	0.1 milliradian/second milliampere <sup>2</sup>	± 5%*	± 0.2% below 0.5 $\frac{\text{radian}}{\text{second}}$	See Part IV, Item D Measured with signal generator output voltage at null**
	20IGb	1.0 milliradian/second milliampere <sup>2</sup>	± 5%*	± 0.2% below 1.0 $\frac{\text{radian}}{\text{second}}$	
B. Ratio of gyro signal output to input angular velocity, $S_{(qu)[W;\dot{\theta}]}$		25 millivolts/second milliradian/second	± 10%*	± 5%	
C. Ratio of gyro output gimbal angle rate to input-axis angular velocity, $S_{(qu)[W;\dot{\alpha}]}$		1.1 or less			
D. Angular rotation limit of gimbal about output axis away from signal null, either direction.*		7.5 degrees	± 2.5 degrees		
E. Characteristic time $(CT)_{(qu)}$ (equivalent first-order time constant)		Less than 0,005 second			Experimentally determined.

IV. PERFORMANCE SPECIFICATIONS (At standard operating conditions under Part II, Column 5)																												
A. Input axis alignment with gyro case references* (as indicated in standard alignment test block)	Maximum error in alignment of IA about SRA: ± 1 milliradian Maximum error in alignment of IA about OA: ± 2 milliradian																											
B. Signal generator null (defined as minimum rms output)	1. From signal generator alone with nominal excitation {quadrature component: 7 millivolts or less harmonic component: 2 millivolts or less 2. Pickup from wheel and torque generator alone, operating at nominal power and frequency: 4 millivolts or less 3. Total null: 9 millivolts or less* (with all 400-cps excitations from the same reference supply)																											
C. Drift rate (Input-axis case angular velocity necessary to keep output signal voltage constant)	At nominal operating conditions (except torque generator currents zero):																											
	Due only to excitation current in torque generator																											
<table border="1"> <thead> <tr> <th></th> <th>Nongravity-sensitive component - at signal null**</th> <th>Nongravity-sensitive component variation as a function of signal generator output voltage</th> <th>Gravity-sensitive component with 1 g in any fixed direction</th> <th>Indicated drift rate with input axis vertical or spin reference axis vertical</th> </tr> </thead> <tbody> <tr> <td>Maximum drift rate</td> <td>0.3 milliradian/second*</td> <td>2.0 milliradian/second within ± 50% of signal generator range</td> <td>0.1 milliradian/second*</td> <td>Implicit in the specifications at the left</td> </tr> <tr> <td>Maximum excursions with time (with gyro continuously at operating temperature)</td> <td>0.01 milliradian/second in 1 hour 0.03 milliradian/second in 1 day 0.1 milliradian/second in 1 month</td> <td>Not specified</td> <td>Not specified</td> <td>0.014 milliradian/second in 1 hour* 0.042 milliradian/second in 1 day 0.14 milliradian/second in 1 month</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th></th> <th>Fixed component (can be padded or trimmed out)</th> <th>Variation with signal generator voltage within ± 50% of signal range</th> <th>Uncertainty variation (can't be trimmed out)</th> </tr> </thead> <tbody> <tr> <td>20IGa (a-c torque generator)</td> <td>1%*</td> <td>5%</td> <td>0.02%</td> </tr> <tr> <td>20IGb (d-c torque generator)</td> <td>1%*</td> <td>5%</td> <td>0.5% without hysteresis erasing 0.02% with hysteresis erasing</td> </tr> </tbody> </table> <p>Percentages of the rate achieved when the signal current equals the excitation current. Maximum values measured at signal generator voltage null.**</p>			Nongravity-sensitive component - at signal null**	Nongravity-sensitive component variation as a function of signal generator output voltage	Gravity-sensitive component with 1 g in any fixed direction	Indicated drift rate with input axis vertical or spin reference axis vertical	Maximum drift rate	0.3 milliradian/second*	2.0 milliradian/second within ± 50% of signal generator range	0.1 milliradian/second*	Implicit in the specifications at the left	Maximum excursions with time (with gyro continuously at operating temperature)	0.01 milliradian/second in 1 hour 0.03 milliradian/second in 1 day 0.1 milliradian/second in 1 month	Not specified	Not specified	0.014 milliradian/second in 1 hour* 0.042 milliradian/second in 1 day 0.14 milliradian/second in 1 month		Fixed component (can be padded or trimmed out)	Variation with signal generator voltage within ± 50% of signal range	Uncertainty variation (can't be trimmed out)	20IGa (a-c torque generator)	1%*	5%	0.02%	20IGb (d-c torque generator)	1%*	5%	0.5% without hysteresis erasing 0.02% with hysteresis erasing
	Nongravity-sensitive component - at signal null**	Nongravity-sensitive component variation as a function of signal generator output voltage	Gravity-sensitive component with 1 g in any fixed direction	Indicated drift rate with input axis vertical or spin reference axis vertical																								
Maximum drift rate	0.3 milliradian/second*	2.0 milliradian/second within ± 50% of signal generator range	0.1 milliradian/second*	Implicit in the specifications at the left																								
Maximum excursions with time (with gyro continuously at operating temperature)	0.01 milliradian/second in 1 hour 0.03 milliradian/second in 1 day 0.1 milliradian/second in 1 month	Not specified	Not specified	0.014 milliradian/second in 1 hour* 0.042 milliradian/second in 1 day 0.14 milliradian/second in 1 month																								
	Fixed component (can be padded or trimmed out)	Variation with signal generator voltage within ± 50% of signal range	Uncertainty variation (can't be trimmed out)																									
20IGa (a-c torque generator)	1%*	5%	0.02%																									
20IGb (d-c torque generator)	1%*	5%	0.5% without hysteresis erasing 0.02% with hysteresis erasing																									
D. Linearity	Percentage deviations in the ratio of input angular velocity to equivalent torque motor current product, $(SR)_{(qu)[i^2;W]}$ , from the average value measured between 0.2 and 0.5 radian/second. Torque motor circuits should be connected in series for equal currents. Percentage deviations to be less than or equal to the values shown. Fixed drift rates may be subtracted from the measured angular velocity to compute the sensitivity ratio. In regions where 0.2% tolerance is indicated, the gyro output signal is to be kept at null.**																											

Torque Generator Equivalent Rate in radians/second

\* Every gyro unit must be tested for sections or individual items marked with a single asterisk.

\*\* Operation at gyro null here means operation with a signal generator voltage equal to or less than 5% of the smaller of the voltages produced when the gyro is at either stop.

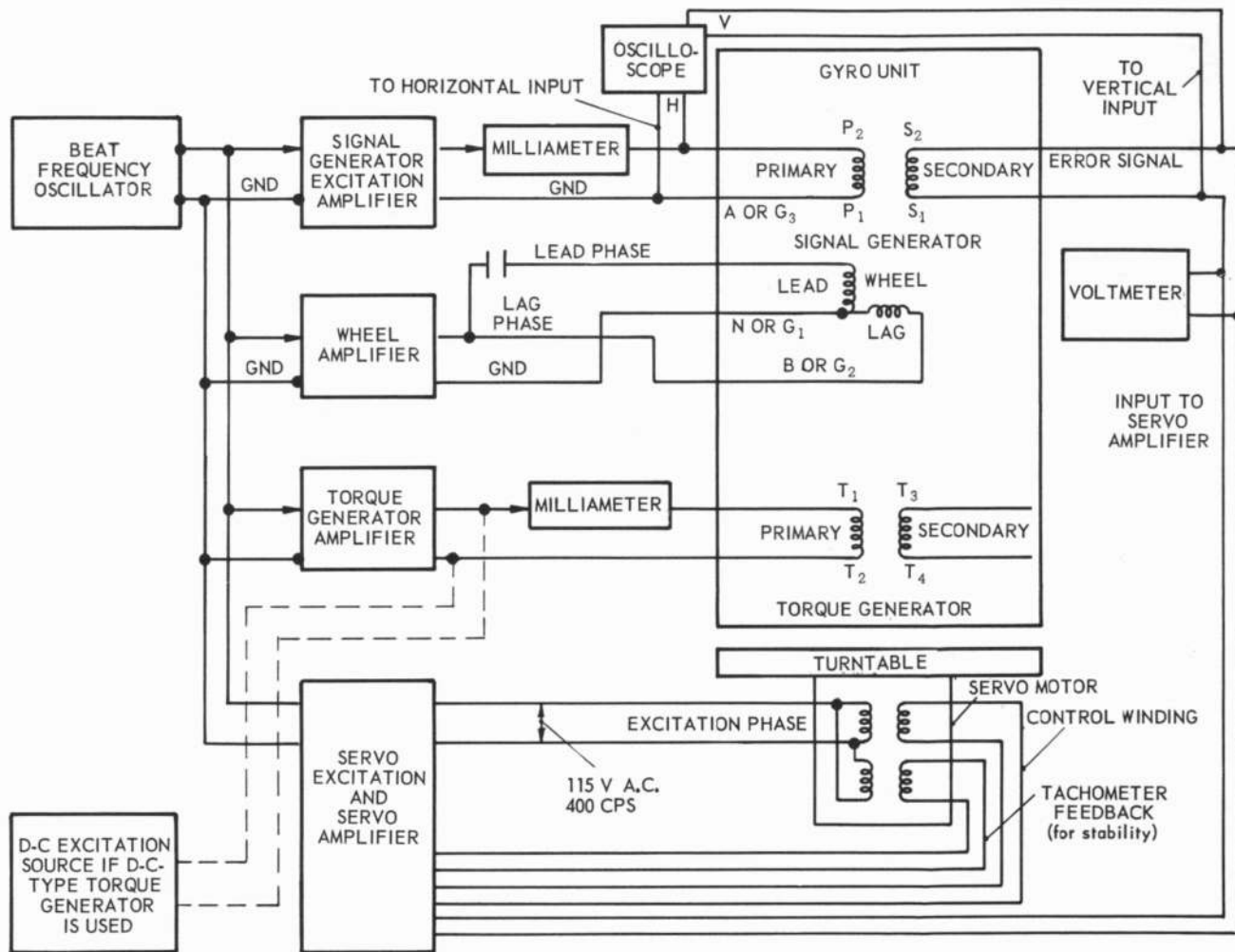
- c. Test console.
- d. Rate table assembly.
- e. Auxiliary electrical equipment.

**Note**

Unless otherwise indicated, all tests are performed with the equipment connected in accordance with Fig. 8-2.

**8-10. SERVO-CONTROLLED TURNTABLE ASSEMBLY.** Figure 8-3 is a pictorial view showing the servo-controlled turntable assembly. A cutaway view is included to show the slip-ring assembly. The turntable achieves smooth operation over an angular velocity range from 0.01 milliradian per second up to 5 radians per second. The servo amplifier (located in the test console) that supplies the power to the servo drive motor receives

its input signals from the signal generator of the gyro unit. The gyro unit, the servo amplifier, and the turntable assembly (which includes the servo motor) form a closed loop to operate as a servo system. By design, this system achieves smooth, steady angular velocity control at a small indicated error from the gyro unit, rather than fast dynamic response, since all tests using the servo loop are for steady-state angular velocity. The turntable assembly incorporates a direct-drive motor having a common shaft connection between the motor rotor and the turntable. Since continuous rotation of the turntable is highly desirable, an adequate number of slip rings are provided on the turntable axis to bring electrical connections from the gyro unit to the associated electrical equipment.



Note: The rate table, its drive motor and associated equipment are not shown since they operate independently of the components shown here.

Fig. 8-2. Schematic diagram of the interconnections between components in the basic test setup.

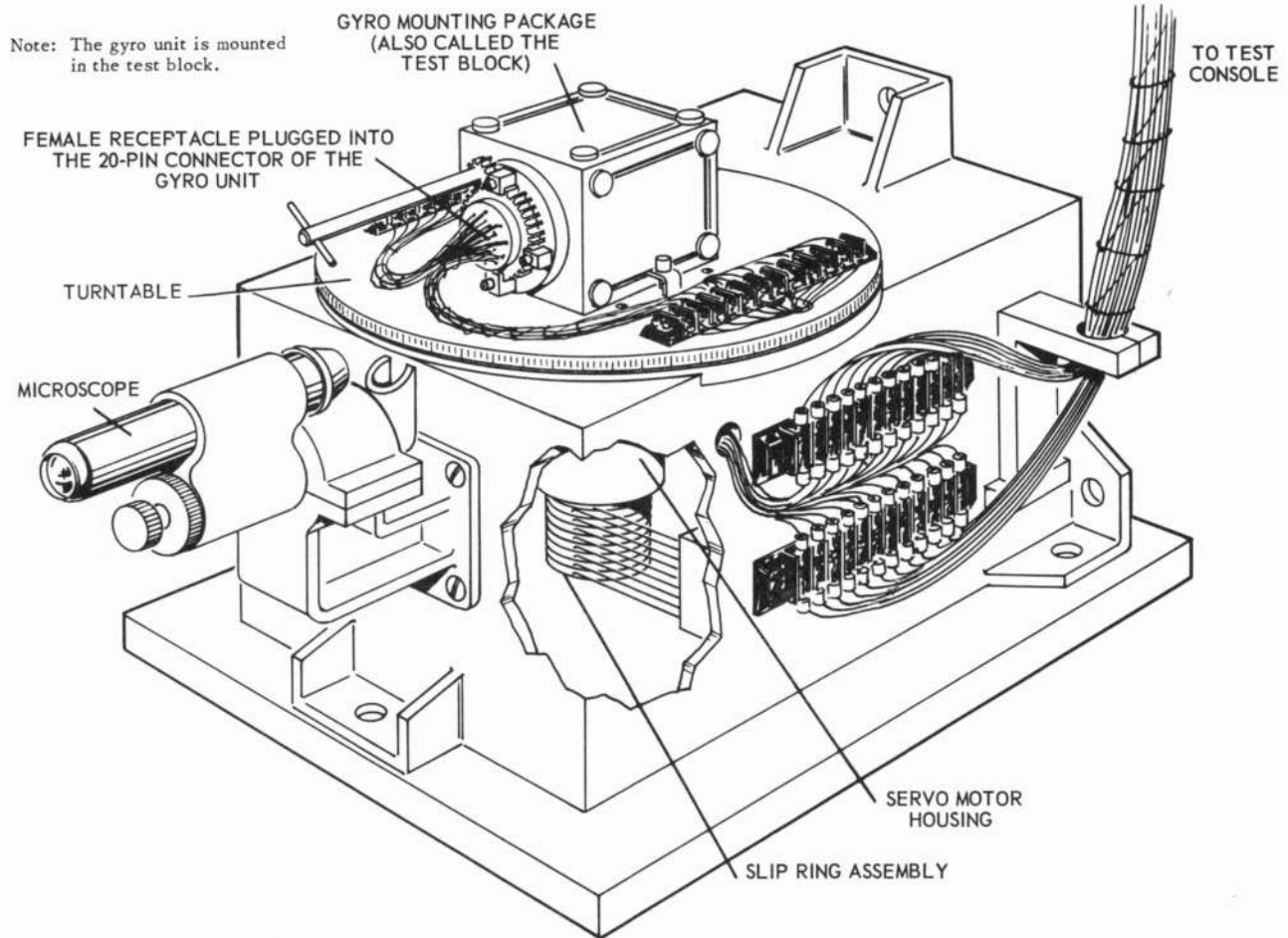


Fig. 8-3. Pictorial view of the servo-controlled turntable assembly and the gyro mounting package.

8-11. The turntable assembly is designed so that it can be readily mounted on the rate table assembly in either of two positions:

- a. With the turntable axis vertical.
- b. With the turntable axis horizontal.

8-12. The best way to measure accurately the angular velocity of the turntable under steady-state conditions is to time the angular increments of the turntable with respect to the base. For high angular velocities, a cam-operated switch can be used to trigger a precision timing equipment. A single cam is used to time integer revolutions; for smaller angular increments, two cams can be used, but they must be similar and accurately located to the required precision. For low angular velocities, the cam method requires excessively long time intervals, so that the use of a microscope and a precision engraved scale is more convenient. The reticle increments in the microscope should be small enough so that very low angular velocities

can be measured conveniently. In all cases, the timing interval must be long enough to achieve the required accuracy of the measured result. For manual timing, accuracy is limited by the consistency of human reaction time. About 0.1-second timing accuracy is the best that can be expected from experienced technicians. This means that for measurements of 0.1 percent accuracy, the timing intervals must be at least 100 seconds long.

8-13. **GYRO MOUNTING PACKAGE.** Figure 8-3 shows the gyro mounting package fastened to the turntable. The purpose of the gyro mounting package is to enable the gyro unit to be positioned in proper alignment with respect to the turntable. The mounting package also contains the necessary temperature control components. This package has the shape of a right rectangular block, with a cylindrical bore in which the gyro unit is mounted. The gyro mounting package may be considered to be a standard alignment test block for the gyro unit.

This standard test block must be used for the input-axis alignment procedure of the gyro unit, and it is very convenient for all the other procedures. In the test block, the gyro input axis is accurately aligned perpendicular to one face of the test block. This is the reference surface upon which the test block is fastened to the turntable when this table is servo-controlled by the gyro, since for this operation the input axis must be parallel to the table

axis. By fastening either of the other two reference surfaces of the test block to the turntable, either the output axis or the spin reference axis can be set parallel to the turntable axis.

8-14. TEST CONSOLE. Figure 8-4 is a pictorial view showing the components of the test console. The important controls, switches and components are identified on the figure. Compare this figure

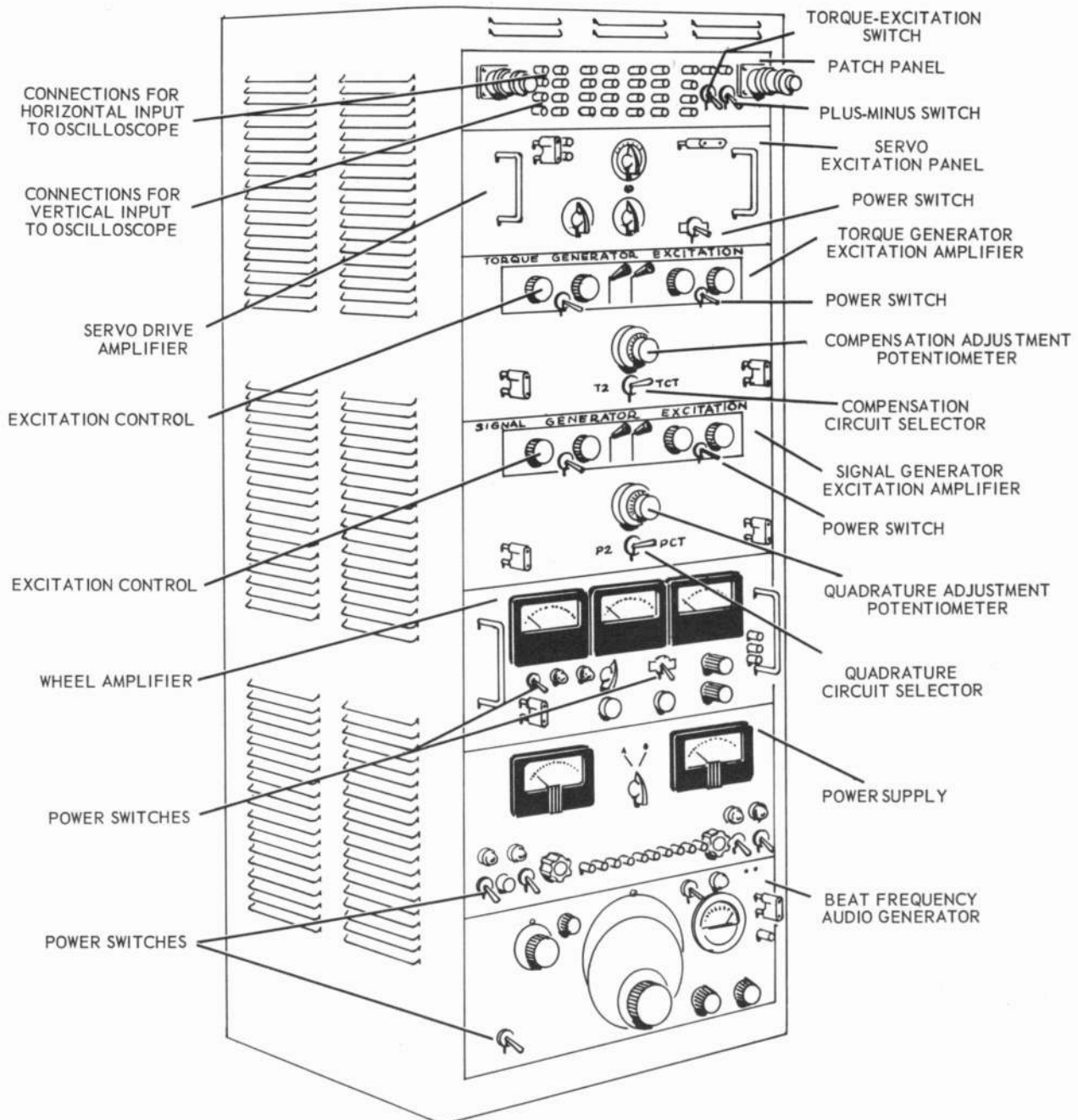


Fig. 8-4. Pictorial view of the test console.



with Fig. 8-2 to see how the various components shown fit into the basic circuit arrangement used for the testing procedure.

**8-15. RATE TABLE ASSEMBLY** (ref. Fig. 8-1). This assembly comprises a rate table, a drive motor and associated controls and auxiliary equipment, all housed as an integral unit. The rate table is mounted horizontally and spins about a vertical axis. The angular velocity of the rate table has been accurately calibrated. This angular velocity is adjustable, in steps, from 0.0255 to 418.88 milliradians per second. The direction of angular rotation is reversible over the entire range of speeds. The rate table is used to impart an angular velocity to the entire servo-controlled turntable assembly, as is required for some of the procedures listed in paragraph 8-5.

**8-16. CIRCUIT ARRANGEMENT OF THE BASIC TEST SETUP.**

**8-17.** Figure 8-2 shows schematically the important features of the circuit arrangement used for the testing procedure. The equipment to supply the excitation current to the gyro wheel and the signal generator is straightforward. A common 400-cps precision reference frequency is required. The excitation currents and the temperature control of the gyro conform to operating conditions like those of Table 8-2, Column 5.

**8-18.** The torque generator currents must be either alternating or direct, depending upon the type of torque generator used in the gyro unit being tested. The a-c frequency for the torque generator in a 20IGa gyro unit is identical with that used to excite the gyro wheel and signal generator. The use of direct current for the torque generator in a 20IGb gyro unit when a fixed excitation is employed introduces the problem of magnetic hysteresis effects when a high maximum-to-minimum rate ratio is required in operation. This hysteresis can be effectively erased by any one of many methods. A simple hysteresis erasing circuit is given in Fig. 8-5.

**8-19.** During some test procedures, the output of the signal generator is used as an input to the servo drive amplifier. The signal generator signal then becomes nulled as a result of torque feedback

within the gyro unit. This is provided by the precession of the gyro rotor in response to the angular velocity of the turntable.

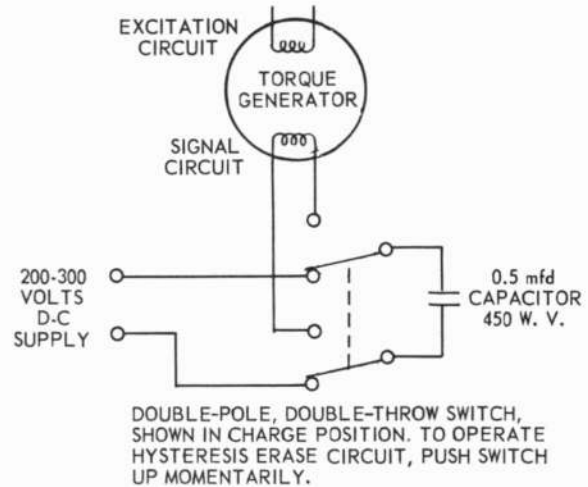


Fig. 8-5. Schematic diagram of a simple hysteresis erasing circuit.

**8-20. PRELIMINARY CONDITIONS.**

**8-21. GENERAL.** Prior to performing any of the tests, it is necessary that the gyro unit be stabilized thermally and mechanically, and that a check of the electrical circuits be made. The gyro unit is stabilized thermally during tests by means of the test block, which maintains the gap temperature at 160° F. The gyro unit is stabilized mechanically, or run in, by a process called "yozzling."

**8-22. ADJUSTING AND MAINTAINING THE GAP TEMPERATURE.** The temperature of the gap must be adjusted to and maintained at 160° F. The equipment required is as follows (ref. Fig. 8-6):

- a. Rubicon Wheatstone Bridge.
- b. Magnetic amplifier.
- c. Double-pole, single-throw relay.
- d. Double-pole, double-throw switch.
- e. Three 380-ohm resistors.
- f. Milliammeter.
- g. 100-ohm variable resistor.

**8-23.** The detailed steps of the procedure are as follows:

- a. Connect the equipment as shown in Fig. 8-6.
- b. Switch the temperature-sensing element (the sensing-coil wire located in the gyro unit) into the magnetic amplifier bridge circuit that is formed with R1, R2, R3 and R4.

Note

The resistance of the sensing-coil wire varies upward or downward in direct proportion to the gap temperature. This variation has been plotted in the form of a calibration curve (see Fig. 8-7) for the standard length of the sensing-coil wire used in each gyro unit.

c. Adjust the variable resistor, R4, to its midrange position.

d. Apply 60-cps power and 400-cps power as shown in Fig. 8-6.

e. Allow the test block to warm up until the relay de-energizes.

f. Adjust the controls of the Wheatstone bridge (ref. Fig. 8-8) to give a known resistance identical with that found from the experimental curve at 160° F. As can be seen from Fig. 8-7, this value is  $387 \pm 1$  ohms.

g. Switch the sensing element to the Wheatstone bridge. If the gap temperature is at 160° F, the bridge will be balanced - that is, no current will flow through the bridge galvanometer. The needle on the scale will then show zero deflection when the GB button is depressed. If the needle swings to the right, the gap temperature is less than 160° F. If the needle swings to the left, the gap temperature is more than 160° F.

h. Note whether the gap temperature is at 160° F, above 160° F or below 160° F.

i. If the gap temperature is at 160° F, switch the sensing element back into the magnetic amplifier bridge circuit. The adjustment is now at an end and the temperature will be maintained automatically at the correct level by the operation of the magnetic amplifier bridge circuit. This is because any change in the gap temperature will unbalance the bridge circuit and cause the heaters in the test block to operate until the bridge circuit is once again in balance.

j. If the gap temperature is below 160° F, switch the sensing element back into the magnetic amplifier bridge circuit and slowly turn the variable resistor, R4, in one direction (and if necessary in the other direction), until the relay is heard to energize.

k. Stop turning the variable resistor, R4, and allow the test block to warm up, until the relay is heard to de-energize.

l. Repeat steps g through k until the desired 160° F gap temperature has been attained.

m. If in step h the gap temperature was found to be higher than 160° F, proceed as follows:

n. Switch the sensing element back into the magnetic amplifier bridge circuit and slowly turn the variable resistor, R4, in one direction (and if necessary in the other direction), until the relay is heard to energize.

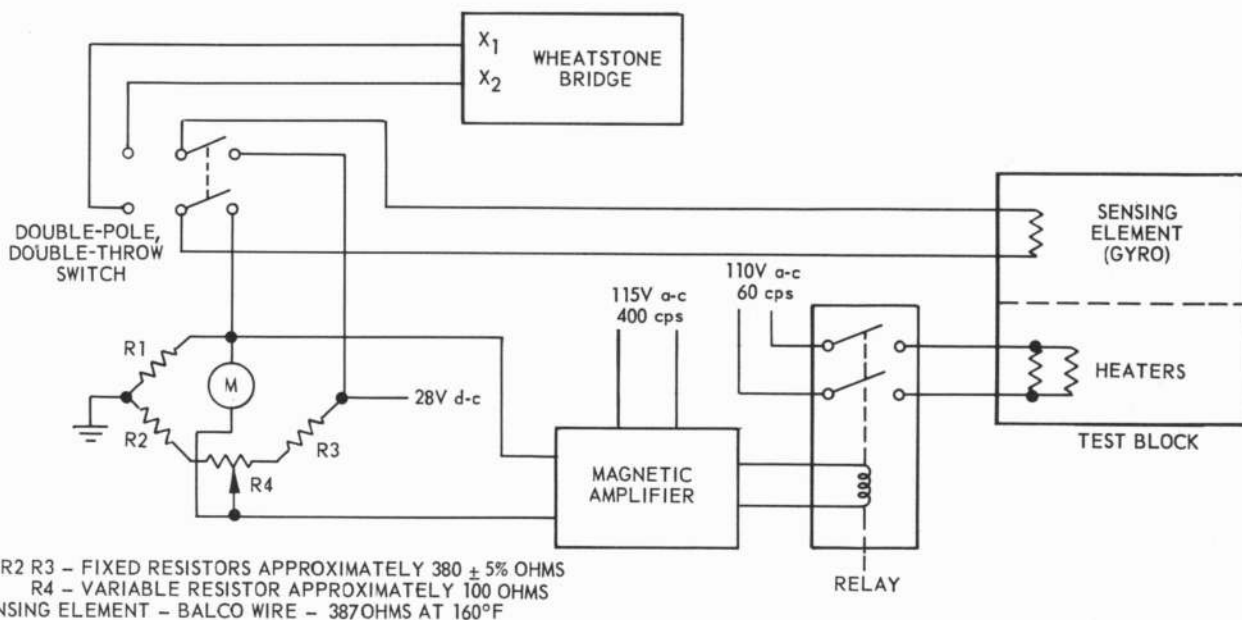


Fig. 8-6. Schematic diagram of the arrangement used for controlling the temperature in the test block.

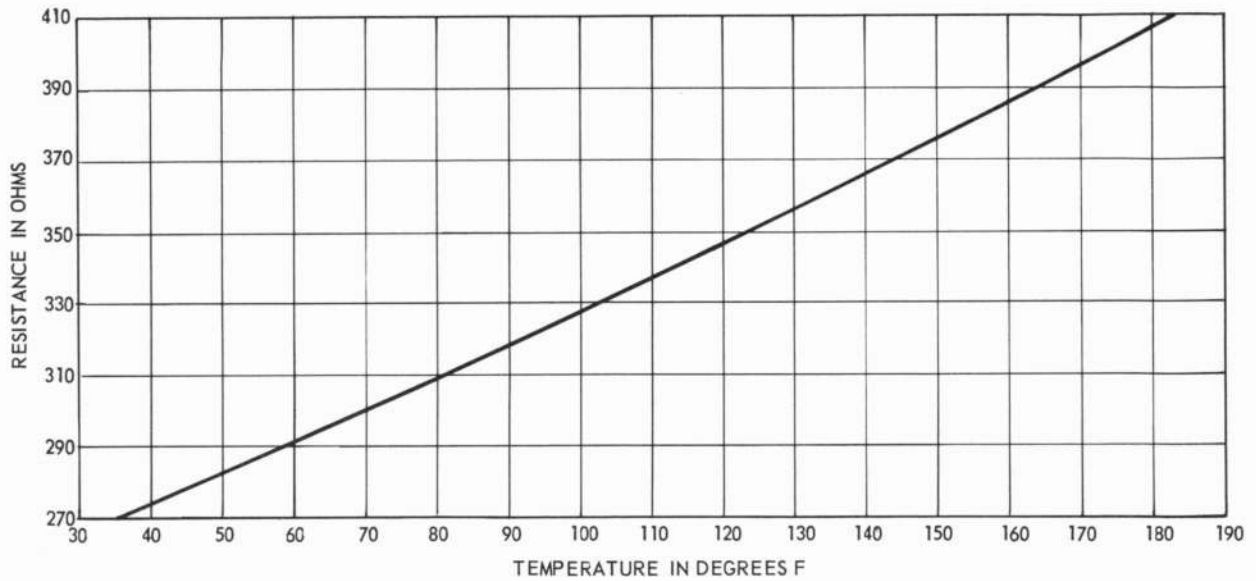
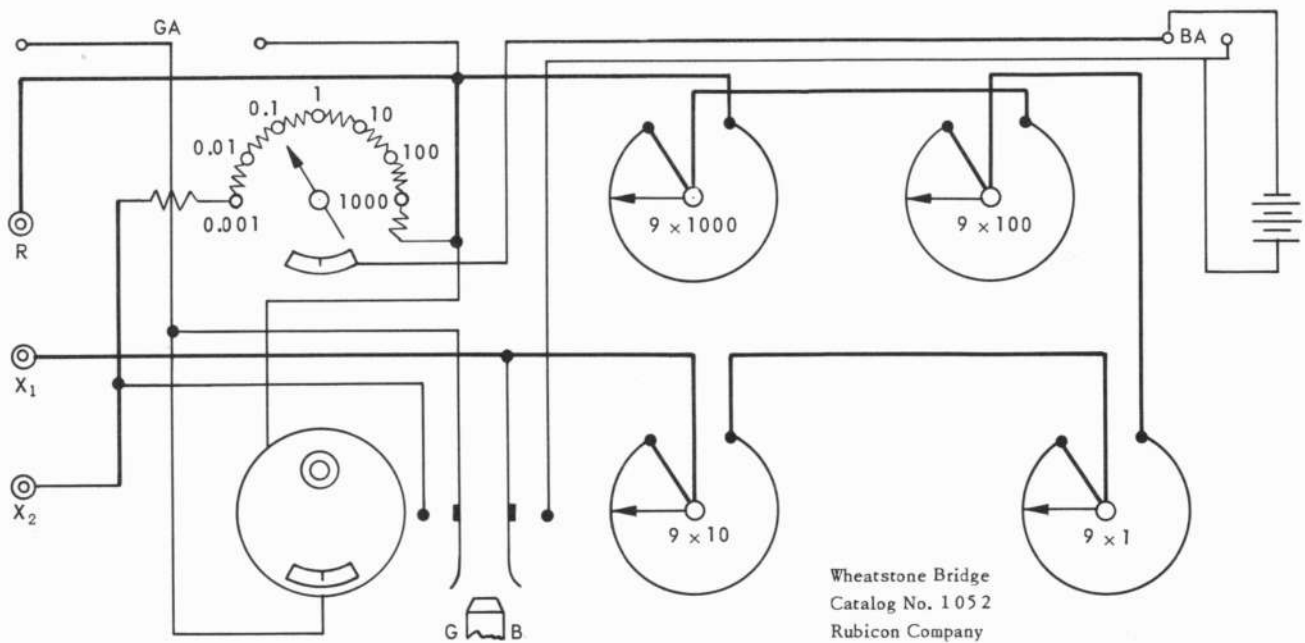


Fig. 8-7. Calibration curve giving the variation of the resistance of the sensing-coil wire with changes in the gap temperature.



**Resistance Measurements:**

Connect the unknown resistance to posts  $X_1$  and  $X_2$ . Set the ratio dial in accordance with the accompanying table. Vary the rheostat dials until the galvanometer shows no deflection when the GB key is closed. The unknown resistance equals the rheostat setting times the ratio dial setting.

**Unknown Resistance**

**Ratio Setting**

Below 10 ohms	0.001
10 ohms to 100 ohms	0.01
100 ohms to 1000 ohms	0.1
1000 ohms to 10000 ohms	1.0
10000 ohms to 100000 ohms	10
100000 ohms to 1000000 ohms	100
1000000 ohms to 10000000 ohms	1000

Fig. 8-8. Schematic diagram showing the details of the Wheatstone bridge arrangement.

o. Back down the variable resistor slightly until the relay de-energizes. Note the direction in which the control shaft of the variable resistor was turned.

p. Stop turning the variable resistor, R4, and allow the test block to cool until the relay is heard to energize again.

q. Repeat steps g, h, and m through p, as required to attain a gap temperature of 160° F.

r. When the gap temperature reaches 160° F, the adjustment is at an end, and the magnetic amplifier circuit will automatically maintain the temperature at the desired level.

**8-24. YOZZLING.** The term "yozzling" means driving the floated units assembly of the gyro unit from stop to stop by means of a direct current applied to the torque generator windings. A direct current of 3 volts is obtained by connecting four 1.5-volt dry cells in the series-parallel arrangement shown in Fig. 8-9. To obtain the required change in polarity of the direct current, a multivibrator is used. This electronic device controls a double-pole, double-throw relay-actuated switch that is connected across the 3-volt output of the dry-cell battery in the manner shown in Fig. 8-9. This arrangement is used regardless of whether the torque generator of the gyro unit is energized with direct current or alternating current.

**8-25.** A constant flux occurs through the primary windings between terminals T1 and T2, regardless of which direction the switch is thrown. The direction of the current is from T3 to T4 when the relay is in its unenergized position; conversely, the current flows from T4 to T3 when the relay is energized. When the relay changes position, the flux direction through the secondary windings changes direction while the flux direction through the primary remains the same. As a result, the rotor of the torque generator turns first in one direction and then the other. Since the rotor of the torque generator is mounted on the shaft of the floated units assembly, this assembly will reverse direction, or "yozzle," every time a switch reversal occurs.

**8-26.** A gyro unit is "yozzled" mainly to run in the movable parts. Usually, the time duration of "yozzling" is extended over a weekend to eliminate

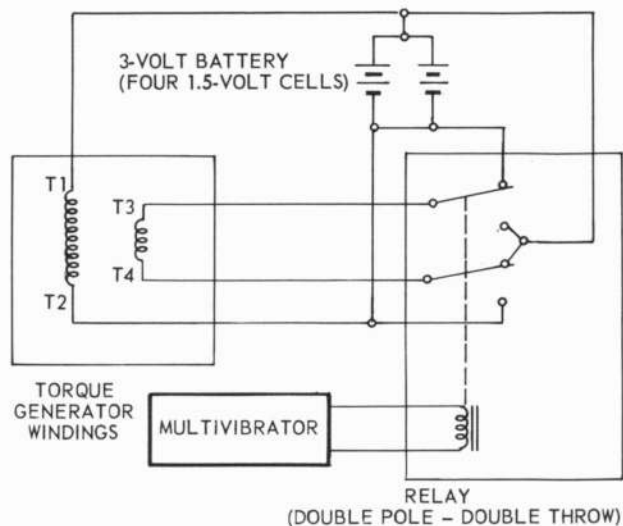


Fig. 8-9. Schematic diagram of the multivibrator circuit used for "yozzling."

most of the stiffness of the gyro unit that is due to its newness. After the unit has been "yozzled," and before any test is performed, an alternating current is run through the torque generator in order to eliminate the hysteresis effect, which results whenever a direct current passes through the torque generator windings. Use the hysteresis erasing circuit shown in Fig. 8-5 to accomplish this.

**8-27. CHECKING OUT THE ELECTRICAL CIRCUITS.** The final step of the gyro unit assembly procedure is to check out the electrical circuits of the gyro unit. If the test procedure follows immediately after this checkout, this test need not be repeated. Otherwise, repeat the checkout procedure, utilizing Tables 4-2 and 4-3, in order to insure that the circuits are still operating properly.

**8-28. SELECTION OF THE SIGNAL GENERATOR QUADRATURE RESISTOR.**

**8-29. EXPLANATORY INFORMATION.** The first item of the over-all testing procedure is to connect a resistance of appropriate value across a primary coil of the signal generator. Its purpose is to cancel the quadrature component of the output voltage at the signal generator null.

**8-30. EQUIPMENT.** Use the basic test setup shown in Fig. 8-1.

**8-31. INITIAL CONDITIONS.** Initial conditions for the procedure are as follows:

- a. Signal generator excitation:  
125 ma at 400 cps.

- b. Torque generator excitation:  
 100 ma at 400 cps for the 20IGa  
 10 ma d-c for the 20IGb  
 Series-connected input circuit in each instance.

8-32. **STEP-BY-STEP PROCEDURE.** The detailed procedure for determining the appropriate resistance is as follows:

a. Place the gyro unit in the test block and mount the block on the turntable in any convenient position.

b. Connect the oscilloscope and the voltmeter to the primary and secondary windings of the signal generator as shown in Fig. 8-10. Leave these connections in place for all subsequent procedures, unless otherwise noted.

c. Leave the servo loop unenergized.

d. Apply the indicated excitation to the signal generator. A Lissajous figure should appear on the face of the oscilloscope.

**Note**

*The amount of signal generator excitation current applied can be controlled by the excitation control knob on the signal generator excitation panel of the test console (ref. Fig. 8-4), and observed on the signal generator excitation milliammeter on top of the test console (ref. Fig. 8-1).*

e. Place the variable resistance located in the test console (ref. Fig. 8-10) across terminals PQA and P2 by placing the quadrature circuit selector on the test console (ref. Fig. 8-4) in the P2 position. Adjust the quadrature adjustment potentiometer so as to obtain a minimum opening of the Lissajous figure on the oscilloscope at the signal generator null. For making fine adjustments, obtain the minimum reading from the voltmeter. Obtain the signal generator null by applying excitation to the torque generator as required (ref. Fig. 8-4).

**Note**

*The amount of torque generator excitation current applied can be controlled by the excitation control knob on the torque generator excitation panel of the test console (ref. Fig. 8-4), and observed on the torque generator excitation milliammeter on top of the test console (ref. Fig. 8-1). With the TORQUE-EXCITATION switch at the top of the console in the EXCITATION position, no torque is applied to the floated units assembly of the gyro unit by the torque generator. With this switch in the TORQUE position, the direction of the resulting torque can be controlled by the PLUS-MINUS switch.*

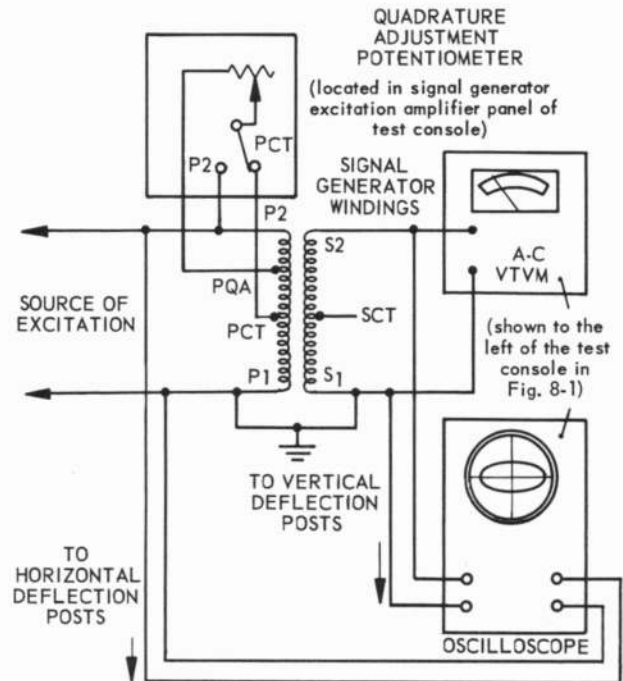


Fig. 8-10. Method of connecting the quadrature resistor, the oscilloscope and the voltmeter to the signal generator windings.

f. Next, place the variable resistance across terminals PQA and P2 (ref. Fig. 8-10) by placing the quadrature circuit selector in the PCT position. Adjust for minimum opening of the Lissajous figure and minimum voltage reading as in step e. This is necessary only if step e fails to close the Lissajous figure.

g. Place the toggle switch in the position that gave the lowest reading on the voltmeter. The variable resistance will remain connected in all the succeeding procedures.

8-33. **ALIGNMENT OF THE INPUT AXIS.**

8-34. **EXPLANATORY INFORMATION.** The proper testing of the gyro unit requires that the input axis be positioned accurately with respect to the turntable platform. The present procedure is used to determine the exact direction of the input axis after the gyro unit has been assembled. During assembly, the approximate direction of the spin reference axis has been indicated on the face of the 20-pin connector by aligning the key with the positive sense of the spin reference axis. This assists in pre-positioning the gyro unit during the present procedure.

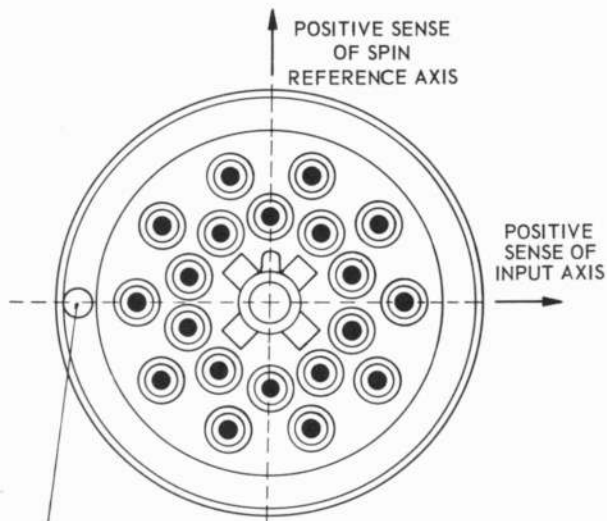
8-35. **EQUIPMENT.** In addition to the basic test setup, a spirit level is used.

8-36. **INITIAL CONDITIONS.** Initial conditions for the procedure are as follows:

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of the gyro unit on the turntable:  
output axis horizontal, spin reference axis upward, this latter condition obtained when the key of the 20-pin connector is pointing upward.

8-37. **STEP-BY-STEP PROCEDURE.** The detailed procedure is as follows:

- a. Place the turntable in a horizontal plane and check its position with the spirit level.
- b. With the gyro unit still mounted in the test block, place the test block on the turntable so that the output axis of the gyro unit is parallel to the plane of the turntable and the spin reference axis is upward.
- c. Apply the indicated excitation to the gyro unit.
- d. Leave the servo loop unenergized.
- e. Rotate the turntable a few degrees by hand, while observing the vertical deflection of the trace on the oscilloscope (see Fig. 8-10 for the standard connections to the oscilloscope).
- f. Rotate the gyro unit inside the test block a few degrees about its output axis and repeat step e. Repeat this procedure until the minimum deflection is obtained.
- g. Lock the gyro unit in this position inside of the test block. The input axis will now lie parallel to the turntable. Its positive sense is 90 degrees clockwise from the positive sense of the spin reference axis (which is directed upward in the direction of the key on the 20-pin connector). Identify the negative direction of the input axis with an accurately positioned mark on the gyro unit.
- h. Remove the test block from the turntable, mount it in a boring jig, drill a small hole (0.1250 in. dia.) as indicated in Fig. 8-11, and insert a dowel pin to indicate the negative direction of the input axis.



0.1250 in. dia. dowel pin, 1/2 in. long. Pin to protrude 0.125 in. Exposed end of pin chamfered 30° included angle, 1/16 in. long. Locate on axis as shown within one milliradian.

Fig. 8-11. Indication of the negative direction of the input axis by means of a dowel pin.

*Note*

*The positive direction of the input axis is already indicated (but not precisely) by the access hole to the input-axis balance nut.*

8-38. **APPLICATION OF COMPENSATION TO THE TORQUE GENERATOR PRIOR TO MAKING MASS UNBALANCE ADJUSTMENTS.**

8-39. **EXPLANATORY INFORMATION.** The reaction torque due to the Microsyn units and the flexible power leads may be of such magnitude that, unless reduced, it will be impossible to make the adjustments necessary to achieve a balance of the floated units assembly. Therefore, a compensating resistor is introduced into the torque generator excitation circuit to cancel or "buck out" this reaction torque.

8-40. **EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

8-41. **INITIAL CONDITIONS.** Initial conditions for the procedure are as follows:

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on the turntable:  
output axis vertical, input axis east-west.

8-42. **STEP-BY-STEP PROCEDURE.** The detailed steps of this procedure are as follows:

a. Secure the test block to the turntable with the gyro unit output axis parallel to the plane of the turntable as before. Then orient the turntable assembly so that the output axis of the gyro unit is vertical and the input axis is in the east-west direction.

b. Place the other variable resistance of the test console across terminals TQA and T1CT by placing the compensation circuit selector on the torque generator excitation amplifier panel of the test console in the TCT position. Turn the compensation adjustment potentiometer to an indicated value of 2.2 K ohms. This resistance value has been found from experience to be a good starting point for the variable resistance to the gyro unit. Figure 8-12 illustrates the circuits concerned.

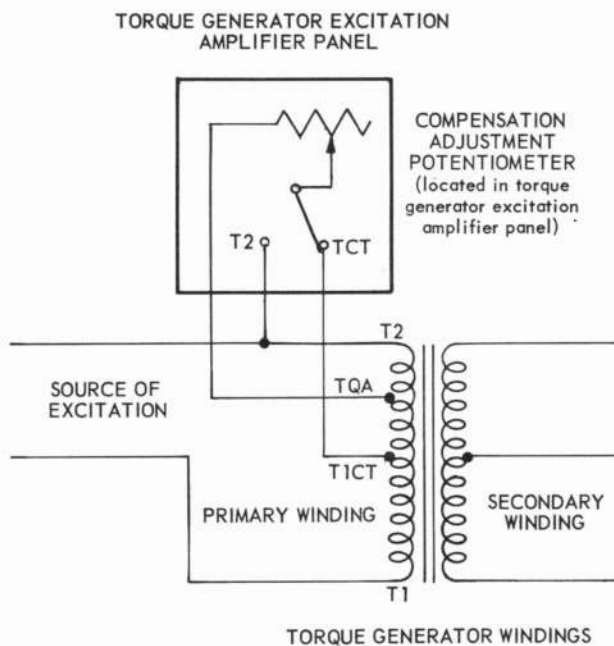


Fig. 8-12. Method of connecting the compensating resistor to the torque generator windings.

- c. Apply the indicated excitation.
- d. Energize the servo loop (ref. Figs. 8-2 and 8-4).
- e. Take a drift reading in accordance with the procedure given in paragraph 8-43 following.
- f. Increase or decrease the resistance to minimize the drift, and take another drift reading.

g. When a minimum drift is observed, throw the compensation circuit selector to the T2 position so that the variable resistance is across terminals TQA and T2. Repeat steps e and f.

h. Place the toggle switch in the position that provided the least drift. This means that the variable resistance will remain connected during all succeeding procedures.

i. The gyro drift rate should now be less than 0.01 mr/sec.

8-43. **PROCEDURE FOR MAKING DRIFT READINGS.** The circumferential surface of the turntable is marked in degrees, with major markers at 15-degree intervals. The Bausch and Lomb 40-power microscope that is used to view the angular displacement of the turntable is equipped with a fixed scale inside of it that has 11 main reference marks, with each interval between the reference marks broken up into 10 equal divisions. The separation between degree markings on the turntable occupies approximately 75.2 divisions inside the microscope, as shown in Fig. 8-13. In mathematical terms, this means that:

1 degree on the turntable circumference  
= 75.2 divisions on the microscope

$$\frac{\pi \times 10^3}{180 \times 75.2} \text{ mr} = 1 \text{ division}$$

$$2.32 \text{ mr} = 10 \text{ divisions}$$

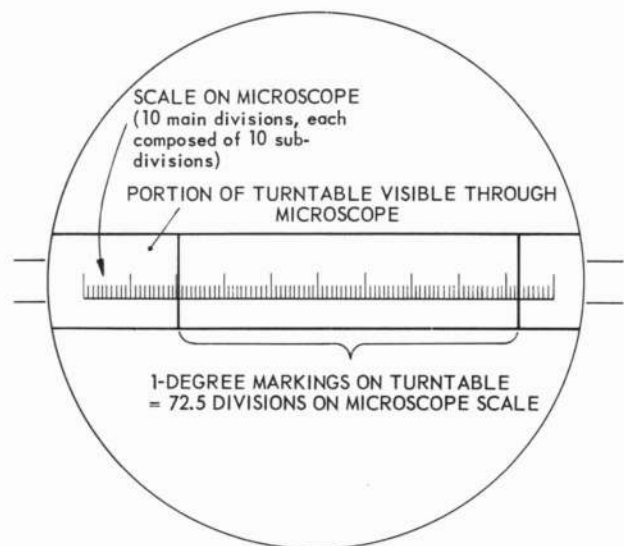


Fig. 8-13. View taken through the turntable microscope.

The foregoing analysis gives a basis upon which to read the angular displacements of the turntable. The main reference marks on the stationary microscope scale are 10 divisions apart. When a moving reference is spotted on the turntable while looking through the microscope and followed through 10 divisions on the microscope scale, the angular displacement of the turntable is 2.32 milliradians. This method is employed for low drift rates. For high drift rates, a division marking on the microscope scale is used as a stationary reference and two consecutive markings on the turntable are used as moving references. Observe the first of the two moving references as it passes the stationary reference of the microscope. When an identical portion of the next consecutive marking - that is, either a leading or a trailing edge - coincides with the stationary reference, an angle of 1 degree on the turntable has been passed through. For both methods, the time required for the angular interval to be traversed is clocked with a stop watch. The ratio of angular displacement to time yields the drift rate.

#### 8-44. MASS UNBALANCE ADJUSTMENTS WITHOUT EARTH-RATE EFFECT.

8-45. EXPLANATORY INFORMATION. With the reaction torques of the Microsyns and the flexible power leads effectively eliminated, there are two remaining torque-producing effects acting on the floated units assembly of the gyro unit. The first is the effect due to earth rate - that is, the angular velocity of the earth about its polar axis. The second is the effect of mass unbalance in the floated units assembly. By orienting the gyro unit with the input axis in an east-west position, the effect of earth rate is eliminated, leaving only the effect of mass unbalance. For the purpose of making the necessary adjustments to reduce the effect of mass unbalance, the two balance nuts on the floated units assembly that are accessible by means of balance-nut forks are employed. In the present procedure, the input axis lies in the horizontal plane and mass unbalance along this axis is minimized by adjusting the balance nut located along the positive direction of the input axis.

8-46. EQUIPMENT. In addition to the basic test setup, a stop watch is used.

#### 8-47. INITIAL CONDITIONS.

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on the turntable: spin reference axis vertical, input axis east-west.

#### 8-48. STEP-BY-STEP PROCEDURE.

- a. With the turntable axis in the horizontal position, mount the test block so that the spin reference axis is vertical and the input axis is in an east-west direction.
- b. Apply the indicated excitation.
- c. Energize the servo loop.
- d. Take a drift reading in accordance with the detailed procedure given in paragraph 8-43.
- e. If the drift exceeds the specification value, de-energize the servo loop and turn the balance nut on the input axis slightly. Observe the trace on the oscilloscope when turning the balance-nut fork. The fork will have made contact with the balance nut when a slight disturbance appears on the oscilloscope. Continued rotation of the fork will change the angular position of the trace.

#### Note

*The drift specification value will be determined by the particular application for which the gyro unit is intended.*

- f. After having turned the balance nut with the fork, back off up to 1/8 turn so that the nut will clear the fork at any position of the floated units assembly.
- g. Energize the servo loop and repeat steps d, e, and f until close balance (that is, as small a drift reading as possible) has been obtained.

#### 8-49. MASS UNBALANCE ADJUSTMENTS WITH EARTH-RATE EFFECT.

8-50. EXPLANATORY INFORMATION. Since the balance nuts are mounted on two perpendicular axes, it will be necessary to perform a second balance adjustment. In this procedure, the spin reference axis is horizontal and the input axis is vertical. This means that the effect of earth rate



will be present. Since it cannot be cancelled when the input axis is vertical, it must be incorporated into the null readings. That is, instead of attempting a minimum drift reading, it will now be necessary to attempt to make the turntable rotate with respect to its base at a rate equal and opposite to the component of earth rate along the gyro unit input axis. At a latitude of  $42^\circ$  North this component has a magnitude of about 0.05 milliradian per second. Total earth rate is about 0.0725 mr/sec.

8-51. **EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

8-52. **INITIAL CONDITIONS.**

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: input axis vertical, spin reference axis horizontal.

8-53. **STEP-BY-STEP PROCEDURE.**

- a. With the turntable axis in the vertical position, mount the test block so that the input axis is vertical and the spin reference axis is horizontal.
- b. Apply the indicated excitation.
- c. Energize the servo loop.
- d. Take a turntable-rate reading in accordance with the detailed procedure given in paragraph 8-43. The net drift in the counterclockwise direction (as viewed from above) is the measured turntable rate minus the magnitude of the earth rate component (about 0.05 mr/sec at latitude  $42^\circ$  North).

*Note*

*The local component of earth rate varies with latitude. For this reason, the component must be calculated for each location where these tests are being performed.*

- e. If the drift exceeds the specification value, de-energize the servo loop and turn the balance nut on the spin axis. Observe the trace on the oscilloscope when turning the balance-nut fork. The fork will have made contact with the balance nut when a slight disturbance appears on the oscilloscope. Continued rotation of the fork will change the angular position of the trace.

- f. After having turned the balance nut with the fork, back off up to  $1/8$  turn so that the nut will clear the fork at any position of the floated units assembly.

- g. Energize the servo loop and repeat steps d, e, and f until the drift is sufficiently close to the specification value.

8-54. **CROSS COUPLING.** There is a possibility that some cross coupling can occur during the two balance tests. This can happen when the threaded studs, to which the balance nuts are attached, are not precisely at right angles to each other. Another cause can be the fact that the balance nuts are not symmetrical. Therefore, the two balance-adjustment procedures should be repeated once again, in the same order as before.

8-55. **DETERMINATION OF THE EXCITATION CURRENT SQUARED - REACTION TORQUE SENSITIVITY OF THE SIGNAL GENERATOR.**

8-56. **EXPLANATORY INFORMATION.** Signal generator reaction torque is a function of the square of the current applied to the excitation winding of the signal generator. The variation of this torque with the square of the excitation current is determined by exciting the signal generator primary windings with various currents below and above the 125-milliampere value used in the procedure for selecting the signal generator quadrature resistor. The reaction torque causes the signal generator rotor to rotate from its null output voltage position and thus induce an output signal across the secondary windings of the signal generator. In turn, this output signal is amplified and fed into the servo motor stator. The servo motor rotates the turntable at a rate that will cause the signal generator rotor to return to its null position, through the operation of the gyro unit. The time interval required for a predetermined angular displacement of the turntable to take place is recorded twice for each excitation current on the primary windings. From these data, an average drift rate for each value of excitation current is calculated. Since this drift rate is directly proportional to the signal generator reaction torque that produced it, the manner in which the reaction torque varies with excitation current squared can be seen from a plot of drift rate versus excitation current squared.

8-57. **EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

8-58. **INITIAL CONDITIONS.**

- a. Signal generator excitation:  
50 to 150 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: output axis vertical downward, input axis horizontal in east-west direction.

*Note*

*When the gyro unit is mounted with its output axis vertical downward and its input axis horizontal in the east-west direction, any residual mass unbalance does not effect a rotation of the float about the output axis and earth rate will not affect the gyro unit.*

8-59. **STEP-BY-STEP PROCEDURE.**

- a. Mount the gyro unit on the turntable with its input axis parallel to the turntable axis.
- b. Orient the turntable assembly so that the turntable axis is horizontal and pointed geographically east-west.
- c. Apply indicated excitation to the gyro unit, with 50 ma to the signal generator primary by means of the signal generator excitation control and the signal generator excitation milliammeter (ref. Figs. 8-1 and 8-4).
- d. Energize the servo loop.
- e. For an angular displacement of 2.32 mr, measure the time interval, using the procedure of paragraph 8-43. Calculate the drift rate. Repeat and average the two values.
- f. Increase the current through the signal generator primary to 75, 100, 125, and 150 milliamperes, repeating step e for each value.
- g. Plot the average drift rate values obtained versus the associated values of the excitation current squared.

*Note*

*The drift rate is directly proportional to the signal generator reaction torque that produced it. The typical plot of average drift rate as a function of excitation current squared given in Fig. 8-14 shows that the sensitivity that is the subject of the present procedure is reasonably linear over the range of excitation currents applied. This plot is based on the typical data given in the next paragraph.*

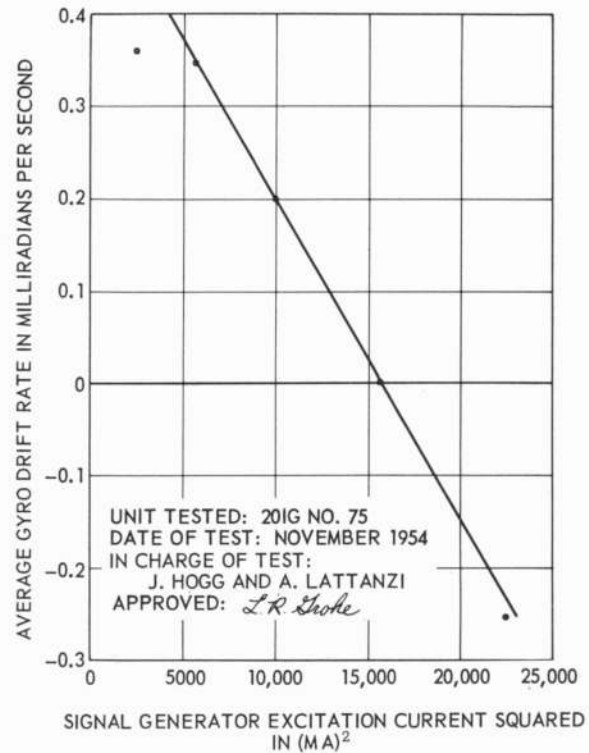


Fig. 8-14. Typical plot of average drift rate versus signal generator excitation current squared.

8-60. **TYPICAL TEST DATA.**

Signal Generator Excitation Current (ma)	Excitation Current Squared (ma) <sup>2</sup>	Turntable Angular Displacement (mr)	Time Required for Displacement (sec)	Drift Rate (mr/sec)	Average Drift Rate (mr/sec)
50	2500	+2.32 +2.32	6.5 6.4	+0.357 +0.363	+0.360
75	5625	+2.32 +2.32	6.6 6.7	+0.352 +0.346	+0.349
100	10,000	+2.32 +2.32	11.0 12.0	+0.211 +0.193	+0.202
125	15,625	(see paragraphs 8-28 through 8-32 on selecting the signal generator quadrature resistor)		<0.01	
150	22,500	-2.32 -2.32	9.0 9.4	-0.258 -0.247	-0.252

8-61. **DETERMINATION OF THE EXCITATION CURRENT SQUARED - REACTION TORQUE SENSITIVITY OF THE TORQUE GENERATOR.**

8-62. **EXPLANATORY INFORMATION.** By virtue of the design of a Microsyn torque generator, the reaction torque is directly proportional to the square of the excitation current. In an earlier procedure, the various reaction torques of the gyro unit were "bucked out" by means of a compensating resistance, so that a state of equilibrium now exists insofar as

these reaction torques are concerned. However, this equilibrium is in effect only for the particular value of excitation current employed when the value of the compensating resistance was determined. In the present procedure, the excitation current through the torque generator primary windings is varied below and above the value previously used in compensating for the reaction torques.

8-63. As the excitation current is varied, a change in position of the torque generator rotor is produced. Since the torque generator rotor and the signal generator rotor are on the same shaft, the signal generator produces an output signal that is fed to the servo motor of the turntable. Via the gyroscopic action within the gyro unit, the turntable rotation nulls the signal generator output signal. The turntable then turns at a drift rate determined by the torque generator reaction torque. It follows that as the difference between the applied excitation current and the original equilibrium excitation current is made greater, the drift rate will increase. Since the drift rate is directly proportional to the reaction torque that caused it, the drift rate values obtained can be used to determine the nature of the excitation current squared - reaction torque sensitivity of the torque generator.

8-64. **EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

8-65. **INITIAL CONDITIONS.**

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation current:  
Variable (10 - 120 ma at 400 cps for the 20IGa; 5 - 15 ma d-c for the 20IGb).
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: output axis vertical, input axis in east-west direction.

8-66. **STEP-BY-STEP PROCEDURE.**

- a. Mount the gyro unit on the turntable as in the previous procedure (ref. paragraph 8-59, steps a and b).
- b. Apply the indicated excitation to the gyro unit.
- c. Energize the servo loop.

d. Introduce various excitations through the torque generator primary windings by adjusting the torque generator excitation control (ref. Fig. 8-4) and reading the output on the torque generator excitation milliammeter (ref. Figs. 8-1 and 8-4).

e. Record the time interval elapsed during which the turntable travels through a predetermined angular displacement, using the procedure of paragraph 8-43.

f. Calculate the drift rates and average the two values obtained for each value of excitation current used.

g. Plot the average drift rates versus the associated value of the torque generator excitation current squared.

**Note**

*Since the drift rate is directly proportional to the reaction torque that caused it, the plot also represents the variation of the reaction torque with the square of excitation current. Figure 8-15 is a plot of this nature, based on the typical data given in the next paragraph.*

**8-67. TYPICAL TEST DATA (for an alternating-current-excited torque generator).**

Torque Generator Excitation Current (ma)	Excitation Current Squared (ma) <sup>2</sup>	Angle	Time (sec)	Drift Rate (mr/sec)	Average Drift Rate (mr/sec)
10	100	-1°	43.3	-0.40	-0.41
			41.5	-0.42	
20	400	-1°	42.9	-0.41	-0.40
			45.2	-0.39	
30	900	-1°	48.0	-0.36	-0.37
			46.5	-0.38	
40	1600	-1°	54.2	-0.32	-0.32
			54.0	-0.32	
50	2500	-1°	64.7	-0.27	-0.27
			64.9	-0.27	
60	3600	-2.32 mr	9.9	-0.23	-0.23
			10.7	-0.22	
70	4900	-2.32 mr	13.0	-0.18	-0.18
			14.0	-0.17	
80	6400	-2.32 mr	22.8	-0.10	-0.12
			18.5	-0.13	
90	8100	-2.32 mr	39.0	-0.06	-0.07
			34.5	-0.07	
100	10,000	+2.32 mr	126.1	+0.02	+0.03
			92.3	+0.03	
110	12,100	+2.32 mr	23.4	+0.10	+0.10
			25.3	+0.10	
120	14,400	+2.32 mr	13.9	+0.17	+0.18
			12.7	+0.18	

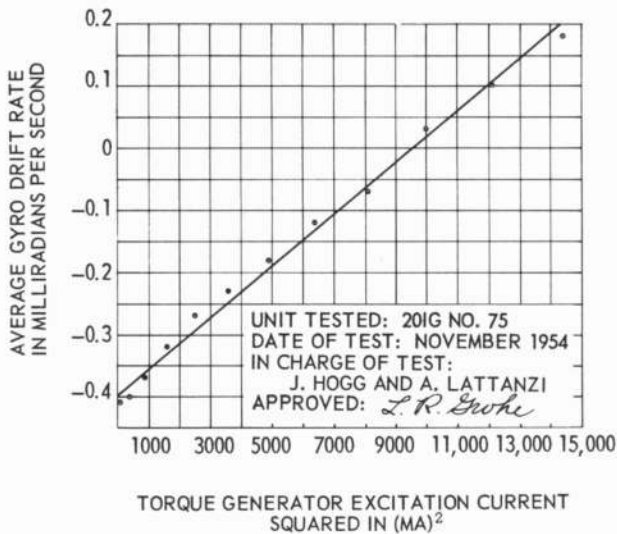


Fig. 8-15. Typical plot of average drift rate versus torque generator excitation current squared.

8-68. DETERMINATION OF THE ANGLE - TORQUE SENSITIVITY OF THE ELASTIC-RESTRAINT-PRODUCING COMPONENTS.

8-69. EXPLANATORY INFORMATION. With the output axis vertical, so that there is no torque due to mass unbalance, and with the reaction torques of the Microsyn units and the flexible power leads "bucked out" by appropriate compensating resistance, there should be very little gyro drift at the signal generator null. When the signal generator is not at null, the elastic restraint torque can either hinder or aid the rotational motion of the floated units assembly. The torque hinders when the leads are winding up (elastic energy being stored up), and aids when the leads are unwinding (elastic energy being released). Elastic restraint torque thus varies with the angular displacement of the floated units assembly.

8-70. Used in this test is a piece of equipment known as the Dummy Director. This is actually another Microsyn signal generator connected series aiding with the existing one in the gyro unit. It must first be calibrated in terms of millivolts per scale divisions. Instructions for accomplishing this are included in the present procedure. Figure 8-16 shows the primary and secondary windings of both the Dummy Director and the gyro signal generator connected series aiding. Figure 8-17 shows how this circuit is connected into the basic test setup.

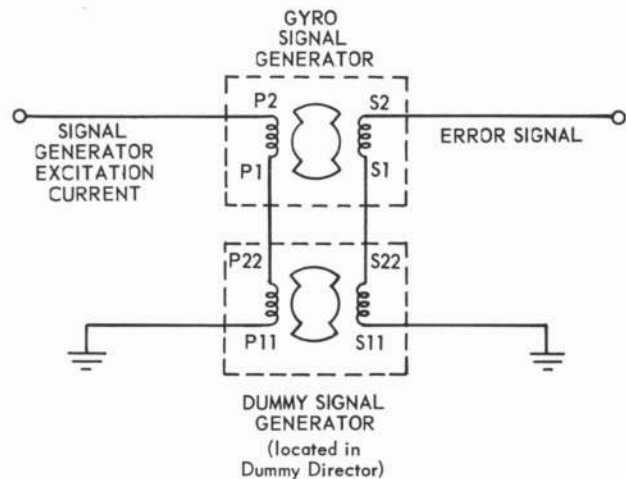


Fig. 8-16. Series winding connections of the dummy signal generator and the gyro signal generator.

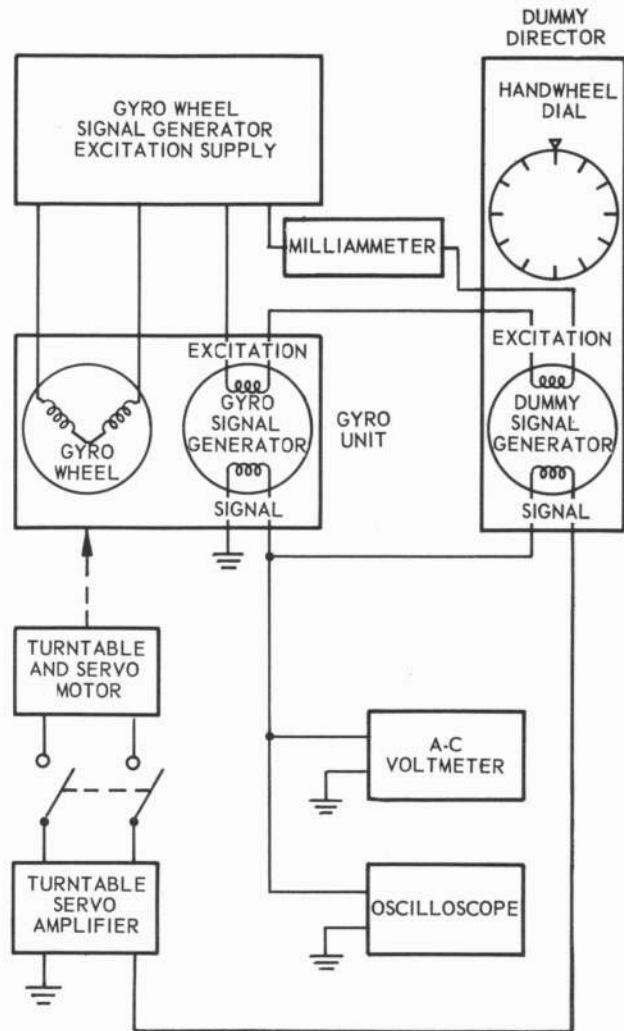


Fig. 8-17. Dummy signal generator circuit.

8-71. Initially, the two rotors are not necessarily in the same relative position. Although the stator field of the Dummy Director is changed with the rotation of its rotor, the current thus induced into the secondary windings is too low to affect the position of the signal generator rotor. Instead, a small error signal, produced by the relative displacement of the two rotors, is fed through the servo loop. The turntable rotates in a direction that drives the signal generator rotor into coincidence with the Dummy Director rotor. The position of the signal generator rotor can thus be controlled by positioning the Dummy Director rotor.

8-72. **EQUIPMENT.** In addition to the basic test setup, a Dummy Director and a stop watch are used.

8-73. **INITIAL CONDITIONS.**

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: output axis vertical, input axis in east-west direction.

*Note*

*When the gyro unit is mounted with its output axis vertical and its input axis horizontal in the east-west direction, the position of the balance nuts does not create any torque about the output axis and earth rate will not affect the gyro unit.*

8-74. **STEP-BY-STEP PROCEDURE.**

- a. Mount the gyro unit on the turntable with its output axis vertical and its input axis in the east-west direction.
- b. Connect the Dummy Director in series with the signal generator in the gyro unit. See Figs. 8-16 and 8-17 for details.
- c. Apply the indicated excitation to the gyro unit.
- d. Turn the control on the Dummy Director until a null is observed as a horizontal line on the oscilloscope.

*Note*

*The oscilloscope and the associated voltmeter remain connected to the excitation and output terminals of the signal generator as shown in Fig. 8-10.*

- e. Turn the Dummy Director control in turn to both stops. That is, so that the maximum angular pattern is obtained on the oscilloscope.

- f. Record the number of divisions from null for both conditions as indicated on the dummy signal generator dial. Also record the millivolt readings associated with the stop positions.

- g. Add both millivolt readings, and divide by the sum of the divisions. This gives a scale calibration number of X mv/div. The reason for the calibration number is to enable the testing technician to introduce known values of voltage, which in turn can be converted to angular displacement of the floated units assembly by using the signal generator sensitivity in mv/mr. For example, suppose the calibration number were 8 mv/div, and a rotation of 300 scale divisions were introduced. The result would be a 2400 mv output. Thus, for a typical signal generator sensitivity of about 22 mv/mr, the angular displacement of the signal generator rotor would be:

$$\frac{2400}{22} = 109.1 \text{ mr}$$

- h. Choose equal multiples of division inputs, beginning with the null position, and going in both directions.

- i. Energize the servo loop.

- j. View the angular displacement of the turntable and clock the time required for the angular displacement, using the procedure of paragraph 8-43.

- k. Calculate the angular velocity of the turntable - that is, the drift rate - in milliradians/second for each angular displacement of the floated units assembly.

- l. Plot the drift rate versus the output voltage of the Dummy Director signal generator.

*Note*

*The angular displacement of the floated units assembly from its reference position is directly proportional to the output voltage of the Dummy Director signal generator. Therefore, the plot will represent the drift rate due to elastic restraint torque as a function of angular displacement of the floated units assembly from its reference position. Since the drift rate is directly proportional to the torque that caused it, the figure also represents the angle-torque sensitivity of the gyro unit's elastic-restraint-producing components. Figure 8-18, based on the typical data of the following paragraph, gives a plot showing how the drift rate due to flex lead reaction torque varies with the output voltage of the Dummy Director signal generator.*

### 8-75. TYPICAL TEST DATA.

Divisions from Null Position	Output Voltage of the Dummy Director Signal Generator (mv)	Turntable Angle	Time (sec)	Drift Rate (mr/sec)	Average Drift Rate (mr/sec)
200	1752	+1°	8.3 8.8	2.102 1.983	2.043
150	1314	+1°	13.6 13.9	1.283 1.255	1.269
100	876	+1°	24.7 24.4	0.706 0.715	0.711
75	657	+1°	37.6 36.0	0.464 0.485	0.475
50	438	+1°	69.8 72.3	0.250 0.241	0.246
40	350.4	+2.32 mr	12.5 11.0	0.186 0.211	0.199
30	262.8	+2.32 mr	18.4 14.7	0.126 0.158	0.142
20	175.2	+2.32 mr	30.8 25.7	0.075 0.090	0.083
10	87.6	+2.32 mr	66.8 61.9	0.035 0.037	0.036
0	0	stopped			
10	87.6	-2.32 mr	34.0 34.3	-0.068 -0.068	-0.068
20	175.2	-2.32 mr	18.8 20.7	-0.123 -0.112	-0.118
30	262.8	-2.32 mr	12.8 13.1	-0.181 -0.177	-0.179
40	350.4	-2.32 mr	9.4 9.8	-0.247 -0.237	-0.242
75	657	-1°	36.0 35.3	-0.485 -0.494	-0.490
100	876	-1°	24.1 24.8	-0.724 -0.704	-0.714
150	1314	-1°	13.0 13.0	-1.34 -1.34	-1.34
200	1752	-1°	6.0 6.2	-2.91 -2.81	-2.86

### 8-76. DETERMINATION OF THE ANGULAR VELOCITY - VOLTAGE RATE SENSITIVITY OF THE GYRO UNIT.

8-77. EXPLANATORY INFORMATION. A gyro unit senses a given angular velocity input about its input axis, and responds in such a manner as to produce a torque on the floated units assembly about its output axis. This torque is theoretically proportional to the input angular velocity. In equation form, this phenomenon is represented by

$$M_{(out)} = H W_{(in)}$$

where

$$M_{(out)} = \text{output torque, in dyne-cm}$$

$$H = \text{angular momentum of rotor, in } \frac{\text{gm-cm}^2}{\text{sec}}$$

$$W_{(in)} = \text{input angular velocity, in rad/sec.}$$

8-78. The signal generator rotor is fixed with respect to the output shaft, and undergoes a rate of angular displacement that is proportional to the output torque. With the signal generator windings excited, the flux distribution in the secondary windings will change because of the angular rotation of the signal generator rotor. Thus the voltage across the secondary windings of the signal generator is changing with time at a rate proportional to the magnitude of the input angular velocity.

8-79. Angular velocity inputs are applied to the gyro unit about its input axis by means of the rate table shown in Fig. 8-1. The corresponding voltage rate output of the gyro unit (the rate of change of the voltage output from the Microsyn signal generator) is determined as follows. The data obtained in the flex lead reaction torque - gimbal angle sensitivity test showed that the output voltage across the secondary windings was 1780 millivolts at each stop position, or a total voltage range of 3560 millivolts. For convenience, the first voltage range used in the test is 3000 millivolts, or 3 volts. An indicated voltage across the secondary windings of 1.5 volts will insure that the rotor is near a stop. If the rotation of the turntable is reversed, the needle of the voltmeter will drop to zero or the null position and then start climbing back up again. When 1.5 volts is reached, the rotor is near the opposite stop and a voltage range of 3 volts has been covered. The time consumed for the voltmeter to drop from 1.5 volts to zero and back up to 1.5 volts is recorded in order to find the voltage-rate output. The procedure is repeated, with the rotor turning progressively through smaller angular positions and with progressively smaller rates of angular velocities applied via the rate table.

8-80. EQUIPMENT. In addition to the basic test setup, a stop watch and a C-clamp are used.

### 8-81. INITIAL CONDITIONS.

- a. Signal generator excitation:  
125 ma at 400 cps.

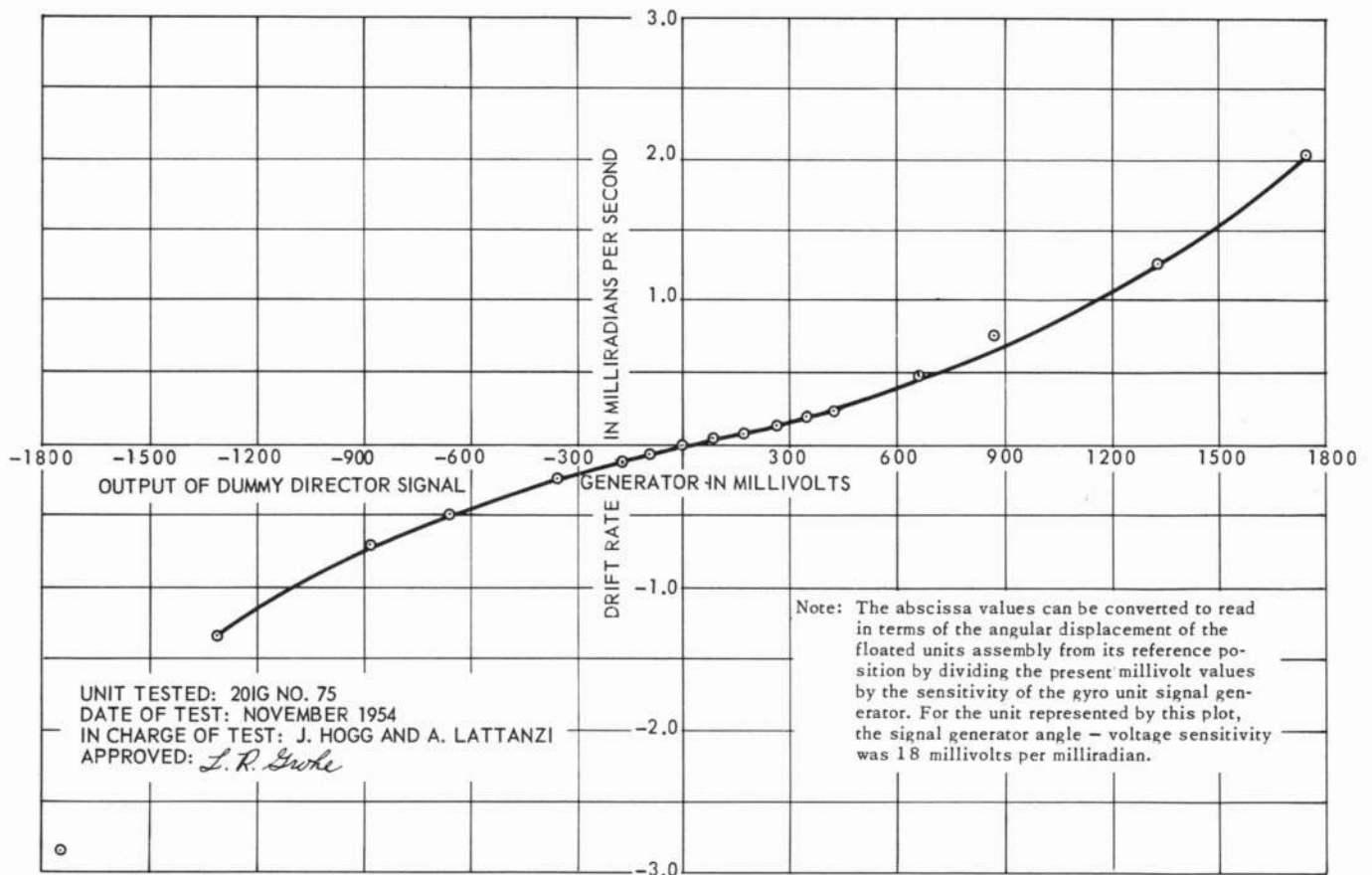


Fig. 8-18. Typical plot of drift rate due to flex lead reaction torque versus the output voltage of the Dummy Director signal generator.

- b. Torque generator excitation:
  - 100 ma at 400 cps for the 20IGA
  - 10 ma d-c for the 20IGb.
- c. Wheel excitation:
  - 0.2 amp/phase at 400 cps for the 20IGA
  - 0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on the turntable: input axis vertical.

*Note*

The gyro unit is mounted in this position in order to receive various angular velocity inputs that are supplied by the rate table (ref. Fig. 8-1).

**8-82. STEP-BY-STEP PROCEDURE.**

*Note*

Leave the servo loop de-energized throughout the present procedure.

- a. Set the voltmeter at its 3.0-volt full-scale range and zero the needle at midscale. (The voltmeter remains connected in the arrangement shown in Fig. 8-10.)

- b. Apply the indicated excitation to the gyro unit.

- c. Rotate the turntable manually, so that the rotor is near a stop. A reading of 1.5 volts will insure that the rotor is near a stop.

- d. Clamp the turntable to the circular plate below it with the C-clamp in order that there be no relative motion between the gyro unit and the overall turntable assembly.

- e. By means of the rate table, introduce an angular velocity to the gyro unit. Begin with the highest rate obtainable.

- f. Start the stop watch when the needle on the voltmeter drops to 1.5 volts. Stop the watch when the needle reads 1.5 volts again but at the opposite end of the scale.

- g. Drive the voltmeter needle off scale, in the direction of its last approach, by setting the range selector of the voltmeter to the 0.3-volt position.

- h. Stop the rate table and reverse its direction of rotation.

- i. Return the range selector to the 3.0-volt position.

- j. Repeat steps f and g.
- k. Stop the rate table.
- l. The next voltage interval is 2 volts. This can best be read on the 1.0-volt scale.
- m. Introduce, by means of the rate table, the next highest angular velocity available.
- n. Record the time interval for the needle to pass from 1.0 to 0, then to 1.0 on the opposite side of the scale.
- o. Drive the needle off scale by turning the selector now to the 0.1-volt position.
- p. Stop and reverse the rate table.
- q. Return the selector to the 1.0-volt position.
- r. Repeat steps n and o.
- s. Continue the procedure by reducing the rate and the full-scale deflection range. Typical values are 500, 250, 120, 60 and 30 millivolts. When the 30-millivolt full-scale range is reached, continue to introduce lower angular velocities until the entire range of the rate table is exhausted.

**8-83. TYPICAL TEST DATA.**

Angular Velocity Input (mr/sec)	Direction of Angular Velocity Input	Voltage Range (mv)	Time (sec)	Voltage Rate (mv/sec)	Average Voltage Rate (mv/sec)
104.72	+	3000	3.3	909.09	909.09
	-		3.3	909.09	
52.36	+	2000	4.4	454.55	454.55
	-		4.4	454.55	
26.18	+	1000	4.4	227.27	227.27
	-		4.4	227.27	
13.09	+	500	4.5	111.11	113.70
	-		4.3	116.28	
6.545	+	250	4.3	58.14	57.48
	-		4.4	56.82	
3.272	+	120	4.2	28.57	28.57
	-		4.2	28.57	
1.636	+	60	4.2	14.29	14.65
	-		4.0	15.00	
0.818	+	30	4.1	7.32	7.23
	-		4.2	7.14	
0.409	+	30	8.5	3.53	3.74
	-		7.6	3.94	
0.2045	+	30	17.2	1.74	1.89
	-		14.8	2.03	
0.1023	+	30	39.3	0.76	0.90
	-		29.2	1.03	
0.0511	+	30	116.0	0.26	0.41
	-		53.6	0.56	
0.0255	+	30	420.6	0.07	0.21
	-		89.5	0.34	

**Note**

The above data is plotted in Figs. 8-19 and 8-20.

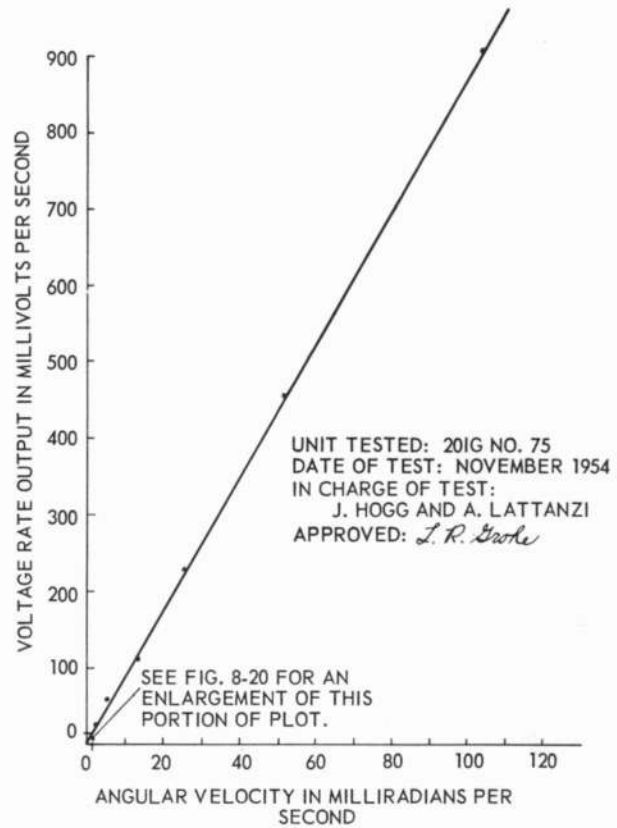


Fig. 8-19. Typical plot of voltage rate output versus angular velocity input.

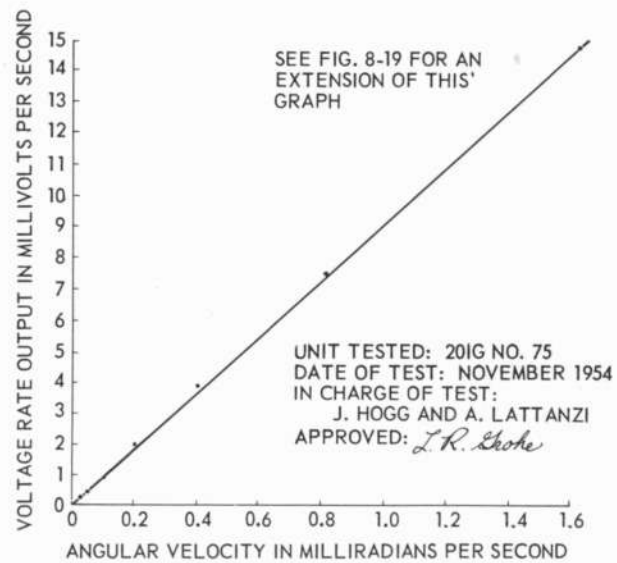


Fig. 8-20. Enlargement of the low-voltage-rate region of the plot given in Fig. 8-19.

**8-84. DETERMINATION OF THE CURRENT SQUARED - VOLTAGE RATE SENSITIVITY OF THE GYRO UNIT.**

**8-85. EXPLANATORY INFORMATION.** By virtue of its design, a Microsyn torque generator produces



an output torque that is directly proportional to the product of the current flowing through its signal circuit and the current flowing through its excitation circuit. In the present procedure, these two circuits are connected in series, so that the output torque produced by the torque generator is directly proportional to the square of the common current flowing through the series-connected windings of the torque generator. The floated units assembly rotates as a result of the applied torque at a rate that is directly proportional to the torque, which in turn is directly proportional to the signal current squared. The resulting rate of change of voltage output from the signal generator can be determined for each value of current applied by the means used in the previous procedure.

8-86. An oscilloscope is used to view the direction of rotation of the signal generator rotor. It is most useful to assign a plus or minus designation to the direction of rotor rotation because the signal-circuit windings of the torque generator are interchanged for the purpose of obtaining two voltage-rate readings for the same input current. In the test data obtained, a plus direction means a clockwise rotation (looking along the positive direction of the output axis).

8-87. In previous procedures, a compensating resistance was placed across the appropriate terminals of the torque generator for the purpose of bucking out any reaction torque and thereby reducing drift. With the series connection used in the present procedure, however, it is not possible to use the compensating resistance and at the same time have the full input current flowing through all the windings. The effect of gyro drift is therefore very noticeable, especially for small current inputs to the torque generator. Since gyro drift is present during this procedure, it will aid, as can be seen from the data, when the signal generator rotor is driven in the negative direction and hinder when the rotor is driven in the positive direction. The procedure is at an end when it becomes evident that gyro drift is predominating.

8-88. **EQUIPMENT.** In addition to the basic test setup, a stop watch is required.

#### 8-89. INITIAL CONDITIONS.

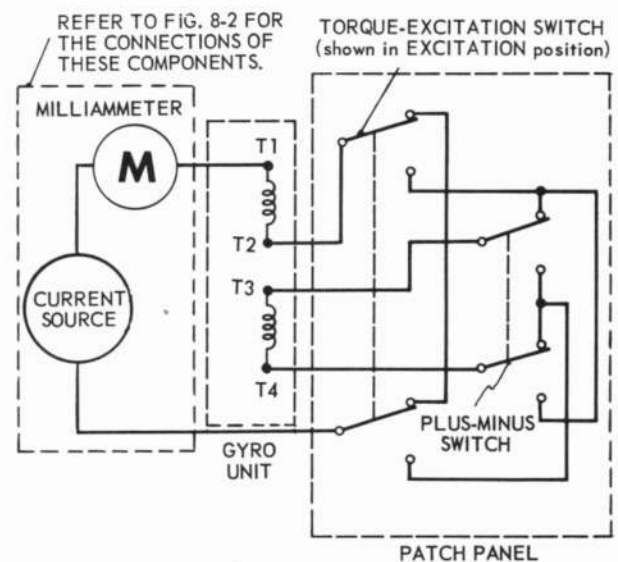
- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation: Variable (1 - 10) ma at 400 cps for 20IGa; 0.1 - 1 ma for the 20IGb; primary and secondary windings in series in each case.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: input axis vertical.

#### 8-90. STEP-BY-STEP PROCEDURE.

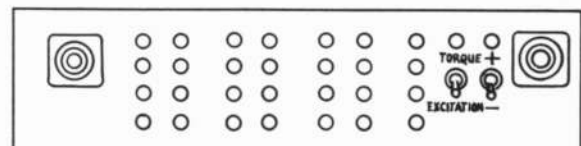
*Note*

*Leave the servo loop de-energized throughout the present procedure.*

- a. Connect the milliammeter, torque generator windings, and the current source in series as shown in Fig. 8-21. Put the windings in series by placing the TORQUE-EXCITATION switch on the patch panel at the top of the test console in the TORQUE position.



a) Schematic diagram of the wiring connections



b) Pictorial diagram of the patch panel on the test console

Fig. 8-21. External connections to the torque generator windings.

b. For an a-c type of torque generator, introduce a current of 10 milliamperes at 400 cps to the torque generator windings. If a d-c type of torque generator is used, apply 1 milliamperes d-c.

c. Record the time taken for the needle on the voltmeter to travel 1000 millivolts.

d. Reverse the current through the torque generator signal-circuit windings by interchanging the connections to terminals T3 and T4. This is accomplished by reversing the position of the PLUS - MINUS switch, which is also located on the test console patch panel.

e. Repeat step c as the signal generator rotor reverses direction.

f. Repeat the above procedure with progressively smaller input currents.

**Note**

*The voltage range used is a matter of judgment.*

**8-91. TYPICAL TEST DATA (for an alternating-current-excited torque generator).**

Torque Generator Input Current (ma)	Input Current Squared (ma) <sup>2</sup>	Direction of Rotation	Voltage Range (mv)	Time (sec)	Voltage Rate (mv/sec)	Current Squared - Voltage Rate Sensitivity (mv/sec) / (ma) <sup>2</sup>	Average Value of Sensitivity (mv/sec) / (ma) <sup>2</sup>	
10	100	+ -	1000	29.0 23.8	34.48 42.02	0.35 0.42	0.39	
9	81	+ -	1000	37.5 27.9	26.67 35.84	0.33 0.36	0.35	
8	64	+ -	500	24.1 17.5	20.75 17.14	0.32 0.27	0.30	
7	49	+ -	200	13.4 8.6	14.93 23.25	0.30 0.47	0.39	
6	36	+ -	200	20.7 11.0	9.66 18.18	0.27 0.51	0.39	
5	25	+ -	200	37.6 14.4	5.32 1.39	0.21 0.56	0.39	
4	16	+ -	200	108.5 18.6	1.84 11.07	0.12 0.69	0.41	
3.5	12.25	+ -	100	288.3 11.1	0.35 9.01	0.03 0.74	0.39	
2.0	9	+ -	No readings were taken below 3.5 milliamperes because at this current input the reaction torque and the resulting drift is beginning to predominate.					
2.5	6.25	+ -						
1.0	1.0	+ -						

**8-92. DETERMINATION OF THE CURRENT SQUARED - ANGULAR VELOCITY SENSITIVITY RATIO OF THE GYRO UNIT.**

**8-93. EXPLANATORY INFORMATION.** In the present procedure, the signal and excitation circuits of the torque generator remain connected in series as in the previous procedure. When various input currents are applied in turn to the torque generator, the resulting voltage output from the signal generator is used to drive the turntable via the servo loop. For each value of input current applied to the torque generator, there is a corresponding steady-state value of turntable angular velocity that - through gyroscopic action - provides a torque on the floated units assembly that exactly counterbalances the torque output of the torque generator. Ideally, the ratio of the angular velocity of the turntable to the associated current squared input should remain constant. This ratio is known as the current squared - angular velocity sensitivity ratio. The present procedure is used to determine how closely this ratio for an actual gyro unit matches the ideal performance. As in the previous procedure, the connections to the signal circuit of the torque generator are reversed for each value of input current. This allows the effects of earth rate and gyro drift to be removed from the determination of the sensitivity ratio values.

**8-94. EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

**8-95. INITIAL CONDITIONS.**

a. Signal generator excitation:

125 ma at 400 cps.

b. Torque generator excitation: Variable (0 - 100 ma at 400 cps for the 20IGa; 0 - 10 ma d-c for the 20IGb; series connected in each instance).

c. Wheel excitation:

0.2 amp/phase at 400 cps for the 20IGa

0.6 amp/phase at 400 cps for the 20IGb.

d. Position of gyro unit on turntable: input axis vertical upwards.

**8-96. STEP-BY-STEP PROCEDURE.**

a. Place the test block on the turntable so that the input axis of the gyro unit is vertical upwards.

b. Leave the voltmeter, oscilloscope and torque generator windings connected as in the previous procedure.

c. Apply the indicated excitation to the gyro unit.

d. Adjust the torque generator excitation control so as to supply an input current of 100 milliamperes to the torque generator. (10 ma d-c for a d-c type of torque generator.)

e. Energize the servo loop.

f. Record the time interval elapsed during which the turntable rotates 360 degrees.

g. De-energize the servo loop.

h. Interchange the connections to terminals T3 and T4.

i. Repeat steps e and f.

j. Repeat the above procedure, introducing input currents from 80 ma down to 0.5 ma. Note that a d-c type of torque generator requires much less current, actually a maximum of 10 ma. Record the time interval elapsed for a suitable angular displacement of the turntable. Note that two time intervals are recorded, one for each direction of rotation of the turntable. Correct the indicated angular velocity for earth rate and drift rate components.

k. The method of correcting for earth rate and drift rate is to remove them from the measurements insofar as possible by taking the average of two angular velocity magnitudes measured with the same torque generator currents but with the current in one torque generator circuit reversed for the second measurement. (Since the angular velocities for the two directions will probably be measured by taking time intervals over equal angle increments, it is important to point out that the average angular velocity magnitude is the average of the angular velocities, not the angular increment divided by the average of the two time intervals.)

l. Divide the corrected angular velocity by the square of the input current to obtain values of the current squared - angular velocity sensitivity ratio.

#### 8-97. TYPICAL TEST DATA (for an a-c type of torque generator).

*Note*

*A plot of the current squared - angular velocity sensitivity ratio versus input current squared, based on the following data, appears in Fig. 8-22.*

Torque Generator Input Current (ma)	Input Current Squared (ma) <sup>2</sup>	Direction of Rotation about IA	Time (sec)	Angle	Angular Velocity (mr/sec)	Current Squared - Angular Velocity Sensitivity Ratio (mr/sec) / (ma) <sup>2</sup>	Average Sensitivity Ratio (mr/sec) / (ma) <sup>2</sup>
100	10,000	+	15.5	360°	405	0.0405	0.0405
		-	15.5	360°	405	0.0405	
80	6,400	+	24.0	360°	262	0.0409	0.0409
		-	24.0	360°	262	0.0409	
60	3,600	+	22.0	180°	143	0.0398	0.0401
		-	21.7	180°	145	0.0403	
40	1,600	+	24.8	90°	63.4	0.0396	0.0399
		-	24.5	90°	64.1	0.0400	
20	400	+	33.8	30°	15.5	0.0388	0.0398
		-	32.2	30°	16.3	0.0408	
10	100	+	48.7	10°	3.58	0.0358	0.0356
		-	49.4	10°	3.54	0.0354	
5	25	+	31.4	1°	0.56	0.0224	0.0392
		-	12.0	1°	1.45	0.0560	
1	1	-	34.6	1°	0.51	0.51	0.06
		-	44.8	1°	0.39	0.39	
0.5	0.25	-	5.3	2.32 mr	0.44	1.76	0.04
		-	5.0	2.32 mr	0.46	1.84	
0 (before run)		-	39.4	1°	0.44		
0 (after run)		-	39.9	1°	0.44		

#### 8-98. DETERMINATION OF THE BASE ANGULAR VELOCITY - CONTROLLED MEMBER ANGULAR VELOCITY SENSITIVITY RATIO OF THE GYRO UNIT.

8-99. EXPLANATORY INFORMATION. The present procedure is performed by introducing a known angular velocity to the turntable assembly (ref. Fig. 8-1) and observing the resulting angular velocity of the turntable when the servo loop is energized. The rate table is used to provide the known input angular velocity. It is calibrated over a wide range of angular rates. The turntable assembly is placed on the rate table so that the turntable axis is vertical and coincides with that of the rate table. The gyro unit is placed on the turntable so that its input axis is also vertical.

8-100. With the gyro unit energized, the servo loop closed, and the rate table rotating the turntable assembly, the output signal from the signal generator will energize the servo motor. The turntable will then rotate with respect to the rate table (and the rest of the turntable assembly), but in the opposite direction. In the absence of mass unbalance, friction and reaction torques, and other drift-producing effects, the angular velocity of the turntable (called the controlled member angular velocity) would equal the angular velocity of the

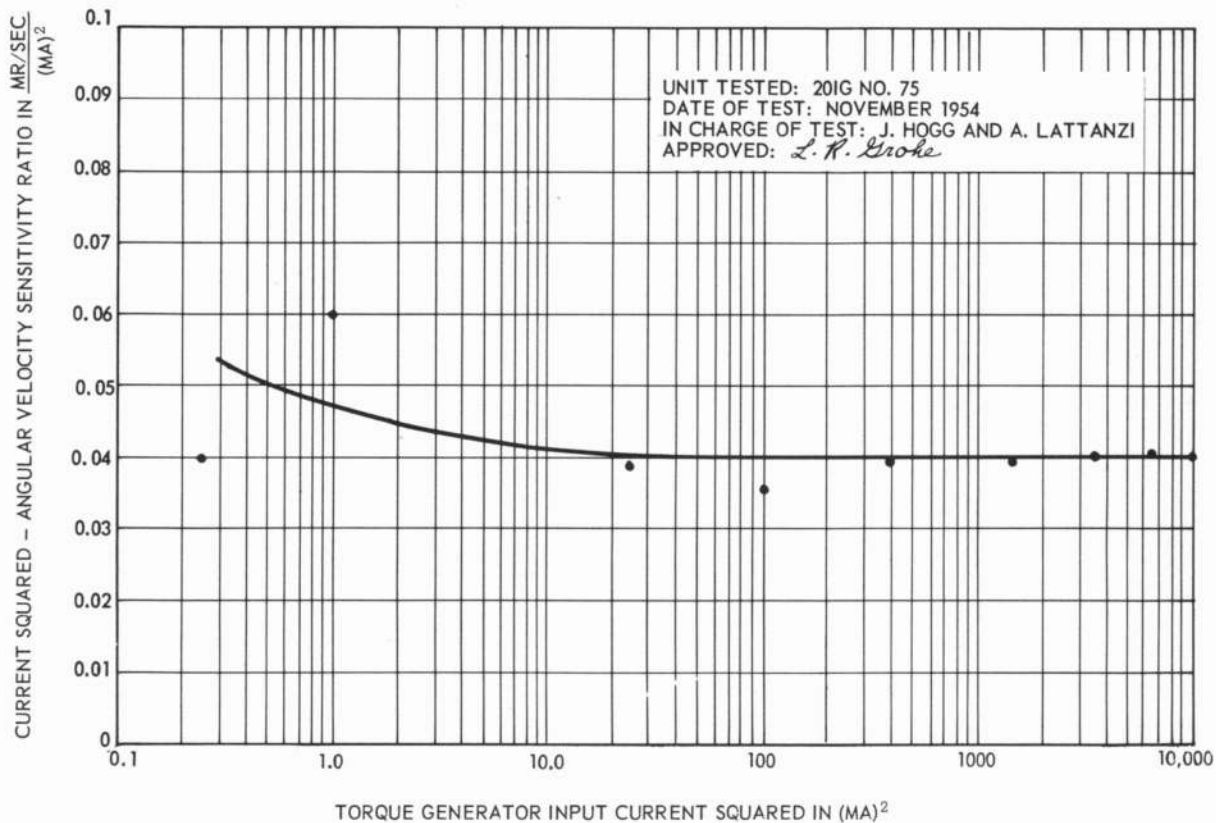


Fig. 8-22. Typical plot of current squared - angular velocity sensitivity ratio versus torque generator input current squared.

rate table (called the base angular velocity). Since these effects are always present, the base angular velocity - controlled member angular velocity ratio will never equal 1.00 unless the various drift components happen to cancel each other.

8-101. **EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

8-102. **INITIAL CONDITIONS.**

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: input axis vertical upward.

8-103. **STEP-BY-STEP PROCEDURE.**

- a. Place the test block on the turntable so that the gyro unit input axis is vertical upward. In

this position, the gyro will receive as an input a component of the earth's angular velocity.

- b. Apply the indicated excitation to the gyro unit.

- c. Energize the servo loop.

- d. Adjust the compensating resistance across the torque generator terminals to reduce the gyro drift due to the torque generator reaction torque, using the procedure of paragraph 8-42.

- e. Give the rate table an angular velocity equal to 418.88 milliradians per second (the maximum angular velocity of the rate table).

- f. Record the time interval elapsed during which the rate table moves through an angle (equal to about 100 degrees) with respect to the turntable. This is done by using as references division marks on the turntable and observing them through the microscope.

- g. Reverse the direction of rotation of the rate table, using the same rate.

- h. Repeat step f.

- i. Repeat steps e through h for reduced rates of the rate table, until the lowest rate obtainable

has been used. In order to keep the elapsed times to a reasonable figure, reduce the observed angular displacement as the rates are lowered.

**8-104. TYPICAL TEST DATA.**

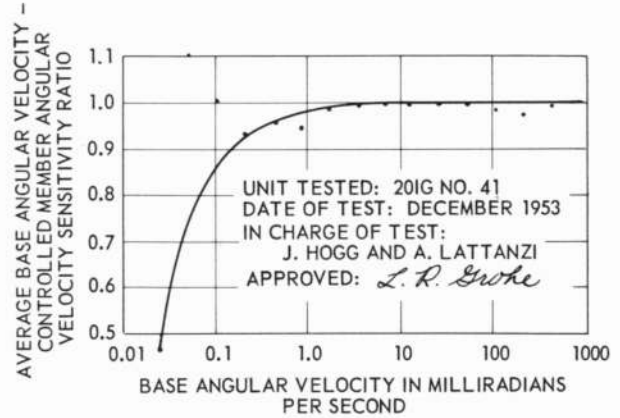
Base Angular Velocity (mr/sec)	Direction of Rotation about IA	Time (sec)	Angle	Controlled Member Angular Velocity (mr/sec)	Average Controlled Member Angular Velocity (mr/sec)	Average Base Angular Velocity - Controlled Member Angular Velocity Sensitivity Ratio
418.88	+	3.73	90°	422.0	417	0.996
	-	3.82		412.0		
209.44	+	7.66	90°	205.0	205.5	0.972
	-	7.78		202.0		
104.72	+	15.25	90°	103.0	103.00	0.984
	-	15.25		103.0		
52.36	+	29.72	90°	52.8	52.45	0.998
	-	30.22		52.1		
26.18	+	60.20	90°	26.1	26.1	0.997
	-	60.18		26.1		
13.09	+	40.02	30°	13.08	13.06	0.998
	-	40.15		13.05		
6.545	+	80.32	30°	6.53	6.545	1.000
	-	79.90		6.56		
3.272	+	53.92	10°	3.23	3.26	0.998
	-	53.23		3.28		
1.636	+	54.63	5°	1.598	1.616	0.987
	-	53.42		1.633		
0.818	+	22.88	1°	0.762	0.774	0.947
	-	22.20		0.787		
0.4090	+	46.55	1°	0.375	0.392	0.958
	-	42.70		0.409		
0.2045	+	13.05	2.32	0.1780	0.1915	0.937
	-	11.35	mr	0.205		
0.1023	+	23.00	2.32	0.1008	0.1052	1.026
	-	21.18	mr	0.1095		
0.0511	+	52.58	2.32	0.0442	0.0572	1.120
	-	33.10	mr	0.0702		
0.0256	+	262.72	2.32	0.0082	0.0112	0.437
	-	162.96	mr	0.0142		

**Note**

A typical plot of base angular velocity - controlled member angular velocity sensitivity ratio versus base angular velocity, based on the above data, appears in Fig. 8-23.

**8-105. DETERMINATION OF THE GRAVITY-SENSITIVE DRIFT RATE, COMPENSATED AND UNCOMPENSATED.**

**8-106. EXPLANATORY INFORMATION.** The purpose of this procedure is to make a final check of the gravity-sensitive component of the gyro drift rate, both with and without the aid of the compensating resistance used in the excitation circuit of the torque generator. The spin reference axis is placed in the vertical direction. The effect of earth



**Fig. 8-23. Typical plot of base angular velocity - controlled member angular velocity sensitivity ratio versus base angular velocity.**

rate is eliminated by placing the input axis in the east-west direction.

**8-107. EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

**8-108. INITIAL CONDITIONS.**

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: spin reference axis vertical, input axis in the east-west direction.

**8-109. STEP-BY-STEP PROCEDURE.**

- a. Mount the test block on the turntable so that the spin reference axis is vertical, and the input axis is in the east-west direction.
- b. Apply the indicated excitation to the gyro unit.
- c. Energize the servo loop.
- d. Record the time necessary for the turntable to rotate one degree. Use the procedure of paragraph 8-43.
- e. Calculate the angular velocity of the turntable - that is, the drift rate - in milliradians per second, using the data obtained in step d. If the drift is excessive, repeat the procedure for selecting the torque generator compensating resistance that is described in paragraph 8-42.

f. Repeat steps d and e, but with the torque generator compensating resistance disconnected.

**8-110. DETERMINATION OF THE NONGRAVITY-SENSITIVE DRIFT RATE, COMPENSATED AND UNCOMPENSATED.**

**8-111. EXPLANATORY INFORMATION.** The purpose of this procedure is to make a final check of the nongravity-sensitive component of the gyro drift rate, both with and without the aid of the compensating resistance used in the excitation circuit of the torque generator. The output axis is placed in the vertical direction. The effect of earth rate is eliminated by placing the input axis in the east-west direction.

**8-112. EQUIPMENT.** In addition to the basic test setup, a stop watch is used.

**8-113. INITIAL CONDITIONS.**

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps for the 20IGa  
10 ma d-c for the 20IGb.
- c. Wheel excitation:  
0.2 amp/phase at 400 cps for the 20IGa  
0.6 amp/phase at 400 cps for the 20IGb.
- d. Position of gyro unit on turntable: output axis vertical, input axis in the east-west direction.

**8-114. STEP-BY-STEP PROCEDURE.**

- a. Mount the test block on the turntable so that the gyro unit output axis is vertical downward, and the input axis is in the east-west direction.
- b. Apply the indicated excitation to the gyro unit.
- c. Energize the servo loop.
- d. Record the time necessary for the turntable to rotate one degree. Use the procedure of paragraph 8-43.
- e. Calculate the angular velocity of the turntable - that is, the drift rate - in milliradians per second using the data obtained in step d. If the drift is excessive, repeat the procedure for selecting the torque generator compensating resistance that is described in paragraph 8-42.
- f. Repeat steps d and e, but with the torque generator compensating resistance disconnected.

**8-115. FINAL BALANCE TRIM.**

**8-116. EXPLANATORY INFORMATION.** The purpose of this procedure is to effect a final balance of the floated units assembly and, consequently, to minimize the gyro drift. Two procedures made previously should be repeated. These are listed below, in the order in which they are to be performed:

a. Mass unbalance adjustments without earth-rate effect (ref. paragraphs 8-44 through 8-48).

b. Mass unbalance adjustments with earth-rate effect (ref. paragraphs 8-49 through 8-54).

**8-117.** Refer to the referenced paragraphs for information on equipment, initial conditions and step-by-step procedures.

**8-118. TYPICAL TEST DATA.**

a. Spin reference axis vertical downward; input axis in the east-west direction: gyro drift rate is less than 0.01 milliradian per second.

b. Input axis vertical upward; spin reference axis horizontal:

Angle (mr)	Time (sec)	Turntable Angular Velocity (Drift Rate + Earth Rate Component) (mr/sec)
- 2.32	38.4	- 0.0604
- 2.32	45.5	- 0.0510
- 2.32	35.5	- 0.0653
- 2.32	36.5	- 0.0636
- 2.32	39.6	- 0.0586
- 2.32	42.9	- 0.0540
- 2.32	41.4	- 0.0560
- 2.32	39.3	- 0.0591
- 2.32	44.4	- 0.0523
- 2.32	39.9	- 0.0582

Average turntable angular velocity : - 0.05785 mr/sec

Known value of earth rate component: + 0.05 mr/sec

Average drift rate: - 0.00785 mr/sec

**8-119. DETERMINATION OF CHARACTERISTIC TIME.**

**8-120. EXPLANATORY INFORMATION.** The dynamic properties of the gyro unit are specified in terms of a measured characteristic time, which is a parameter indicating the ability of the gyro unit to respond to sudden changes.

**8-121. EQUIPMENT.** In addition to the basic test setup, a DuMont oscilloscope, a Polaroid camera, and a slip platform are used. The schematic diagram of Fig. 8-24 shows the method of setting

up the slip platform, oscilloscope and camera for this test. The slip platform is mounted on top of the turntable, and friction coupled to it, but free to rotate with respect to the turntable about the common axis by slipping, as shown in Fig. 8-24. A pair of stop pins on the slip platform and another on the base of the turntable assembly can stop the angular velocity of the gyro unit stepwise for dynamic response tests when the gyro unit is mounted on the slip platform. The stop pins are electrically insulated in such a way that they can be used to make electrical contacts in a timing circuit at first touch. To prevent windup and breakage of the cable that connects the gyro unit on the slip platform to the rotor of the slip rings, a servo motor cutout disconnects the servo motor power

when the relative angle change between the slip platform and the turntable exceeds a pre-set amount. The slip platform is easily removable from the turntable, so that it need be installed only during tests that require its features.

**8-122. INITIAL CONDITIONS.**

- a. Signal generator excitation:  
125 ma at 400 cps.
- b. Torque generator excitation:  
100 ma at 400 cps, series connected, for a-c excitation; 10 ma d-c, series connected, for d-c excitation.
- c. Wheel excitation:  
0.6 amp/phase at 400 cps.
- d. Position of gyro unit on slip platform: input axis vertical upwards.

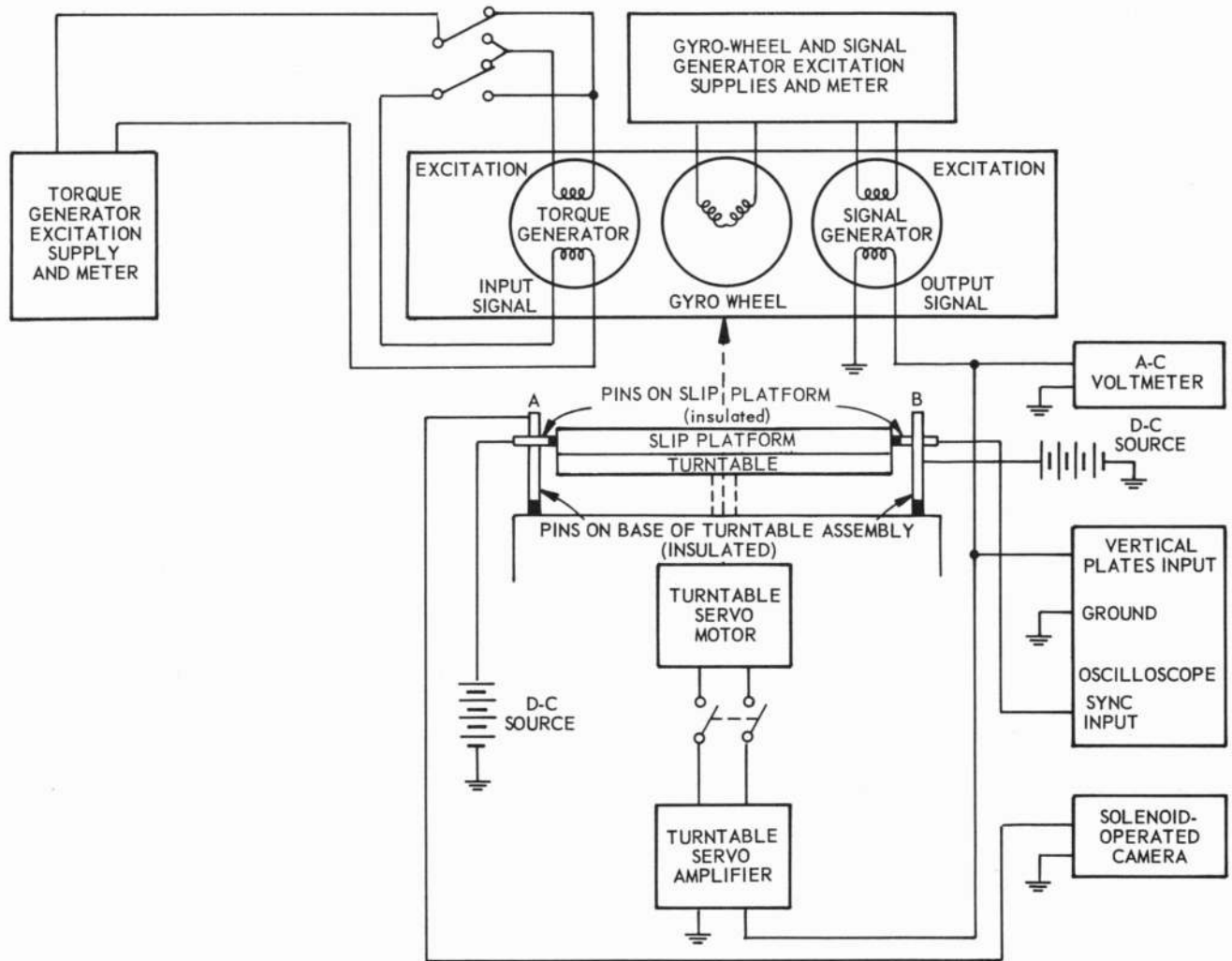


Fig. 8-24. Schematic diagram of the test setup for measuring characteristic time

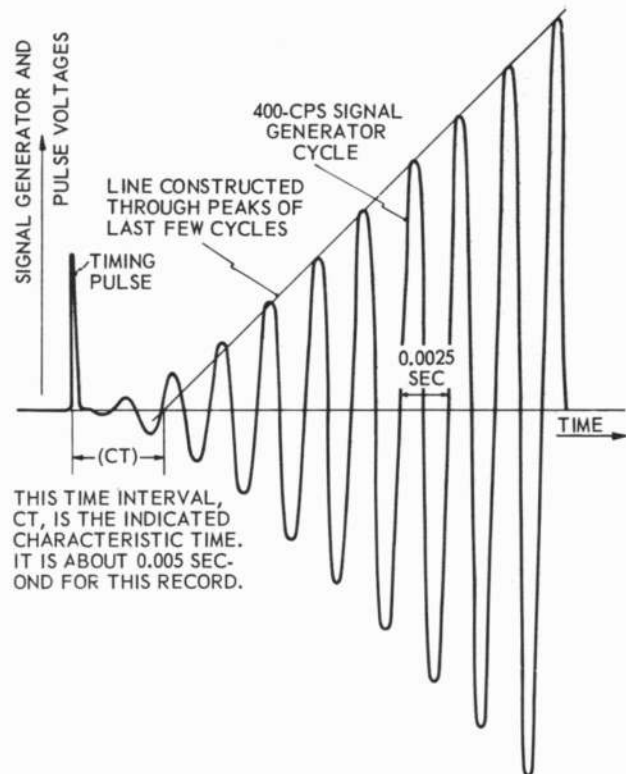
### 8-123. STEP-BY-STEP PROCEDURE.

- a. Mount the slip platform on the turntable.
- b. Mount the test block on the slip platform with the gyro unit input axis vertical upwards.
- c. Adjust the horizontal sweep frequency of the oscilloscope to approximately 30 sweeps per second.
- d. Mount a solenoid-operated Polaroid camera in front of the oscilloscope.

#### Note

As indicated in Fig. 8-24, the camera shutter is operated at the instant Pin A (on the base of the turntable assembly) makes contact with the pin on the slip platform.

- e. Apply the indicated excitation to the gyro unit.
- f. Energize the servo loop.
- g. Allow the turntable to rotate the slip platform pins against the stationary pins on the base of the turntable assembly, so that the gyro rotation is suddenly stopped.
- h. Remove the photograph from the Polaroid camera and observe the oscilloscope trace. It should resemble the trace shown in Fig. 8-25.
- i. On the photograph draw a straight line connecting the last few carrier peaks, as shown in Fig. 8-25. Extend the line to the time base line.
- j. The measured characteristic time is the time interval from the leading edge of the timing pulse to where the time axis intersects the straight line.



THIS TIME INTERVAL, CT, IS THE INDICATED CHARACTERISTIC TIME. IT IS ABOUT 0.005 SECOND FOR THIS RECORD.

Fig. 8-25. Typical oscilloscope record of the characteristic time measurement for the 20IG gyro.

8-124. TYPICAL TEST DATA. In the example shown in Fig. 8-25, the indicated characteristic time is about 0.005 second.

#### Note

This completes the standard testing procedure applied to 20IG Integrating Gyro Units at the Instrumentation Laboratory, M. I. T.



# APPENDIX A

## 20IG ASSEMBLY RECORD BOOK

Prepared by:  
Date:

20IG ASSEMBLY RECORD BOOK

Sheet 1  
of 15

---

Gyro Unit No. \_\_\_\_\_ (This number is to be scribed on 20-pin connector)

For Project No. \_\_\_\_\_

Date Started \_\_\_\_\_ Date Completed \_\_\_\_\_

### Notes

#### Note

*As the steps of the detailed assembly procedure are performed, the appropriate circles and blanks in the Assembly Record Book should be checked and completed, respectively. This will help to keep track of progress during the assembly procedure and serve as a record that the basic steps of the procedure have been carried out. A separate record book is used for each gyro unit being assembled. It is important to note that the Assembly Record Book should not be used as a substitute for the detailed assembly procedure presented in Sections IV through VII.*

MOTOR ASSEMBLY

ROTOR

Rotor Type: \_\_\_\_\_

Rotor bore diameter (Air Gauge) as received: \_\_\_\_\_ inch at 72° F (room temp.)

Rotor bore diameter (Air Gauge) after honing: \_\_\_\_\_ inch at 72° F (room temp.)

Rotor No. 00-96 tapped holes cleaned and screws fitted.

Hysteresis ring and bushing assembled.

Rotor checked for hysteresis ring chips.

SHAFT

Shaft diameter at bearing surface (Elec. Ind. Gauge) as received: \_\_\_\_\_ inch at 72° F.

Shaft diameter at bearing surface (after fitting): \_\_\_\_\_ inch at 72° F.

Nut fitted to shaft.

BEARINGS

Bearing Type: Spring Retainer  Synthane

Manufacturer: \_\_\_\_\_ Manufacturer's Designation: \_\_\_\_\_

Lubrication Type: Grease  Oil  Dry

Lubricant Manufacturer: \_\_\_\_\_ Manufacturer's Designation: \_\_\_\_\_

Where Applied: Balls  Retainer  Races

Bearings centrifuged.

Rotor heated to 250° F.

Bearings and outer race spacer pushed home with arbor press. Inner race spacer  
dropped in place.

Caution

*Bearings are assembled with lettering on outer races facing each other.  
The use of a plastic hammer or any rapping device is prohibited.*

Bearing retainer assembled with six, No. 00-96, 3/32 inch long, flat fillister  
head screws; screws tightened while at 250° F.

MOTOR STATOR

Stator visually inspected under microscope for impregnation sloppiness on  
laminations, hub and hub seat faces.

Stator terminal board securely in place.

**MOTOR STATOR (Cont.)**

Stator shaft hole and mating motor shaft checked for push fit.

Winding resistance: Phase  $G_3 - G_1$  \_\_\_\_\_ ohms

Phase  $G_2 - G_1$  \_\_\_\_\_ ohms

Phase  $G_3 - G_2$  \_\_\_\_\_ ohms

**FLOATED UNITS ASSEMBLY**

Copper plating of the gimbal shell and gimbal fork inspected to insure that there are no blisters, pock marks, or bad scratches on critically mating surfaces.

Three No. 000-120 holes in gimbal shell retapped and pivot cone seat cleaned.

Gimbal fork Stupakoff bore diameter (small hole gauge): \_\_\_\_\_ inch.

Stupakoff outside diameter (micrometer): \_\_\_\_\_ inch.

Stupakoff inspected under microscope for presence of through cracks.

Insulation resistance meter check for grounds.

Cone seat and No. 000-120 thread in Stupakoff cleaned.

Pivot seating checked.

No. 1-64 NC-2 hole in gimbal fork retapped and metal chips removed with vacuum hose.

Wire clamp checked for proper seating in gimbal fork (clamp must be flush with surface).

Power lead-in holes in gimbal fork cleaned and sized to receive silicon-rubber-fiber glass insulating sleeves.

Inside of gimbal fork shaft coated with soldering flux.

Stupakoff properly seated in gimbal shaft (rim should be 0.005 inch to 0.010 inch below top of gimbal shaft).

Soldering Procedure: Mount gimbal fork in discarded gimbal shell.

Mount shell in positioning device.

Place a ring of 50/50 solder around upper circumference of Stupakoff.

Apply heat to gimbal fork shaft by induction soldering machine.

Float Runout Procedure: Assemble gimbal fork and gimbal shell. (They must be positioned with respect to one another just as in final assembly.)

Float Runout Procedure (Cont.):

Check the alignment of the parts by resting the Microsyn rotor mounting pads on a pair of V-blocks. (Correct alignment is assured when the flats of both rotor pads lie flush against the blocks.)

Insert pivots with a runout less than 0.0001 inch T.I.R. in each shaft.

Place assembly between jewel centers.

Record runout on damping surface at balance end: \_\_\_\_ inch.

Record runout on damping surface at Stupakoff end: \_\_\_\_ inch.

Repeat Stupakoff soldering procedure if runout exceeds 0.0002 inch T.I.R.

Disassemble if found satisfactory.

Gimbal cleaned in acetone to remove soldering flux.

Wire clamp inserted and pulled up snugly with No. 1-64 screw.

Check made for grounds between power lead-in wires and gimbal fork using insulation resistance meter.

Record exact reading:  $G_3$  \_\_\_\_ ohms,  $G_2$  \_\_\_\_ ohms,  $G_1$  \_\_\_\_ ohms.

(Resistances should be greater than 2 megohms.)

Gimbal forked placed in oven and cured at \_\_\_\_ °F for \_\_\_\_ hrs.

Recheck made for grounds after curing:

$G_3$  \_\_\_\_ ohms,  $G_2$  \_\_\_\_ ohms,  $G_1$  \_\_\_\_ ohms.

**BALANCE ASSEMBLY**

Select a balance assembly and measure the inside diameter (small hole gauge): \_\_\_\_ inch.

Measure mating shaft diameter of the float shell (micrometer): \_\_\_\_ inch.

If necessary, polish shaft until balance assembly fits with light push fit.

Record final float shell shaft diameter: \_\_\_\_ inch.

Gimbal shell washed and packaged for future use.

Small balance nuts poised.

Each balance stud and mating nut checked for smooth mating along entire

length of stud. (If necessary, apply Molykote to balance studs. Rinse

off assembly in acetone to remove any chips after smooth mating is assured.)

**BALANCE ASSEMBLY (Cont.)**

Record largest turning torque (torque wrench) of small balance nuts (Maximum allowable torque is 2-1/2 inch-ounces.)

SRA Nut: \_\_\_\_\_ in-oz.

IA Nut: \_\_\_\_\_ in-oz.

Record least turning torque.

SRA Nut: \_\_\_\_\_ in-oz.

IA Nut: \_\_\_\_\_ in-oz.

Balance assembly cleaned and packaged for future use. ○

**SELECTING THE MOTOR SPACERS**

Select nominal motor shaft upper spacer: \_\_\_\_\_ inch thick.

Select nominal motor shaft lower spacer: \_\_\_\_\_ inch thick.

Measure over-all length of spacers plus gyro rotor (bearing assembled) plus motor stator with a micrometer: \_\_\_\_\_ inch.

Measure the opening between gimbal fork prongs with telescoping gauge: \_\_\_\_\_ inch.

*It must be remembered that the gimbal fork must be sprung apart between 0.001 inch and 0.002 inch to permit assembly of gyro motor.*

Record the difference in the dimensions: \_\_\_\_\_ inch.

**ASSEMBLY OF GYRO MOTOR**

Gyro shaft checked for very snug push fit through gimbal fork (sprinkle Molykote on shaft and rub in before attempting to fit shaft). ○

Align the motor component parts with the motor shaft holes, drop the motor shaft in place, and secure with the motor shaft nut. Remember, the prongs of the gimbal fork will have to be sprung apart. ○

Turn up shaft nut to a 40 inch-ounce torque, using Molykote under shaft nut to reduce friction. ○

**MINIMIZING THE PENDULOSITY**

Gimbal fork and gimbal shell assembled together, observing previous alignment. ○

Balance assembly removed from plastic bag and secured on gimbal shell shaft. ○

Pivots in place. ○

Support floated units assembly between jewel centers. ○

Pendulosity of floated units assembly minimized. ○

(One full turn of large balance nut corresponds to moving motor assembly \_\_\_\_\_ inch; one full turn of small balance nut corresponds to moving the motor assembly \_\_\_\_\_ inch.)

**MINIMIZING THE PENDULOSITY (Cont.)**

Any pendulosity resulting from the gyro motor assembly along SRA should be removed by changing the thickness of each spacer, remembering still to keep the sum of the two spacer dimensions constant. The spacers should have parallel faces.

Record upper spacer final thickness:\_\_\_\_\_ inch.

Record lower spacer final thickness:\_\_\_\_\_ inch.

Remove gyro motor from gimbal fork.

Weigh gyro rotor:\_\_\_\_\_ gm.

Weigh motor stator:\_\_\_\_\_ gm.

Weigh motor upper spacer:\_\_\_\_\_ gm.

Weigh motor lower spacer:\_\_\_\_\_ gm.

Weigh gyro motor shaft:\_\_\_\_\_ gm.

Weigh shaft nut:\_\_\_\_\_ gm.

Total weight: gm.

**RUNNING IN THE BEARINGS**

Solder temporary power leads to motor and insert motor in receptacle inside heat chamber.

Temporary power leads connected to terminal strip inside the heat chamber.

(Correct phase relationship observed, i. e.,  $G_1$  to  $G_1$ ,  $G_2$  to  $G_2$ ,  $G_3$  to  $G_3$ .)

Apply a 6-volt, 2-phase, 400 cycle per second, a-c voltage to the leads. (Phase currents should be equal and not exceed 0.8 ampere per phase or 0.4 ampere per phase for high-impedance motors.)

Run motor for 15 minutes and note coast time:\_\_\_\_\_ sec.

If coast time exceeds 24 seconds, tighten bearing retainer screws. Recheck shaft nut; adjust if necessary to a 40 inch-ounce torque.

Recheck coast time:\_\_\_\_\_ second.

Glass window on oven secure.

Add 1 psig of helium to oven.

Oven flushed once or twice.

Temperature of oven adjusted to 168° F and motor assembly allowed to come up to heat. (Approximately 1 hour.)

**RUNNING IN THE BEARINGS (Cont.)**

Motor run for one hour.

Listen to motor (while running) with a stethoscope.

Note any unusual grittiness or erratic tone. Motor should have a dry metallic whine.

Note coast time after one hour run in: \_\_\_\_\_ sec.

If time is satisfactory, run motor for 40 hours and record the following:

Date	Time	Volts	Amps.	Sec.
	After 10 hrs.			
	After 20 hrs.			
	After 30 hrs.			
	After 40 hrs.			

Remove motor from heat chamber and unsolder temporary leads.

Stupakoff leads soldered to gyro terminal board with correct phase relationship observed.

Leads clear wheel.

Float shell and gimbal fork soldered together using special soldering fixture and induction soldering machine.

Outside surface of gimbal shell polished to remove copper plating.

Runout at balance assembly end of damping surface rechecked: \_\_\_\_\_ inch.

Runout at Stupakoff end of damping surface rechecked: \_\_\_\_\_ inch.

Air removed from inside the float by using the vacuum pump arrangement.

Float filled with helium at a pressure of 4 psig.

Evacuation procedure repeated and float refilled at 3, 2 and 1 psig.

Copper tubing on gimbal fork crimped and solder sealed.

Leak test the float with mass spectrometer. (Float must be full of helium to make the leak test.)

**SELECTING MICROSYN COMPONENTS (Refer to Microsyn check-off sheet for tested and approved Microsyns.)**

Record signal generator stator type number: \_\_\_\_\_

Record torque generator stator type number: \_\_\_\_\_

SELECTING MICROSYN COMPONENTS (Cont.)

Record signal generator rotor serial number: \_\_\_\_\_

Record torque generator rotor serial number: \_\_\_\_\_

Record weight of signal generator rotor: \_\_\_\_\_ grams.

Record weight of torque generator rotor: \_\_\_\_\_ grams.

PREPARING THE MICROSYN STATOR FOR ASSEMBLY

Stator mounts secured to stator cores with teflon bushings, stainless steel screws and nuts.

Pigtails cut to appropriate lengths; booting and wire strands inspected to see that there are no loose strands of booting and that none of the original strands are cut off.

Cut ends of pigtails thoroughly cleaned.

Cut ends of pigtails tinned.

Pigtails soldered to appropriate stator pins.

Coil winding resistances checked (see table at end of Assembly Record Book).

Mounting feet checked for squareness, and any sharpness or roughness along the edges of the mounting feet removed.

Microsyn stators placed in plastic bags for future use.

END-FOR-END AND ROTATIONAL BALANCE IN FLUOROLUBE

Signal generator rotor fastened down with clamping screws. ("X" marking on -SRA, facing gimbal shell.)

Torque generator rotor fastened down with clamping screws. ("X" marking on -SRA, facing gimbal shell.)

Balance assembly and pivots in place.

Floated units assembly supported at pivots by chains of a pair of analytical balances.

Add sufficient weights to both balance pans to balance floated units assembly.

Pan weight at balance assembly end before balancing: \_\_\_\_\_ gm.

Pan weight at Stupakoff end before balancing: \_\_\_\_\_ gm.

Total weight (floated units assembly weight) before balancing: \_\_\_\_\_ gm.

Floated units assembly suspended in Fluorolube tank so that assembly rests midway between the top and bottom of the tank.



END-FOR-END BALANCE IN FLUOROLUBE (Cont.)

Floated units assembly end-for-end balance obtained in Fluorolube.

Pan weight at balance assembly end after balancing: \_\_\_\_\_ gm.

Pan weight at Stupakoff end after balancing: \_\_\_\_\_ gm.

Total weight (floated units assembly) after balancing: \_\_\_\_\_ gm.

HOUSING ASSEMBLIES

SIGNAL GENERATOR END HOUSING

Pin connector wires cut; booting strips, and strands of wire inspected.

Wires soldered in pin connector.

Wire screen induction soldered to signal generator end housing.

Insulating booting slipped over all pin connector wires except the two sensing-coil leads.

Pin connector wires threaded through signal generator end housing.

Pin connector induction soldered to signal generator end housing.

Jewel assembly checked for dirt deposits and looseness of jewel bearing inside jewel holder.

Jewel holder extractor and jewel assembly inserted in signal generator end housing. (Make sure jewel holder bottoms.)

Balance forks inserted and held in place by pins.

O-ring, pressure washer, and pressure screw inserted over each balance fork stem.

Signal generator end housing washed clean in industrial washing machine.

MAIN HOUSING

Check for presence of stop pin.

Sensing coil wound and resistance checked: \_\_\_\_\_ ohms.

Outside diameter of float (micrometer): \_\_\_\_\_ inch.

Damping gap: \_\_\_\_\_ inch.

BAFFLE PLATE

Brass power-lead terminals permanently bonded to baffle plate.

Flex leads formed and annealed.

Flex leads soldered to power-lead terminals.

**TORQUE MOTOR END CAP ASSEMBLY**

Dirt and foreign matter removed from jewel bearing by injecting ether inside bearing.

Jewel holder pushed lightly into end cap.

Positioning of pivot checked with respect to jewel bearing.

Eccentric power lead baffle cam in place.

**OVER-ALL ASSEMBLY**

Check made for any dirt or foreign matter inside signal generator end housing and in jewel assembly.

Check made for any dirt or foreign matter on threads that engage mating threads of outer case.

Check made to see that no bare wires are in evidence as leads come out of signal generator end housing.

Float lowered inside main housing; stop pin engages stop-pin hole.

No. 1 and No. 2 shield in place.

Signal generator stator assembled with feet facing main housing. (Make sure that positive spin reference axis directions of both the stator assembly and main housing are in correct alignment.)

Microsyn filler block smooth surface flush against stator.

Balance assembly in place.

Main housing and signal generator end housing firmly pressed together and joined with 4 signal generator tie rods.

Signal generator stator leads soldered to 20-pin connector leads.

Signal generator resistances, resistances to ground, and insulation resistance between windings checked and values entered in table.

Soldered ends inserted into wire clamps and clamps secured to main housing.

Sensing-coil wires soldered and inserted in wire clamp; wire clamp secured to main housing.

Torque generator stator correctly positioned on main housing.

Torque generator stator leads soldered to 20 pin-connector leads.

Torque generator resistances, resistances to ground, and insulation resistance between windings checked and values entered in table.

Microsyn filler block smooth surface flush against stator.

END-SHAKE MEASUREMENTS

Height of bottom of adapter ring above micrometer zero.  $D_{(ref)}$ : \_\_\_\_\_ inch.

Height of top of upper pivot above micrometer zero.  $D_1$ : \_\_\_\_\_ inch.

Distance from top of torque motor end housing sleeve to top of upper pivot.

$$D_2 = D_{(ref)} - D_1: \text{_____ inch.}$$

Height of top of ball above micrometer zero.  $D_3$ : \_\_\_\_\_ inch.

Distance from top of torque motor end housing sleeve to bottom of ball.

$$D_4 = D_3 - D_{(ref)}: \text{_____ inch.}$$

Amount to be machined from torque motor end housing.  $D_5 = D_2 - D_4$ : \_\_\_\_\_ inch.

Amount to be machined off shaft of jewel ball retainer: \_\_\_\_\_ inch.

End shake: \_\_\_\_\_ inch.

Torque motor end housing sleeve fastened down with torque motor tie rods.

Baffle plate inserted observing correct alignment.

Motor leads from 20-pin connector soldered to baffle plate.

Flex leads soldered to Stupakoff Kovar rods.

Motor resistances checked and noted in table at end of Assembly Record Book.

Torque motor end housing cap fastened down.

Baffle plate fastened to torque motor end cap by means of 3 No. 0-80 NF-2 flat  
fillister head machine screws.

Ball retainer fastened in place.

MICROSYN CENTERING DATA

SIGNAL GENERATOR

Signal Generator M. Y. \_\_\_\_\_ Stator No. \_\_\_\_\_ Rotor No. \_\_\_\_\_

Sensitivity \_\_\_\_\_ mv/mr with \_\_\_\_\_ ma or volts \_\_\_\_\_ cps excitation.

ROTATIONAL CENTERING

Oscillator frequency set at 400 cycles per second.

Signal generator primary excitation set at 125 ma at 400 cps.

Signal generator tie rods loosened.

Torque motor energized to drive float.

Clockwise stop-position voltage with tie rods loosened: \_\_\_\_\_ mv.

Counterclockwise stop-position voltage with tie rods loosened: \_\_\_\_\_ mv.

(If stop-position voltages are unequal, rotate stator so that voltages at  
stops increase or decrease as required.)

ROTATIONAL CENTERING (Cont.)

Clockwise stop-position in voltage: \_\_\_\_\_ mv.

Counterclockwise stop-position voltage: \_\_\_\_\_ mv.

Minimum (null) voltage: \_\_\_\_\_ mv.

RADIAL CENTERING ALONG Y (LONG) AXIS

Rotor in null position.

TORQUE-OFF-RESTRAINT switch in OFF position.

Radial null voltage with signal generator primary winding excited: \_\_\_\_\_ mv.

Side shake determined by tipping centering fixture approximately 30 degrees,  
first in one direction and then in opposite direction about X-axis.

Record the change in voltage: \_\_\_\_\_ mv.

RADIAL CENTERING ALONG X (SHORT) AXIS

Signal generator secondary excitation set at 125 ma at 400 cps.

Minimum voltage on radial vacuum tube voltmeter: \_\_\_\_\_ mv.

REPEAT SIGNAL GENERATOR CENTERING PROCEDURE

Record the following optimum values.

Voltages at stops: CW \_\_\_\_\_ mv. CCW \_\_\_\_\_ mv.

Angular null voltage: \_\_\_\_\_ mv.

Radial voltage with primary excited (Y-axis centering): \_\_\_\_\_ mv.

Radial voltage with secondary excited (X-axis centering): \_\_\_\_\_ mv.

Signal generator tie rods tightened.

Retract adjusting rods and pressure rods from Microsyn stator and repeat and  
record centering measurements.

Voltages at stops: CW \_\_\_\_\_ mv. CCW \_\_\_\_\_ mv.

Angular null voltage: \_\_\_\_\_ mv.

Radial voltage with primary excited (Y-axis centering): \_\_\_\_\_ mv.

Radial voltage with secondary excited (X-axis centering): \_\_\_\_\_ mv.

TORQUE GENERATOR

Torque Generator M. Y. \_\_\_\_\_ Stator No. \_\_\_\_\_ Rotor No. \_\_\_\_\_

Sensitivity \_\_\_\_\_ dyne-cm/ma<sup>2</sup> with 400 cps excitation.

ROTATIONAL CENTERING (Cont.)

Torque motor primary excitation set at 100 ma at 400 cps.

Torque motor tie rods loosened.

Signal generator energized to drive float.

Clockwise stop-position voltage with tie rods loosened: \_\_\_\_\_ mv.

ROTATIONAL CENTERING

Counterclockwise stop-position voltage with tie rods loosened: \_\_\_\_\_ mv.

(If stop-position voltages are unequal, rotate stator so that voltages at stops increase or decrease as required.)

Clockwise stop-position voltage: \_\_\_\_\_ mv.

Counterclockwise stop-position voltage: \_\_\_\_\_ mv.

Minimum (null) voltage: \_\_\_\_\_ mv.

RADIAL CENTERING ALONG Y (LONG) AXIS

Rotor in null position.

TORQUE-OFF-RESTRAINT switch in OFF position.

Radial null voltage with torque motor secondary winding excited: \_\_\_\_\_ mv.

RADIAL CENTERING ALONG X (SHORT) AXIS

Radial null voltage with torque motor primary winding excited: \_\_\_\_\_ mv.

REPEAT TORQUE MOTOR CENTERING PROCEDURE

Record the following optimum values.

Voltages at stops: CW \_\_\_\_\_ mv. CCW \_\_\_\_\_ mv.

Angular null voltage: \_\_\_\_\_ mv.

Radial voltage with secondary winding excited (Y-axis centering): \_\_\_\_\_ mv.

Radial voltage with primary winding excited (X-axis centering): \_\_\_\_\_ mv.

Torque motor tie rods tightened.

Retract adjusting rods and pressure rods from Microsyn stator and repeat and record centering measurements.

Voltages at stops: CW \_\_\_\_\_ mv. CCW \_\_\_\_\_ mv.

Angular null voltage: \_\_\_\_\_ mv.

Radial voltage with secondary winding excited (Y-axis centering): \_\_\_\_\_ mv.

Radial voltage with primary winding excited (X-axis centering): \_\_\_\_\_ mv.

**FLEX LEAD NULL ADJUSTED TO SIGNAL GENERATOR NULL**

Test setup the same as for rotational centering of signal generator.

Signal generator rotor at null position.

TORQUE-OFF-RESTRAINT switch OFF.

Minimum voltage from angular voltmeter: \_\_\_\_\_ mv.

**FRICITION LEVEL**

Test setup the same as for rotational centering of signal generator.

Signal generator rotor at null position.

Observe voltage readings of Primary Input Voltmeter and Secondary Input

Voltmeter when float begins to move away from null when torqued by torque motor. Repeat in opposite direction.

Clockwise Rotation:

Counterclockwise Rotation:

Primary Voltage: \_\_\_\_\_ mv.

Primary Voltage: \_\_\_\_\_ mv.

Secondary Voltage: \_\_\_\_\_ mv.

Secondary Voltage: \_\_\_\_\_ mv.

$$\text{Friction Level} = \frac{\text{Primary Voltage} \times \text{Secondary Voltage}}{100} \times \text{Torque Motor Sensitivity}$$
$$= \text{_____ dyne-cm}$$

**Note**

*The primary input voltmeter and the secondary input voltmeter are each set up to read the voltage across a 10-ohm resistor. Therefore, the current inputs (in milliamperes) into the primary and secondary circuits of the torque motor are found by dividing the voltage readings (in millivolts) by ten. The sensitivity of the torque motor has the units of dyne centimeters per (milliampere)<sup>2</sup>.*

**FILLING DATA**

Fluorolube type: \_\_\_\_\_ at \_\_\_\_\_ ° F.

Assembled gyro unit checked for leaks.

Kinney pump started (time): \_\_\_\_\_

Megovac pump started (time): \_\_\_\_\_

Pirani gauge reading when diffusion pump started: \_\_\_\_\_ microns.

Diffusion pumps started (time): \_\_\_\_\_

Pirani gauge reading when sealing screw dropped and valve opened: \_\_\_\_\_ microns.

Sealing screw dropped and valve opened (time): \_\_\_\_\_

Prepared by:  
Date:

20IG ASSEMBLY RECORD BOOK

Sheet 15  
of 15

- Fluid showing in glass bulb (time): \_\_\_\_\_
- Sealing screw raised and valve closed (time): \_\_\_\_\_
- Heater switch turned off (time): \_\_\_\_\_
- Copper tubing crimped and soldered (time): \_\_\_\_\_
- Sealing screw replaced by filling screw.
- Gyro unit placed in oven set at 165° F for 20 minutes.
- Filling screw soldered in place.
- Final electrical check made and results entered in tables.
- Microsyn centering rechecked.
- Unit ready for test.

Gyro motor stator-winding resistance check list.

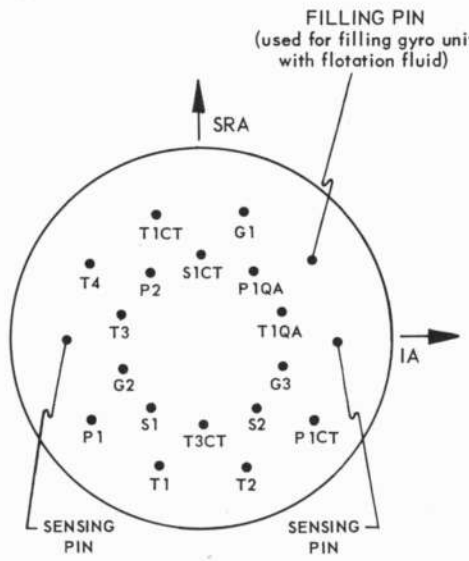
Resistance Across	Nominal Value of Resistance (ohms)	Check Before Assembly of Power Leads	Check After Assembly of Power Leads	Check Before Filling Gyro	Check After Filling When Gyro is Hot	Check After Filling When Gyro is Cold	Check Before Delivery of Gyro
G1 - G2 or N - B	4.2						
G1 - G3 or N - A	4.2						
G2 - G3 or B - A	9						
G1 - Ground or N - Ground	More than 2 megohms						
G2 - Ground or B - Ground	More than 2 megohms						
G3 - Ground or A - Ground	More than 2 megohms						

Microsyn resistance check sheet.

Signal generator MY 1.5-25  
Torque motor MY 1.5-4

Rotor No. \_\_\_\_\_ Stator No. \_\_\_\_\_  
Rotor No. \_\_\_\_\_ Stator No. \_\_\_\_\_

Resistance Across	Nominal Value (ohms)	Check Before Soldering Pigtailed	Check After Soldering Pigtailed	Check Before Assembly into Unit	Check After Assembly into Unit	Check Before Centering	Check Before Filling	Check After Filling
P1 - P2	7.0							
P1 - PICT	3.5							
P2 - PICT	3.5							
P1 - PIQA	5.0							
P2 - PIQA	2.0							
PICT - PIQA	2.0							
S1 - S2	280							
S1 - SICT	140							
S2 - SICT	140							
P1 - GND	more than 2 megohms							
P2 - GND								
PICT - GND								
PIQA - GND								
S1 - GND								
S2 - GND								
SICT - GND								
P1 - S1								
T1 - T2	32							
T1 - TICT	16							
T2 - TICT	16							
T3 - T4	24							
T3 - T3CT	12							
T4 - T3CT	12							
T1 - T1QA	24							
T2 - T1QA	8							
TICT - T1QA	8							
T1 - GND	more than 2 megohms							
T2 - GND								
TICT - GND								
T3 - GND								
T4 - GND								
T3CT - GND								
T1QA - GND								
T1 - T3								



IDENTIFICATION OF TERMINAL PINS ON THE GYRO UNIT 20-PIN CONNECTOR



# APPENDIX B

## A STATISTICAL ANALYSIS OF THE 20 SERIES OF FLOATED INSTRUMENTS

by  
Mr. Godfrey Harris\*  
of  
ELLIOTT BROTHERS, LTD.  
London, England

### ACKNOWLEDGMENT

Acknowledgment is due to the staff of the Miniature Components Group at the Instrumentation Laboratory for providing the data summarized in this report. Under the direction of Mr. Lester R. Grohe, Assistant Director for Miniature Components at the Instrumentation Laboratory, these data have been painstakingly gathered and correlated over a period of several years.

( from Instrumentation Laboratory Internal Report E-534, dated June, 1956, in )  
which the material of this appendix was originally published.

Data relating to the properties, performance and history of the various units of the 20\*\* series of floated instruments that have been produced by the Instrumentation Laboratory, M. I. T., have been transcribed from the assembly record books into the form of a units history. Among the items tabulated in the units history are the faults found in this series of instruments, represented by failures and other untoward incidents that have occurred during the assembly and use of the instruments. The object of this appendix is to summarize this information and to indicate the frequency of occurrence of each type of incident.

Some degree of uncertainty must be assumed to exist in this study. The assembly record books have been compiled by many different technicians over a period of several years, so that there are differences in emphasis and in the completeness of the records. Also, it is unlikely that the real cause of a failure has been discerned with equal precision.

\* This report was prepared by Mr. Harris while observing gyro assembly and testing methods used at the Instrumentation Laboratory, M. I. T.

\*\* The designation "20" refers to the diameter of the case in tenths of inches.

It is probable in some cases that an effect rather than a prime cause has been recorded as the reason for a failure.

The various types of instruments that have been considered in the analysis are tabulated in Table B-1. The total number of instruments included is slightly less than the number actually built.\*\*\* In a few instances, the records of particular instruments were not available at the time of this study; these instruments have not been included in the totals.

Table B-2 lists the nature of the various incidents that have occurred. These are totaled under two headings: the number of times a given type of incident has occurred during assembly, and the number of times a given type of incident has necessitated the opening of a completed instrument. Figure B-1 has been included to show the components in which the different incidents have occurred. Tables B-3, B-4 and B-5 summarize the types of

\*\*\* Some earlier instruments were rebuilt several times, sometimes in a different form. Depending upon the individual circumstances, the rebuilt units were considered as either the same unit or as an entirely new unit. Thus the number of units considered to have been actually built is somewhat arbitrary.

incidents for gyroscopic instruments, nongyroscopic instruments, and Microsyn units, respectively.

Figure B-2 shows on a time base the approximate date of the first completion of the various instruments analyzed. Also are shown the approximate dates of occurrence of the various incidents. Sometimes the dates are not given in the records and so have been inferred with as much accuracy as possible.

The total of electrical faults given in Table B-3 includes Microsyn electrical failures but does not include failure of flex leads by burning out. Such burning out was due to either an electrical fault, a maladjustment external to the instrument (note the series of flex-lead incidents during February and March, 1954, in Fig. B-2), or a tendency for flex leads to bend in the plane of the flex-lead material when carrying a heavy current. This sideways flexure caused the flex leads to short against the end plate. To overcome this, the end plates have

been insulated by hard anodizing, and the flex-lead current has been reduced by the introduction of high-impedance motor windings. These features first appeared in September of 1954, and it may be significant that there have been no flex-lead incidents since that time.

Table B-1. The various instruments of the 20 series that have been considered in the analysis.

Instruments	Quantity	Number of Microsyn Units in Each Instrument
Gyroscopic Instruments		
20 IG Integrating Gyro Unit	84	2
20 RG Rate Gyro Unit	8	1
20 PIG Pendulous Integrating Gyro Unit	7	2
Nongyroscopic Instruments		
20 FP Floated Pendulum Unit	6	2
20 EPA Elastic Pendulous Accelerometer Unit	3	1
20 VI Viscous Integrator Unit	2	2
Total number of gyroscopic instruments	99	
Total number of nongyroscopic instruments	11	
Total number of Microsyn units involved	209	

Table B-2. A summation of the incidents that have occurred in the various instruments of the 20 series noted in Table B-1.

Nature of Incident	Gyroscopic Instruments			Nongyroscopic Instruments		
	Occurred During Assembly	Required Opening a Completed Instrument	Total	Occurred During Assembly	Required Opening a Completed Instrument	Total
Microsyn: Electrical fault	8	14	22		1	1
Mechanical fault	9	1	10			
Flex leads: Burned out		9	9			
Other incidents	1	5	6			
Motor: Rotor bearing fault <sup>1</sup>	5	1	6			
Stator electrical fault	1		1			
Insulation of connectors and wiring broke down	4	7	11	1		1
Gimbal bearings: Faulty jewel	5		5			
Faulty end ball	3	1	4			
Faulty pivot	3	4	7	1		1
Leakage: Float	3		3			
Outer case	3	3	6			
Macrodir <sup>2</sup>	3		3			
Other causes: Filling tube blocked	2		2			
Excessive balance cross-coupling	1	1	2			
Bellows distorted	1		1			
Faulty: Jewel extractor	1		1			
Stop pin	1	1	2			
Centering	1	1	1			
Filling procedure	1		1			
Pendulosity incorrect		1	1			
Combination of eccentricities	1		1			
Excessive float run-out	1		1			
Balance arms too long		1	1			
Unit "sticky"		1	1			
Unit dropped		1	1			
Unit opened but no reason given		2	2			
TOTALS	57	54	111	2	1	3

Notes:

1. Some rotor bearing failures are believed to have been caused by distillation of solvents from insulation and potting media onto balls and race-ways.
2. Macrodir means obvious, observable dirt or contamination. Certain bearing failures, however, may have been caused by unobservable microdir.

**Table B-3. A summary of incidents for gyroscopic instruments of the 20 series.**

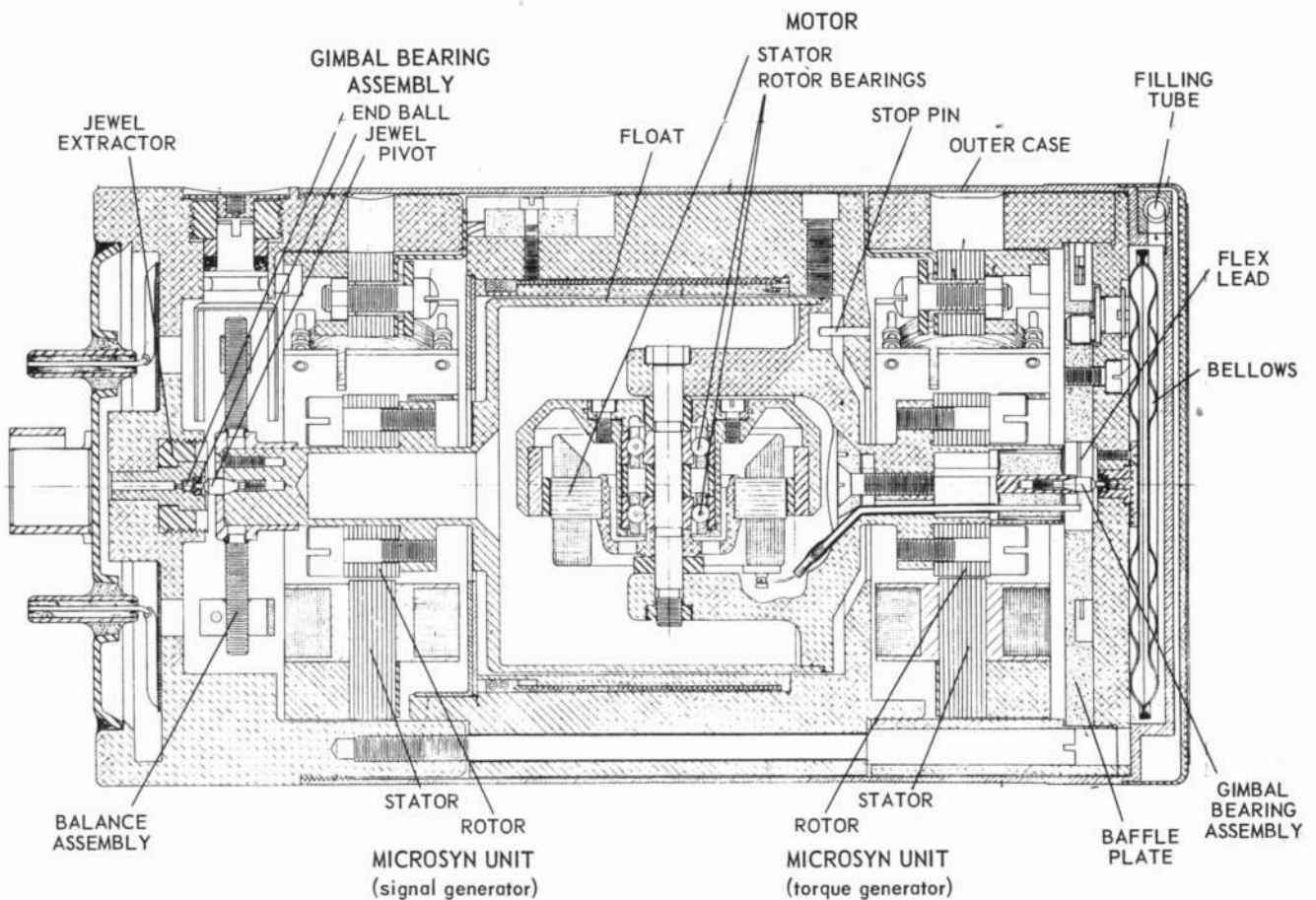
<u>99 Instruments Considered</u>	
36 without incidents	
63 with incidents . . . . .	= 63.7% of gyroscopic instruments
111 incidents . . . . .	= 1.76 per faulty gyroscopic instrument
	= 1.12 per gyroscopic instrument
Total electrical faults* = 34 = 30.6% of all incidents	
Microsyn faults	= 32 = 28.8% of all incidents
Jewel bearing faults	= 16 = 14.4% of all incidents
Flex lead incidents	= 15 = 13.5% of all incidents
Leakage incidents	= 9 = 8.1% of all incidents
Rotor bearing faults	= 6 = 5.4% of all incidents
Presence of macrodirt	= 3 = 2.7% of all incidents
* See comment in text.	

**Table B-4. A summary of incidents for nongyroscopic instruments of the 20 series.**

<u>11 Instruments Considered</u>	
9 without incidents	3 Incidents: 1 Microsyn electrical fault
2 with incidents	1 insulation fault
	1 pivot fault

**Table B-5. A summary of incidents for Microsyn units used in the 20 series.**

<u>209 Microsyn Units Considered</u>	
33 faults . . . . .	= 15.8% of total Microsyn units
23 electrical faults . . . . .	= 69.8% of Microsyn faults



**Fig. B-1. Assembly drawing of a typical 20IG integrating gyro unit. (This gyro unit includes all the components in which various incidents associated with the 20 series of floated instruments have occurred.)**

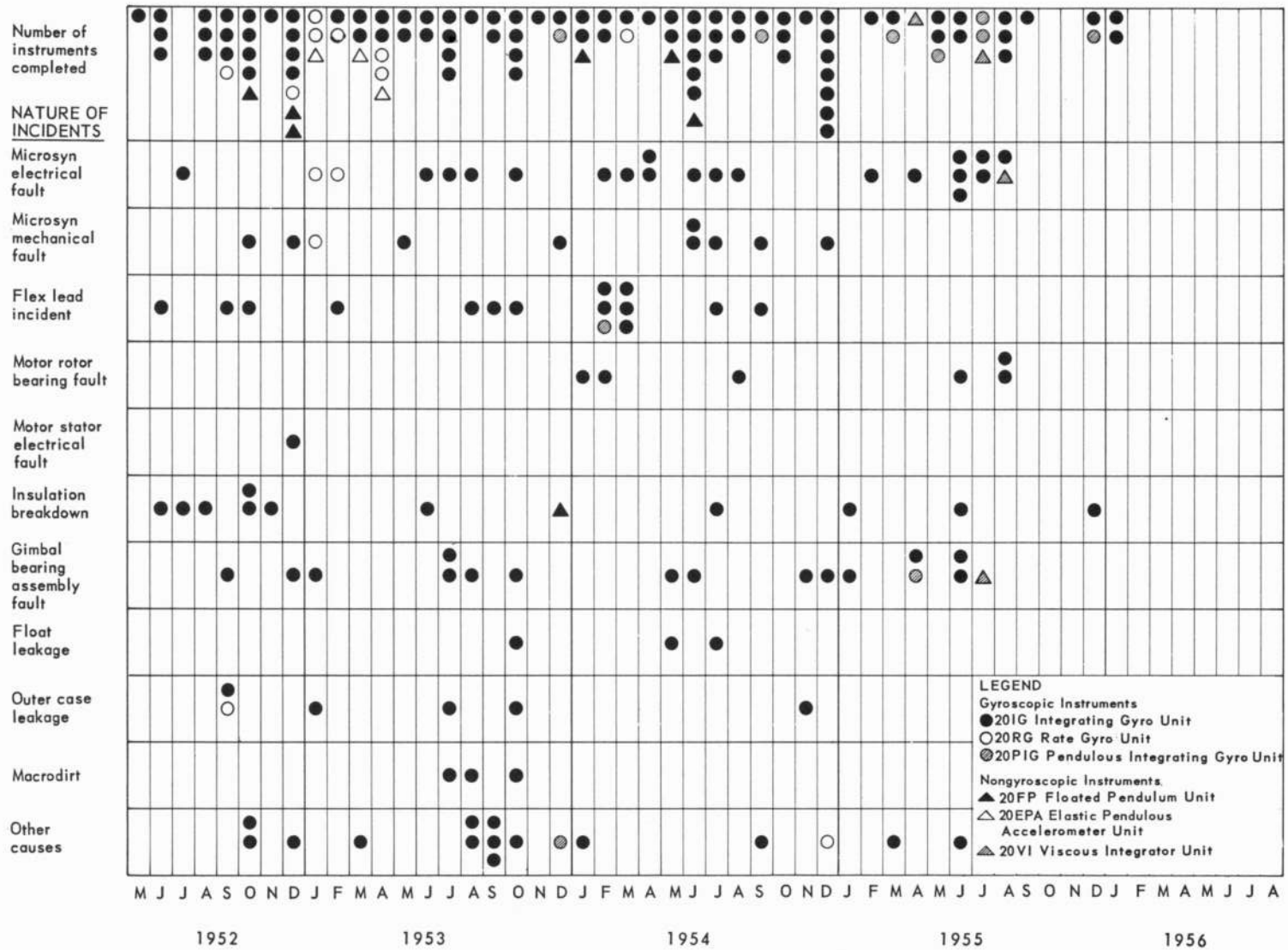


Fig. B-2. Scatter chart of the various incidents during the production program for the 20 series of floated instruments.

# APPENDIX C

## PARTS LIST FOR THE 20IG INTEGRATING GYRO UNIT

### MOTOR ASSEMBLY

1. Rotor.
2. Bushing.
3. Hysteresis Ring.
4. Motor Shaft.
5. Motor Bearing (two required).
6. Bearing Preload Spacer (two required).
7. Stator.
8. Bearing Retainer.
9. No. 00-96 Flat Fillister Head Machine Screw, 3/32 inch long (six required).
10. Motor Shaft Nut.

### FLOATED UNITS ASSEMBLY

1. Gimbal Fork.
2. Gimbal Shell.
3. Power Lead-in Body.
4. Power Lead-in Wire Clamp.
5. No. 1-64 NC-2 Flat Head Machine Screw, 5/16 inch long (one required).
6. Pivot Assembly (two required).
7. Balance Assembly (one required).
8. Balance Nut (four required, two heavy and two light).
9. No. 000-120 Flat Head Machine Screw, 5/32 inch long (three required).
10. Microsyn Signal Generator Rotor.
11. Microsyn Torque Generator Rotor.
12. No. 1-64 NC-2 Rotor Clamp Screw (four required).
13. Motor Spacer (two required).

### MICROSYN COMPONENTS

1. Microsyn Signal Generator Stator.
2. Microsyn Torque Motor Stator.
3. Microsyn Stator Mount (two required).
4. Stator Screw Bushing (eight required).
5. No. 2-56 NC-2 Fillister Head Machine Screw, 5/16 inch long (eight required).
6. Stator Nut (eight required).
7. Microsyn Filler Block (two required).

### SIGNAL GENERATOR END HOUSING ASSEMBLY

1. Signal Generator End Housing
2. Wire Screening.
3. 20-Pin Connector.
4. No. 0-80 NF-2 Filling Screw.
5. Balance Adjustment Fork (two required).
6. Balance Adjustment Fork Retaining Pin (four required).
7. C-Ring (two required).
8. C-Ring Pressure Washer (two required).
9. O-Ring Pressure Screw (two required).
10. Balance Fork Cover (two required).
11. Jewel Assembly.
12. Jewel Holder Extractor.

### MAIN HOUSING ASSEMBLY

1. Main Housing.
2. Sensing-Coil Form.
3. Magnetic Shield No. 1.
4. Magnetic Shield No. 2.
5. Two-Hole Wire Clip (three required).
6. Three-Hole Wire Clip.
7. Signal Generator Tie Rod (four required).
8. Stop Pin.

#### TORQUE MOTOR END HOUSING ASSEMBLY

1. Torque Motor End Housing Sleeve
2. Torque Motor Tie Rod (four required).
3. Power Lead Baffle Plate.
4. Power Lead Terminal (three required).
5. Torque Motor End Housing Cap.
6. Jewel Assembly, Including Tungsten Carbide Ball.
7. Jewel Ball Retainer.
8. Power Lead Baffle Cam.
9. Retaining Ring.
10. No. 000-120 NF-2 Flat Head Machine Screw (three required).
11. No. 0-80 NF-2 Flat Fillister Head Machine Screw, 1/8 inch long (three required).
12. No. 1-72 NF-2 Flat Head Machine Screw, 1/4 inch long (four required).

#### OUTER CASE ASSEMBLY

1. Outer Case.
2. Tubing Connector.
3. Copper Tubing.
4. Outer Case Cap.
5. Diaphragm.

#### MISCELLANEOUS

1. No. 30 A. W. G. Tensolite (as required).
2. Silicon Rubber Fiber Glass Insulation (as required).
3. Soldering Sleeves, long and short (as required).
4. Flex Lead, Eutetic Silver, 0.001 inch thick by 0.009 inch wide (as required).
5. Sensing-Coil Wire (approximately 27 feet required).
6. Liquid C-8 Resin, Bakelite No. 6020A and No. 6022 (as required).
7. Fluorolube (as required).

APPENDIX D  
TAP SIZES REQUIRED FOR THE 20IG  
INTEGRATING GYRO UNIT

<u>Size</u>	<u>Location</u>	<u>Size</u>	<u>Location</u>
1. No. 00-96	Gyro rotor.	8. No. 0-80 NF-2	Filling hole in 20-pin connector.
2. No. 1-64 NC-2	Gimbal fork.	9. No. 2-56 NC-2	Signal generator tie rod holes.
3. No. 000-120	Power lead-in body, and holes in float shaft at signal generator end.	10. No. 00-96 NF-2	Wire clip holes in main housing.
4. No. 1-120 NS-3	Balance nut.	11. No. 2-56 NC-2	Torque motor tie rod holes in main housing.
5. No. 1-64 NC-2	Rotor mounting pad.	12. No. 1-72 NF-2	Torque motor housing.
6. No. 2-56 NC-2	Motor shaft nut.	13. No. 0-80 NF-2	Power lead baffle plate.
7. 5/16-40 NS-3	Balance fork port holes and center of signal generator housing.	14. No. 000-120 NF-2	Torque motor end cap.

## APPENDIX E

### SCREW SPECIFICATIONS FOR THE 20IG INTEGRATING GYRO UNIT

<u>Size</u>	<u>Location</u>	<u>Size</u>	<u>Location</u>
1. No. 00-96	Flat Fillister Head Machine Screw, 3/32 inch long (six required to fasten bearing retainer to gyro rotor).	8. No. 2-56 NC-2	Torque Motor Tie Rod (four required).
2. No. 1-64 NC-2	Flat Head Machine Screw, 5/16 inch long (one required to fasten power lead-in wire clamp to gimbal fork).	9. No. 2-56 NC-2	Fillister Head Machine Screw, 5/16 inch long (four required by each Microsyn stator to clamp stator mount).
3. No. 000-120	Flat Head Machine Screw, 5/32 inch long (three required to fasten balance assembly to float shaft).	10. No. 1-72 NF-2	Flat Head Machine Screw, 1/4 inch long (four required to fasten torque motor end housing cap to torque motor end housing sleeve).
4. No. 1-64 NC-2	Rotor Clamp Screw (four required).	11. No. 0-80 NF-2	Flat Fillister Head Machine Screw, 1/8 inch long (three required to fasten torque motor end housing cap to power lead baffle plate).
5. No. 0-80 NF-2	Fillister Head Machine Screw, 1/4 inch long (filling screw).	12. No. 000-120 NF-2	Flat Head Machine Screw (three required to fasten jewel ball retainer to torque motor end housing cap).
6. No. 2-56 NC-2	Signal Generator Tie Rod (four required).		
7. No. 00-96 NF-2	Flat Fillister Head Machine Screw, 3/16 inch long (four required to fasten wire clips to main housing).		



INITIAL DISTRIBUTION

AF Camb. Res. Cen., Bedford, Attn: CROTT-2  
AF Inst. of Tech., Attn: MCLI, Elec. Eng. Dept.  
Capt. W. McKenna  
ARDC, Baltimore  
RDSTIL  
RDTDGB  
RDTDGG  
RDTDGF  
RDTDCG, Col. Gibson  
ASTIA, Dayton, Attn: DSC-SD (25)  
Chief, Bur. of Ships, Washington, Attn: Code 822  
Bur. of Aeronautics, Washington, Attn: E1-71  
Bur. of Ordnance, Washington, Attn: Section Re4e  
DCS/Development Hdqs. Washington, Attn: Arm. Div.  
Eglin AF Base  
Langley AF Base, Attn: Com. Adjutant  
Patrick AF Base  
Edwards AF Base, Attn: FTDTR  
Maxwell AF Base, Attn: CR-3250  
Brig. Gen'l L. I. Davis, Holloman AFB  
Holloman AF Base, Attn: HDTE, R. B. Savage  
Melvin Jenny, Patent Office, M.I.T.  
Dir. Naval Res. Lab., Attn: Code 1110  
Penn State College  
Rand Corp.  
Aberdeen Proving Grd., Attn: Maj. J. B. Adams  
Aberdeen Prv. Grd., Attn: Ballistic Res. Lab.  
Lincoln Lab., Attn: Mary Granese, Librarian  
Inyokern, China Lake, Calif.  
Attn: D. R. Scheller  
N. Y. A. F. Dev. Field Off., Attn: E. H. Millson  
Weapons Sys. Eval. Grp., Attn: Ex. Sec.

Naval Air Devel. Center, Johnsville, Pa.  
Attn: Librarian  
Rome Air Devel. Center, Griffin AFB  
Rome, N. Y.  
Attn: RCENT  
Dir. of Systems Management, Detach #1  
Hdqs. ARDC, Wright-Patterson  
Cornell Aero. Lab.  
Western Devel. Div., Inglewood, Calif.  
Attn: WDSIT (39)  
Lt. John Herther  
Capt. Earl Thompson  
WDTLG, Capt. Mitchell  
Commander  
Wright Air Development Center  
Wright-Patterson AF Base  
Attn: WCLGR-4, Lt. Rohlinger  
WCLGN-5  
WCLGT-3, Capt. Lynch  
WCLN, Dr. Burka  
WCLGF-1  
WCLCX-1, Capt. Wood  
WCLCX-2  
WCLCX-3  
WCLOO-1  
WCREO-2  
WCLGL-3  
WCLGL-4  
WCLRO  
WCLSO  
WCOL-5 (3), Mr. W. J. Underwood  
RDZSB  
WCLCI  
WCLGO  
WCLGT  
WCLCE  
WCLCM  
WCOSR, Mr. Sheppard (3)  
WCRRH (6)  
WCRRE, Dr. Devol  
WCLGN, Mr. Banta  
WCLG  
WCLOT, Capt. Penick

