A ROTATING GONIOMETER FOR THE LOW FREQUENCY HIGH POWER OMNIRANGE

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Technical Development Report No 70

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT
INDIANAPOLIS, INDIANA
July 1949

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Manuscript received, March 1947

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SUMMARY

This report describes the development of a rotating goniometer for the high power, low frequency omnirange located on Nantucket Island. The frequency range is 190 to 400 kc

The goniometer is driven at 1800 rpm by a 220-volt, one-half horsepower synchronous motor One end of the motor shaft is coupled to the goniometer and the opposite drives a 210-cps tone wheel and a small 30-cps pilot generator.

The goniometer was designed for a primary rf input power of 3 kw with a secondary load resistance of 35-ohms The efficiency of the goniometer is approximately 90 per cent The goniometer characteristics show a departure of approximately five per cent from a true sine wave Nulls are sharp and displaced by 180° from each other The input impedance varies about 6 5 per cent for 360° rotation of the primary, with each secondary loaded at 35-ohms The mutual inductance measures 39 microhenries The input impedance at the 15°, 105°, 195°, and 285° positions is approximately 63-ohms

Special attention was given to the development of satisfactory low resistance contact brushes and collector rings to prevent arcing and heating A number of methods using different types of materials were given prolonged tests to determine their operating characteristics when carrying heavy rf currents Copper-carbon brushes and heavy brass rings were found to be the most satisfactory from the standpoint of minimum heating and low contact resistance, and are used to transfer the rf energy from the transmitter to the primary coil of the goniometer

While it was not possible to test the goniometer at rated input due to lack of a suitable rf source of power, tests were made using the rated rf currents in the primary and secondary circuits by reducing the load resistance No appreciable heating of the brush and ring assemblies or tuning components was discernible after a test period of six hours at an ambient temperature of 82° F

INTRODUCTION

Low frequency goniometers of the manually operated type have been successfully used in four-course radio ranges during the past 20 years These units were of considerable size, and required no rotating machinery for their operation The stator windings were approximately 14 inches in diameter, while the diameter of the rotor windings was about seven inches. They were fabricated almost entirely of bakelite tubing and sheet stock and were of simple construction The two rotor windings were displaced 90° from each other and terminated on collector rings on one end of the rotor shaft The stator windings also were displaced 90° and coaxial with the rotor

In the development of the low frequency omnirange, it was necessary to construct a goniometer that could be rotated at a constant speed of 1800 rpm and deliver several kilowatts of rf power to the transmission lines feeding the omnirange antennas

This report describes the construction of a low frequency rotating goniometer having a rated rf input of 3 kw when its output circuits are terminated in 35-ohm resistance loads The frequency range is 190 to 400 kc

MECHANICAL DESIGN

In order to keep the cost of this unit reasonably low and reduce mechanical problems to a minimum, a rotor winding diameter of 4 3/4 inches and a stator winding diameter of eight inches, was chosen

The rotor winding, wound on a length of high-grade bakelite tubing, consists of 16 turns, 8/32/36 litz wire, closely spaced The length of the winding is 15 3/4 inches and the width is 2 1/8 inches. The rotor winding is connected to the collector rings by copper strips which extend through slots in the rotor shaft The winding ends are terminated in copper lugs securely fastened to suitable sockets One end of the copper strips, terminated in brass plugs, fits snugly into the sockets The other end of the copper strips is secured to the collector rings with machine screws. Four contact brushes are provided with each collector ring to insure a smooth and uninterrupted transmission of rf power to the rotor winding under normal operating conditions. The winding is cemented to the bakelite tubing with a high-grade bakelite varnish.

Fig. 1 shows a view of the rotor winding with the positioning sleeves partially removed. The positioning sleeves are for the purpose of keeping the rotor winding firmly in place when it is rotating at 1800 rpm. Fig. 2 shows the rotor form with shafts disassembled. Fig. 3 is a view of the rotor completely assembled and mounted in an aluminum frame.

A close-up view of the collector rings and brushes is shown in Fig. 4. A 360° dial calibrated at 10° intervals is mounted on the driven end of the rotor shaft. The dial can be oriented to any desired position by loosening the set screws which secure it to the shaft. The dial provides a means of ascertaining the angular relation of the rotor to either secondary, which is required when obtaining the electrical characteristics of the goniometer. The dial is usually adjusted to indicate maximum or minimum coupling between the rotor and each secondary at the 0°, 90°, 180°, and 270° positions.

The secondary windings are rectangular in shape, wound flatwise and securely fastened to the bakelite form by a high-grade insulating varnish and suitable clamps. Each winding consists of two sections wound with seven turns, 7/32/38 litz wire per section. Winding dimensions are; 15 1/4 inches and width three-fourths inch. The complete stator assembly is shown in Fig. 5.

The end plates, Fig. 6, which contain the bearing housings, are constructed of ribbed aluminum castings bolted to a heavy steel base. Spacing between the end plates is maintained accurately by four aluminum tie rods which are insulated from one end plate by bakelite bushings.

The goniometer is driven by a one-half horsepower, 1800 rpm, synchronous motor

Fig. 1 Rotor Winding

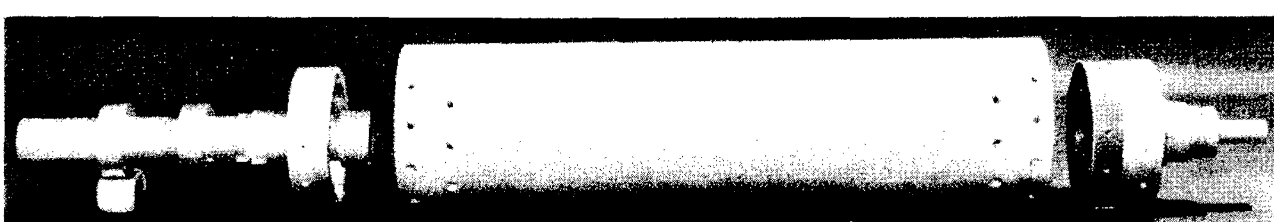

Fig. 2 Rotor Form and Shafts

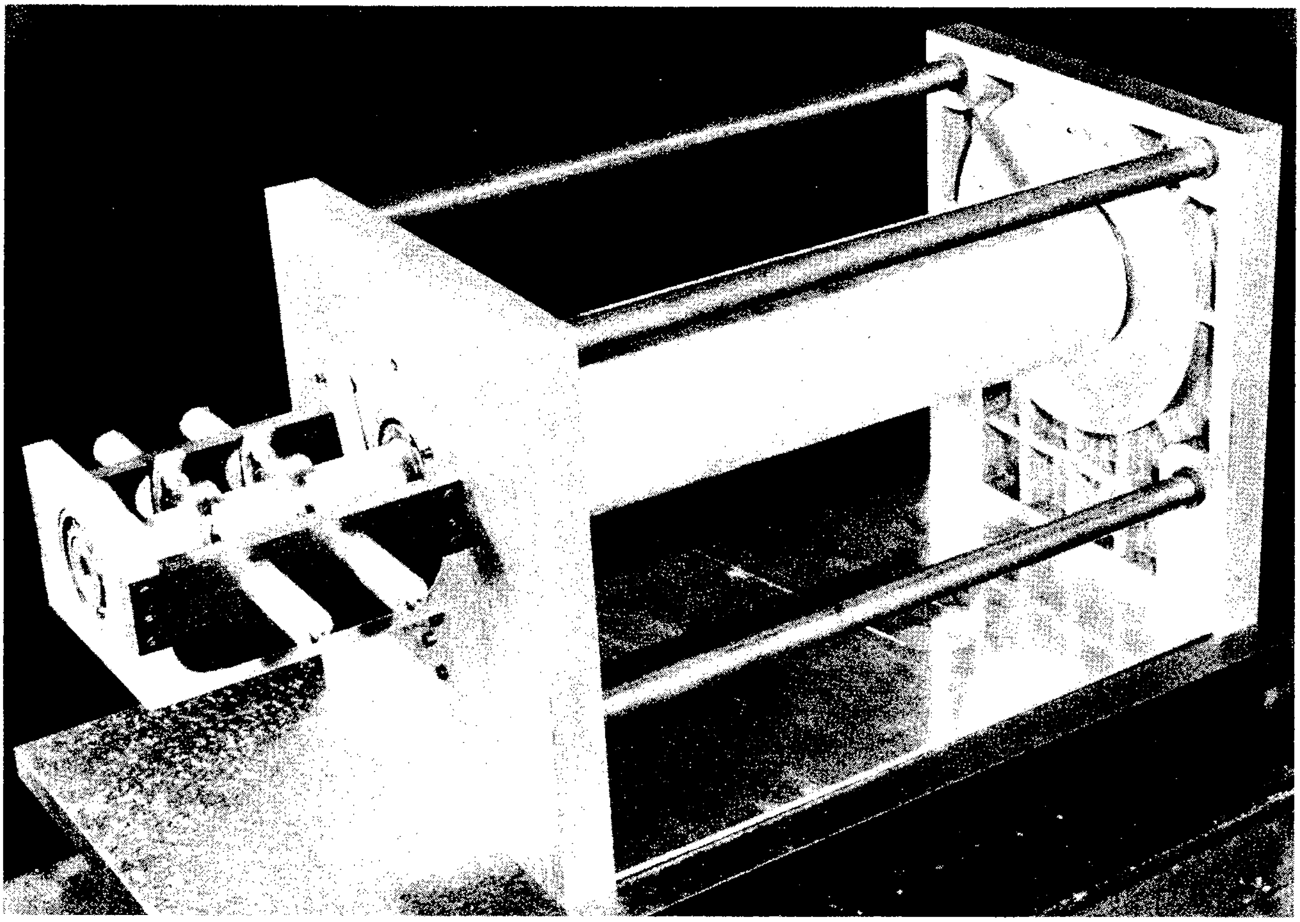

Fig. 3 Rotor Assembled in Frame

operating from a 220-volt single phase 60-cps supply. The motor also drives a 210-cps frequency modulated tone wheel and a 30-cps pilot generator.

The tone wheel, Fig. 7, is a flat cast iron disc with irregularly spaced teeth (seven in number) cut to a predetermined shape. The magnetic field of the pickup unit is affected by the tone wheel in a manner such as to produce a 210-cps frequency, which is frequency modulated at 30-cps with a deviation ratio of one. The tone wheel is mounted on a steel shaft equipped with ball bearings and supported by a cadmium plated brass framework.

The completely assembled goniometer with driving motor, tone wheel, and pilot generator is illustrated in Fig. 8. The goniometer (including collector rings and brushes) is enclosed on three sides by perforated bakelite panels.

The mechanical design features of the goniometer make a quick and simple disassembly possible for inspection or repair to its internal parts. By disconnecting the rotor shaft from the driving motor, removing the dial and disengaging the brush assembly bracket from its locating dowels, the rotor with bearings and bearing housings assembled on the rotor shaft, is easily drawn out through the end plate at the brush assembly end by removal of the bearing housing screws.

Inspection of the rotor winding may be made by removing the outer positioning sleeve which is held in place by two rows of machine screws at each end of the rotor frame. When the screws are disengaged, the outer sleeve may be slipped back from the rotor frame exposing the winding to view. The slip-ring shaft then may be removed by giving it a gentle pull away from the rotor frame.

An aluminum cabinet, Fig. 9, houses the variable and fixed tuning capacitors for resonating the goniometer primary and secondary inductances over the frequency range

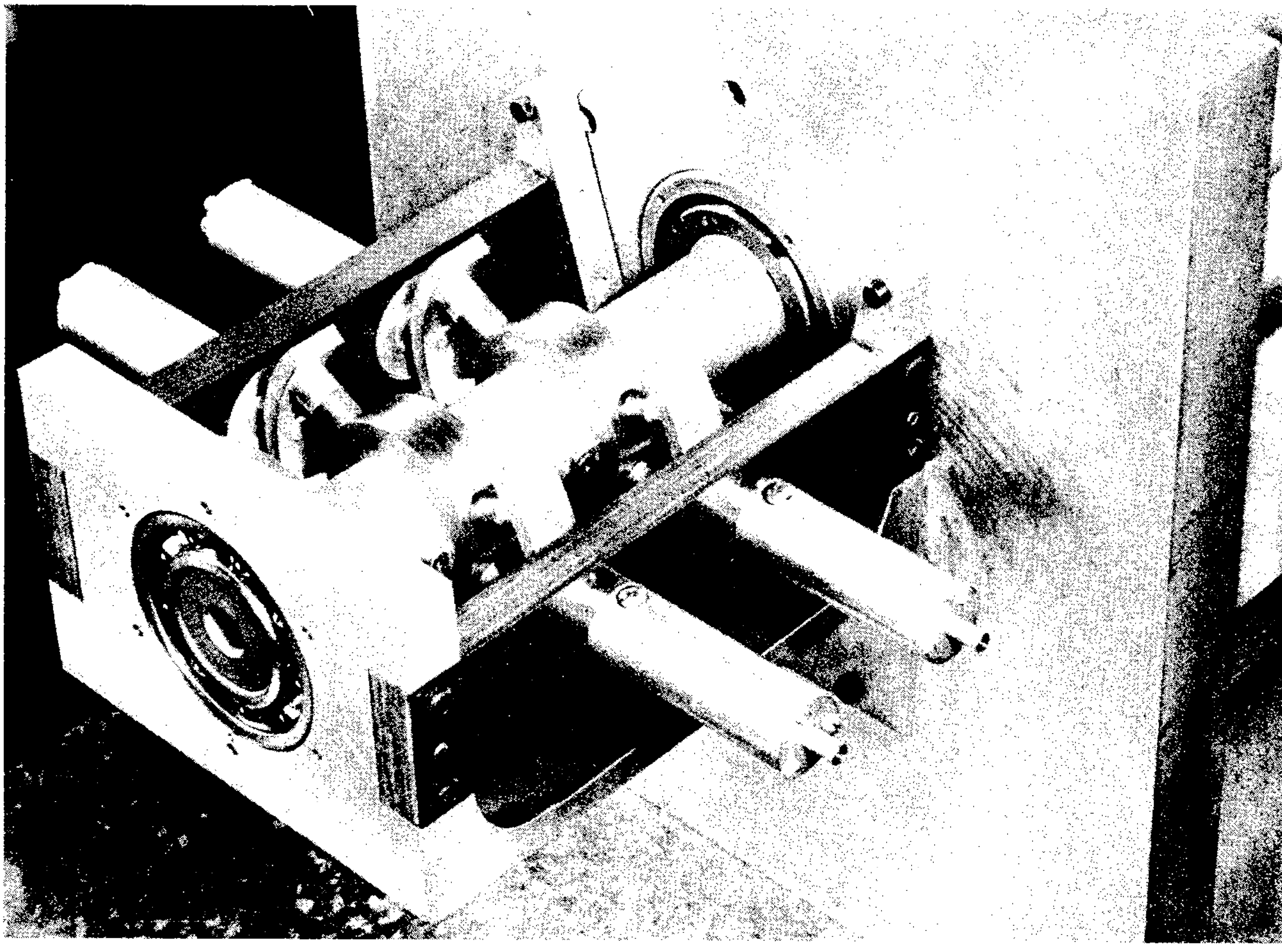

Fig. 4 Collector Rings and Brushes

190 to 400 kc. The cabinet is divided into three compartments to provide for shielding of the components associated with the goniometer input and output circuits. Fig. 10 shows the arrangement of the fixed and variable tuning capacitors inside the cabinet. Wiring connections are made with tinned copper strap. A wiring diagram of the unit is shown in Fig. 11.

ELECTRICAL DATA

The electrical tests on the goniometer were conducted at a frequency of 194 kc at the Avon, Indiana, LF omnirange station. Goniometer characteristics were obtained with the secondary windings terminated in dummy resistive loads of 35-ohms each. With the rotor current held constant, the voltage across the secondary loads was measured with a General Radio Model 726-A V.T.V.M. for each 10° rotation of the rotor. The data obtained from these measurements were plotted and showed the departure from a true sine wave to be approximately five per cent. Nulls were sharp and displaced by 180° from each other. (See Fig. 12)

The reflected impedance characteristics plotted in Fig. 13, showed a variation of 6.5 per cent. Measurements were made with CAA impedance bridge, Type AC-263 and also by the ammeter-voltmeter method. Both methods of measurement showed approximately the same amount of variation. Measurements were made for each 10° position of the rotor with secondary windings terminated in 35-ohm resistive loads.

With an rf carrier input of approximately 500-watts, the secondaries terminated in 35-ohms dummy resistive loads, the efficiency measured 95 per cent. This value was obtained for an input power of 490-watts

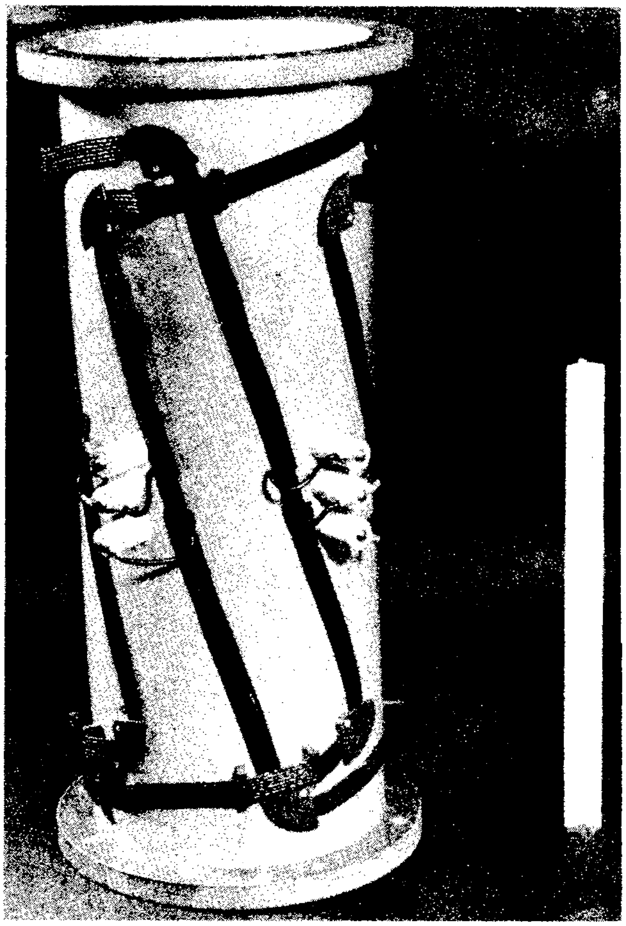

Fig. 5 Stator Winding Assembly

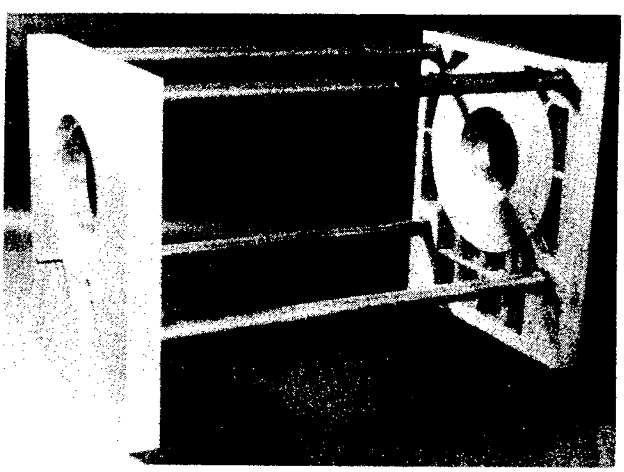

Fig. 6 Aluminum Frame

(I_p = 2.8 amp and R_p = 63-ohms). The output power, indicated by a General Radio Model 726-A V.T.V.M. measured 470-watts

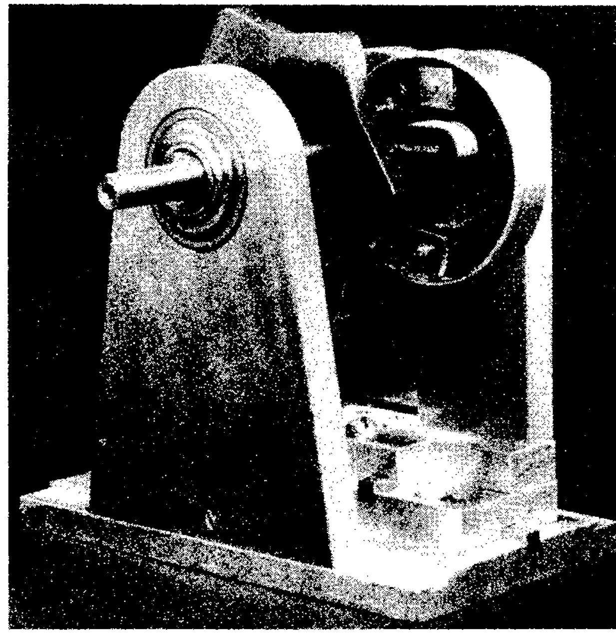

Fig. 7 210-cps, FM, Tone Wheel

(130-volts rms across a 35-ohm resistive load).

Since the rf power available at the Avon station was limited to 500-watts, it was not possible to test the goniometer at its rated input of 3 kw. Therefore, tests were made using the rated rf currents in the rotor and secondary circuits independently. The rotor circuit was tested with a current of 8 amp through collector rings and brushes for a period of six hours. No undue heating of any electrical or mechanical component was observed at the end of the test period. The ambient temperature was 82° F with the goniometer running at normal speed. The collector rings and brushes showed no appreciable rise in temperature above the room ambient and no evidence of insulation breakdown or flashover was indicated throughout the test. The secondary windings were tested at an rf current of 11 amp for a 4-hour period in an ambient temperature of 81° F. The temperature rise in the windings was approximately 15° above ambient at the end of test. No insulation rupture or flashover or undue heating of the tuning capacitors was noticeable during the test period.

Inductance measurements on the rotor gave a value of 113 microhenries and a Q of 365. The secondary inductance measured 101 microhenries and Q of 270. The mutual in-

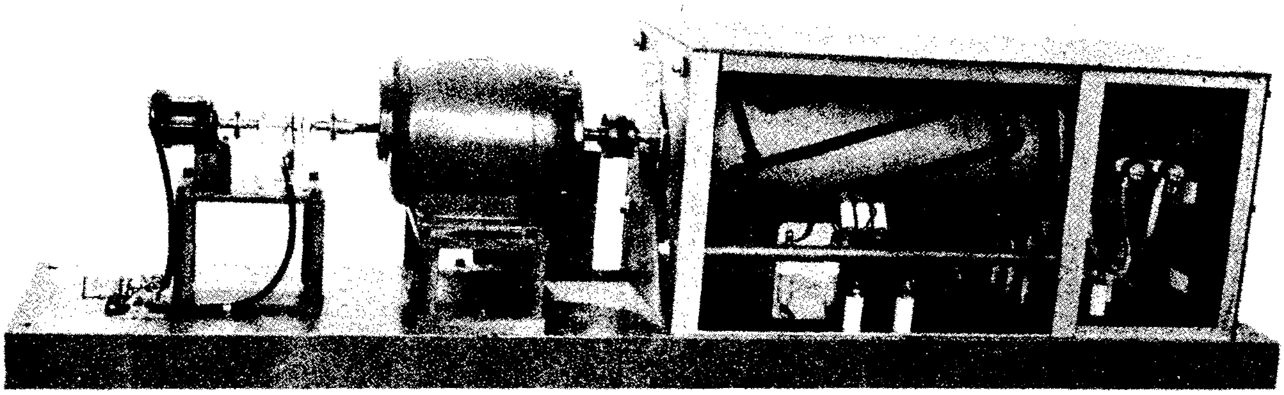

Fig. 8 Goniometer With Driving Motor, Complete Assembly

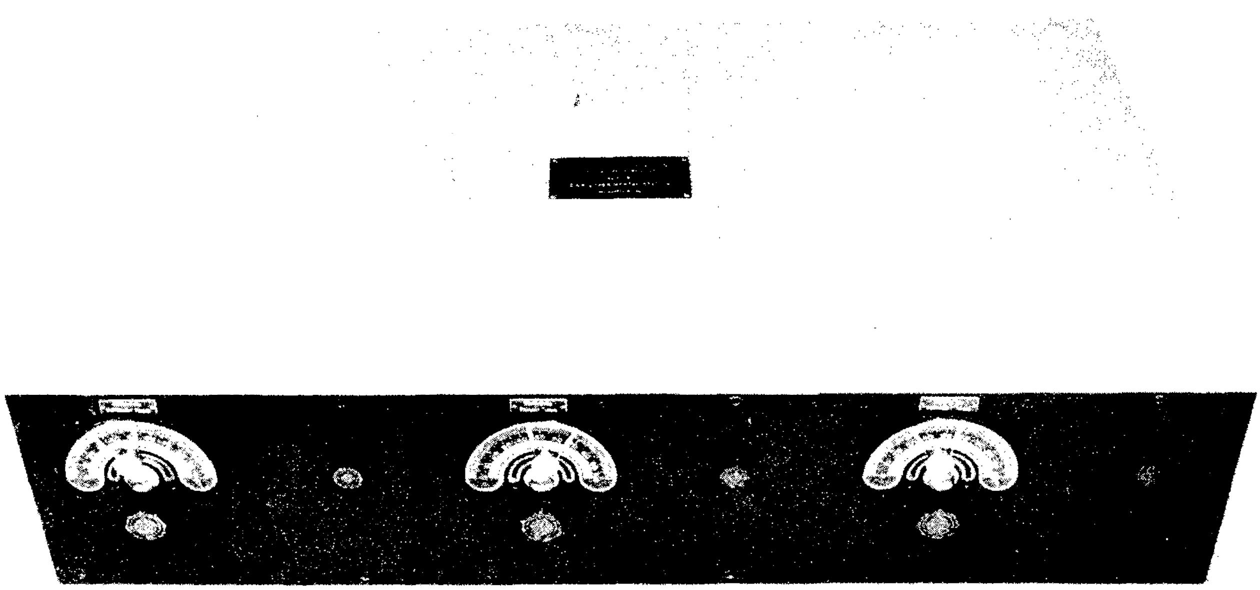

Fig. 9 Tuning Cabinet

ductance for maximum coupling between rotor and secondary measured 38 microhenries. All measurements were made at 200 kc and were made with a Boonton Type 106-A Q-meter.

Rf current ratings for the fixed tuning capacitors are indicated as follows:

Type	Capacitor Mfd	Current at 200 kc	Current at 300 kc
191 - 50	.004	8.6 amp	12.0 amp
961 - 30 BL	.002	5.0 "	7.5 "
960 - 30 BL	.001	3.0 "	4.5 "
959 - 30 BL	.0005	1.5 "	3.0 "

To avoid excessive currents and abnormal circuit voltages, the rated input current (7 amp) to the goniometer should not be exceeded. Some positive means of removing rf power to the goniometer should be provided at the transmitter in case of accidental removal of either secondary load during normal operation.

A 0-10 amp rf meter or 10 amp rf fuse (Littlefuse) should be installed in series with the transmission line feeding the goniometer to provide protection for the rotor circuit during abnormal conditions.

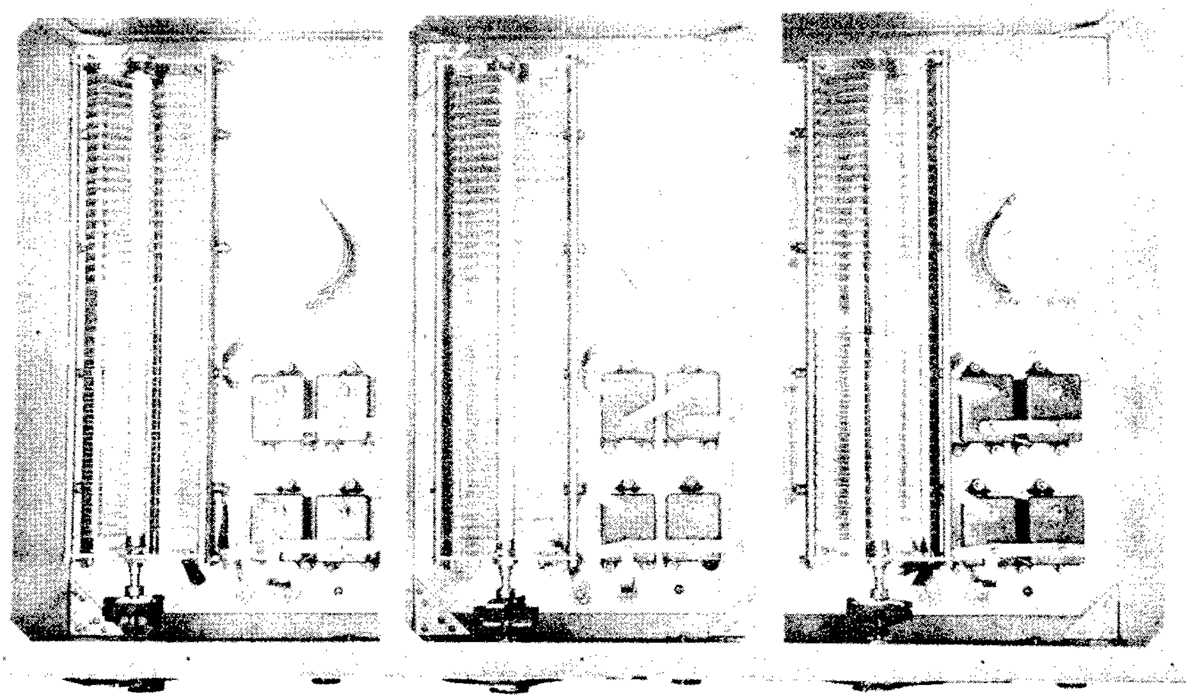

Fig. 10 Inside View of Tuning Cabinet

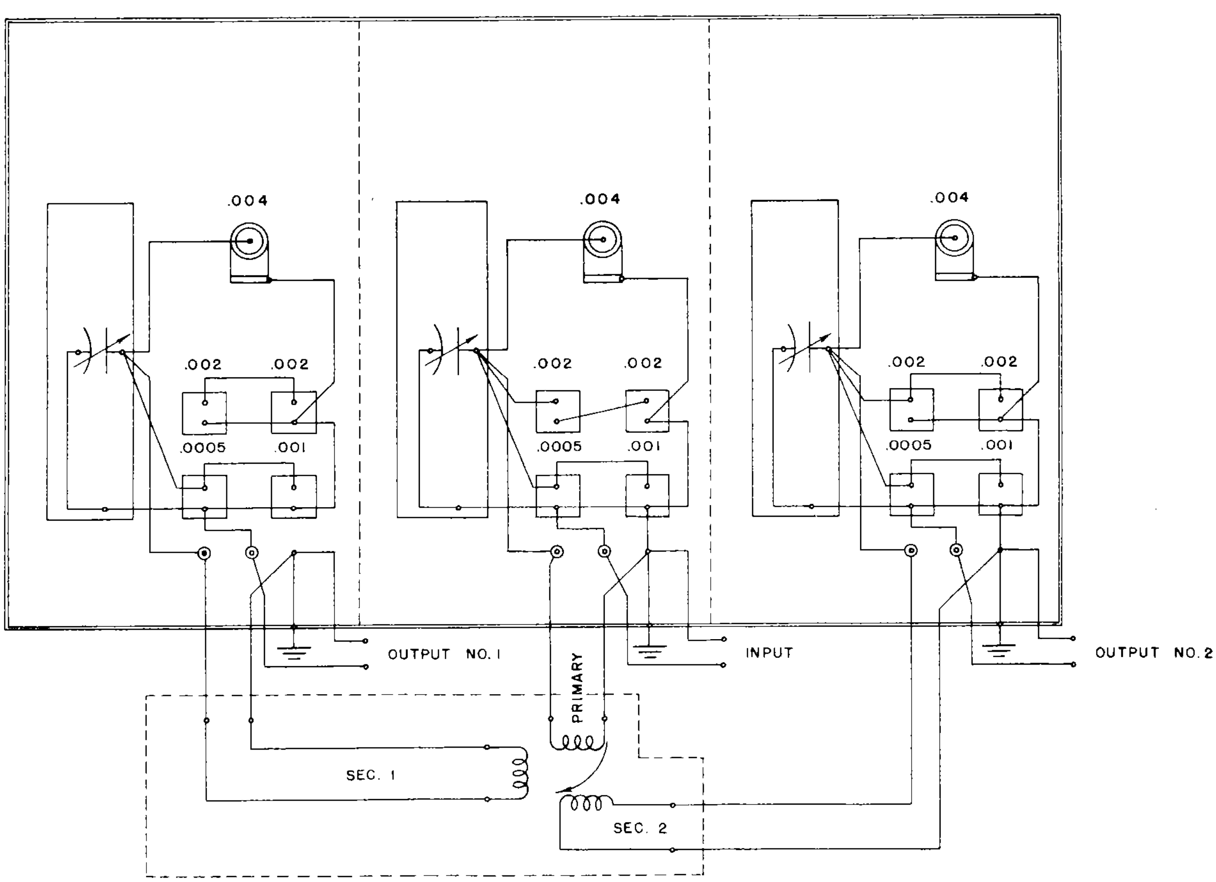

Fig. 11 Schematic Diagram of the Low Frequency Rotating Goniometer

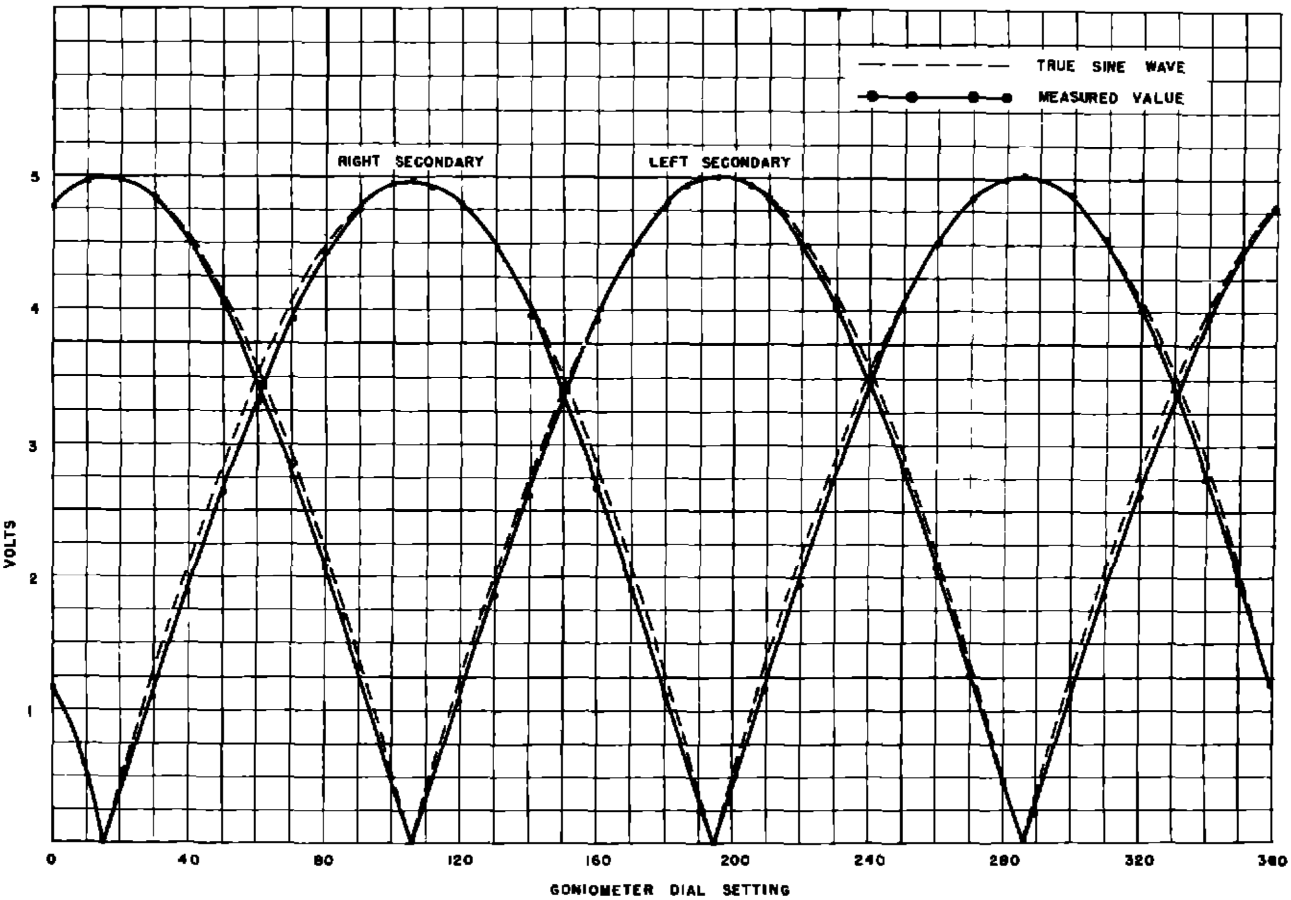

Fig 12 Goniometer Characteristics

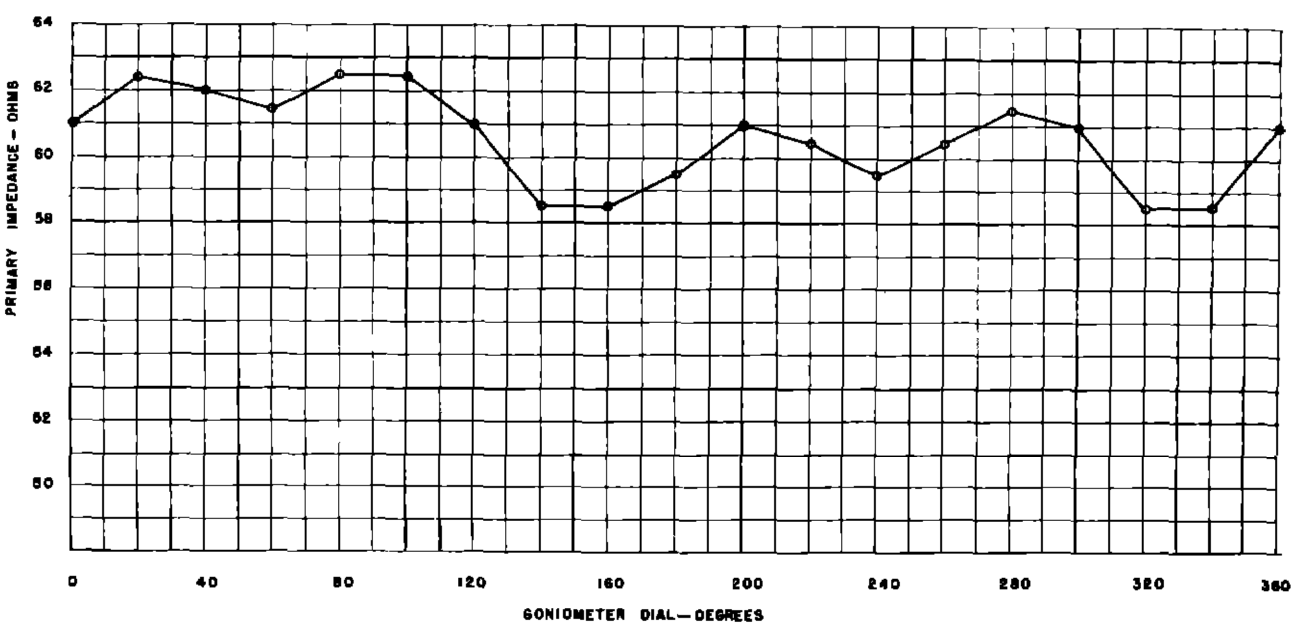

Fig 13 Goniometer Input Impedance Characteristics

GPO CH FSO 7-20-49 2 000