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Report
on
Completely Portable Radioactivity Meter
Requiring
No High Voltage Battery

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ABSTRACT

A radioactivity meter has been designed which has certain special features such as light weight, complete portability, high sensitivity and which requires no high potential battery for its operation.

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AUTHORIZATION

1. This instrument was designed and constructed in connection with the problem of developing methods for detecting defects in non-magnetic materials, as authorized in references (a) and (b).

Reference: (a) BuAer let. Aer-E-252-FAM L5-2(1)
JJ46-1 of 14 Sept. 1936.

(b) BuEng 1st end. JJ46-1/L5(6-9-Ds)
of 17 Sept. 1936.

2. In view of the fact that this radioactivity meter may be of interest in other naval problems where radioactivity is involved, this report will be limited to a description of this instrument.

STATEMENT OF PROBLEM

3. In studying the possibilities inherent in the use of radioactive substances for testing metals and metal parts for defects, as reviewed in NRL Report No. M-1389, a need was seen for a portable detector of radioactive material sensitive to extremely minute amounts of radioactive material, completely portable (requiring no external power supplies, etc.), light, and convenient for use. An instrument meeting all such requirements could not be obtained in the market and required development.

KNOWN FACTS BEARING ON THE PROBLEM

4. During the past years, research in radioactivity has produced various tools for its study such as electroscopes, electrometers, ionization meters, and Geiger-Müller counters. The latter are known to be the most sensitive devices yet discovered and considerable valuable literature on them has appeared. In addition, various attempts have been made to incorporate Geiger-Müller counters in portable apparatus with fair success, but even in these portable outfits there is much to be desired. Gringrich, Davis, and Edgerton* have described a semi-portable meter which requires attachment to electric mains for operating. G. L. Locher has developed a portable G.M. detector which is fairly heavy because it requires many internal batteries for producing a high voltage and in addition requires auxiliary apparatus to make it serviceable as a quantitative instrument or meter.

DESCRIPTION OF APPARATUS

5. The general exterior view of this radioactivity meter is shown in Plate 1 and consists of a main cabinet containing the supply batteries, voltage generating apparatus, impulse rate measuring apparatus, and an extension part which allows the sensitive Geiger-Müller counter tube and its detector tube contained therein to be conveniently brought into any desired location. In Plate 1 may be seen alongside of the extension handle, a glass Geiger-Müller tube of the type contained in the mounted handle. The Geiger tubes were made at the Naval Research Laboratory by Messrs. P. D. Kueck and J. T. Carruthers.

6. Telephone jacks are provided on the main case for plugging in telephones for listening to the pulses in the Geiger tube circuit or for any auxiliary amplification and recording apparatus which may in special cases be found desirable. The apparatus as shown, without telephones, weighs about 20 pounds.

7. Plate 2 shows the main case with the upper portion carrying the indicating meters removed. It may be noted that no disconnection of meter leads is required for the meter terminals bear directly on beryllium bronze contact springs on pillars fixed to the chassis. The midget batteries supplying filament and plate power for the five vacuum tubes of the set are located in the center of the chassis and are readily replaceable.

8. Plate 3 shows the bottom of the chassis with cover plate removed. The left end of the chassis contains the sockets for plugging in the Geiger-Müller extensions and the telephones, the switch and other apparatus for the detecting and measuring part of the instrument. The right end of the chassis contains the apparatus for generating and controlling the necessary high voltage for operating the Geiger-Müller tube. This part is controlled by its own switch so that it is possible to use the outfit independently as a source of high d-c voltage for voltages up to around 1400 volts and power not to exceed 1/2 watt. The high voltage in this apparatus is not derived from a bank of small cells as in some instruments, but from a vacuum tube oscillator circuit discussed farther on.

9. Plate 6 shows the details of the extension handle. The 1A4 type vacuum tube is mounted slightly off center to permit the high voltage cable to extend to the upper end of the case. The Geiger tube is mounted in a bakelite tube which in turn is mounted in a porcelain vacuum tube base. This arrangement allows Geiger tubes to be changed at will. Details of connections within the case are evident from the drawing.

10. The complete circuit diagram of the instrument is shown in Plate 4. The upper part of the diagram shows the oscillator circuit for generating the high potential for the Geiger tube. This circuit was suggested to the writer by Mr. R. M. Page of the Radio Division. Some experimenting was required to find the necessary coil inductances and arrangements to make the circuit function. Most of the circuit constants are given in Plate 4. The three coils L₁, L₂, and L₃ form the members of an air core transformer, the construction of which is illustrated in Plate 5. The winding B is the tickler coil L₁; the winding C, the plate circuit coil L₂; and the two windings A connected in series form the high voltage secondary coil L₃. These coils are insulated from the others, as shown, by disks of empire cloth. Coils A are universal wound inductances of about 42 millihenries each, inside diameter 1/2 inch, outside diameter 2-1/8 inches, and thickness 1/8 inch. The wire is #35 D.S.C. The windings B and C were made from a single universal wound coil of inside diameter 1 inch, outside diameter 2-3/8 inches and thickness 1/2 inch containing about 480 turns of #24 enamel and silk covered Litz wire. The winding was broken at about 190 turns and the 190 turn inside portion used for coil L₁. The compact tight

coupling of this arrangement was found quite necessary to get the maximum voltage from the secondary coils.

11. In Plate 4 it may be noted that the plate supply battery is connected so that the battery voltage is added to the peak positive voltage generated in the coil enabling a higher rectified voltage to be obtained than that due to just the coils alone.

12. In operation the circuit may tend to oscillate at either one of two frequencies, but if the oscillator is started by sudden application of the plate voltage after the filament is emitting, the circuit oscillates at its higher frequency giving the larger voltage. The anticapacity switch for the battery supply may be adjusted to do this.

13. The voltage output of the oscillator unit is indicated by a 0 - 200 microammeter in series with a 10 megohm resistor. It may be controlled grossly by changing the plate supply voltage. With 135 volts on the plate, the voltage output will be around 750 - 900 volts depending on the internal resistance of the batteries used. With 270 volts it was found possible to obtain around 1450 volts, at which the type 30 rectifier tube would break down. The voltage can be regulated continuously over a certain range by altering the grid potential with the potentiometer R. With 135 volts on the plate the output voltage is continuously variable from 450 to 750 volts. The output voltage is quite steady if no advanced deterioration of the plate battery is present. The plate current varies from 5 to 10 milliamperes depending on the voltage demand.

14. The second part of the circuit, the radioactivity meter circuit is shown in the lower part of Plate 4. A part of this is a multivibrator neon tube coupled circuit which has been proposed by T. H. Johnson ** as a very reliable circuit for recording Geiger counter pulses. Since this circuit delivers uniform pulses in the plate circuit of the second tube, it was possible to develop a simple form of counting rate meter. The output pulses of the second tube are passed through the primary of a 1:6 output transformer. The voltage pulses in the secondary are rectified by another type 30 tube and are fed into the tank circuit shown. The tank condenser consists of two 40 mf midget electrolytic condensers of 100 volt rating. Either a 100 or 200 microampere meter may be used as the pulse rate indicating meter. The tank circuit is equipped with three variable resistances controlled by a three way toggle switch permitting three degrees of sensitivity of the meter.

15. A brief description of the operation of the circuit may be given now. A radioactive particle or radiation quantum passes through the Geiger tube GT starting a discharge which is immediately quenched by the 10^9 ohm resistance. A negative pulse is communicated to the grid of the 1A4 tube, which normally operates with plate current flowing. The potential of the point P in the circuit has previously been adjusted to a value just below the flash point of the neon tube N. The negative pulse on the grid causes the potential of point P to rise and a discharge through N takes place giving a

positive pulse to the grid of the second tube and a negative pulse on the plate of this tube which is fed back through condenser C₆ to the screen grid of the 1A4 tube which is held in a non-conducting state while the condenser C₆ is discharging through the 0.1 megohm resistance. The neon discharge glow stops, allowing the grid of the second tube to become negative again and a positive pulse to be transmitted back to the screen grid of the 1A4 tube locking it for an instant in the conducting state while the condenser is relaxing. Meanwhile the pulse in the plate circuit of the second tube has caused a definite charge to flow into the tank condenser and counting rate meter circuit.

REMARKS ON OPERATION AND USE

16. This instrument was designed with high sensitivity, flexibility, and ease of portability as the main objects in mind. These have been fairly well realized in this instrument but of necessity they have been obtained at the expense of a certain amount of possible ruggedness and ability to operate continuously over fairly long intervals of time. To reduce the weight midget batteries were incorporated. These do not have the life that heavier batteries have. Since the apparatus was designed for detecting and measuring weak sources, its usefulness is limited when strong radioactive sources are involved.

17. In spite of these limitations the instrument has been found to be quite serviceable. When used intermittently for services not over two or three hours, the batteries retain their vigor fairly well. The instrument is fairly rugged and not harmed by the ordinary shocks of transportation and use. The flexible extension makes it possible to bring the Geiger-Müller counter tube into any position easily and also to introduce it into small spaces such as the interiors of pipes, castings, etc. The Geiger tube itself is quickly and easily replaced with another because of its vacuum tube base. Thus the breaking of a Geiger tube will not interrupt the use of the instrument if spare tubes are available.

18. The instrument as shown in Plate 1 has proved very useful in recovering a 3 milligram radium capsule lost at a service hospital. At a distance of ten feet this small source gives a large indication on the instrument. Location of this radium capsule would have been very difficult, if not impossible, by means of the ionization radium finder used at present by the Navy Department for locating lost radium capsules of high strength (100 milligrams or more).

19. The present instrument may be redesigned so that it can be used for locating radioactive sources of any strength, by utilizing a scaling circuit devised by Johnson** which automatically registers only an arbitrary fraction of the number of discharges in the Geiger tube. This feature would require two more vacuum tubes calling for an increase in both weight and size of the apparatus and was therefore not attempted.

20. The instrument is so constructed that large batteries can be installed through a simple change in the size of the instrument. It may be noted that the case of the instrument is a standard make

of amplifier cabinet. By placing another one of the upper members of the cabinet inverted below the chassis, a large battery compartment is easily obtained.

SUGGESTED USES AND RECOMMENDATIONS

21. While designed for a special purpose, this instrument has other possible applications that may well be pointed out here:

- (a) The measurement of the radioactive content of luminescent materials and manufactured articles such as instrument dials, etc.
- (b) A means of testing persons for possible poisoning by radioactive materials or contamination of rooms and work places by radioactive matter.
- (c) A means of testing directly the intensity of radiation from x-ray apparatus and radiographic radium to insure the safety of operating personnel. Tests of this type might well be incorporated in safety codes pertaining to the use of gamma rays and radium.
- (d) Experiments conducted abroad appear to indicate that the Geiger-Müller counter enables a rapid indication of the thickness of metal parts by measurement of the intensity of x-radiation passing through. Claims of detecting 1% changes in wall thickness of metal tubes are made.***

BIBLIOGRAPHY

- * N. S. Gringrich, R. D. Evans, and H. E. Edgerton, Rev.Sci.Instr. Vol.7, Dec.1936, pp.450-456.
- ** T. H. Johnson, *ibid*, Vol.9, July 1938, pp. 221-222.
- ***A. Frost, Stahl u. Eisen, Vol. 58 (1938) pp. 668-670
Abs. Metals and Alloys, Oct. 1938, p. MA 616.

APPENDIX

List of Standard Parts Required for Construction of Naval Research Laboratory Radioactivity Meter.

- 1 - Budd Radio Inc. Amplifier Cabinet, 5" x 13-1/2" x 8-3/4" size.
- 7 - Isolantite 4 prong tube sockets.
- 2 - Anticapacity switches.
- 1 - Type 1A4 vacuum tube.
- 4 - Type 30 vacuum tubes
- 2 - Telephone jacks.
- 2 - 0-200 or 0-100 microammeters.
- 1 - Output transformer 1:6
- 1 - Neon lamp, GE Type CD-1010-C₁ 0.4 watt.
- 1 - Variable resistor, Clarostat 250,000 ohms.
- 1 - Filament resistor 15 ohms.
- 9 - Resistors, fixed; (1) 1,000 megohm; (2) 10 megohm;
(1) .2 megohm; (3) 0.1 megohm; (1) 50,000 ohm; and
(1) 10,000 ohm.
- 5 - Capacitor, fixed: 500 μ f, 5 μ f, (2) .01 μ f, 0.5 μ f.
- 2 - Capacitances, electrolytic, Dubilier 100 v. 40 μ f.
- 1 - Capacity .02 μ f oil vibrator 1,000 v.
- 6 - Batteries, midget B, Burgess, W30 F1 45 v. 8 oz.
- 4 - Batteries, clock type, Burgess No. 312, 1.5 v. 5-1/2 oz.
- 2 - Batteries, 7-1/2 v. C, Burgess, 5540.
- 1 - Auto lamp, Mazda base.

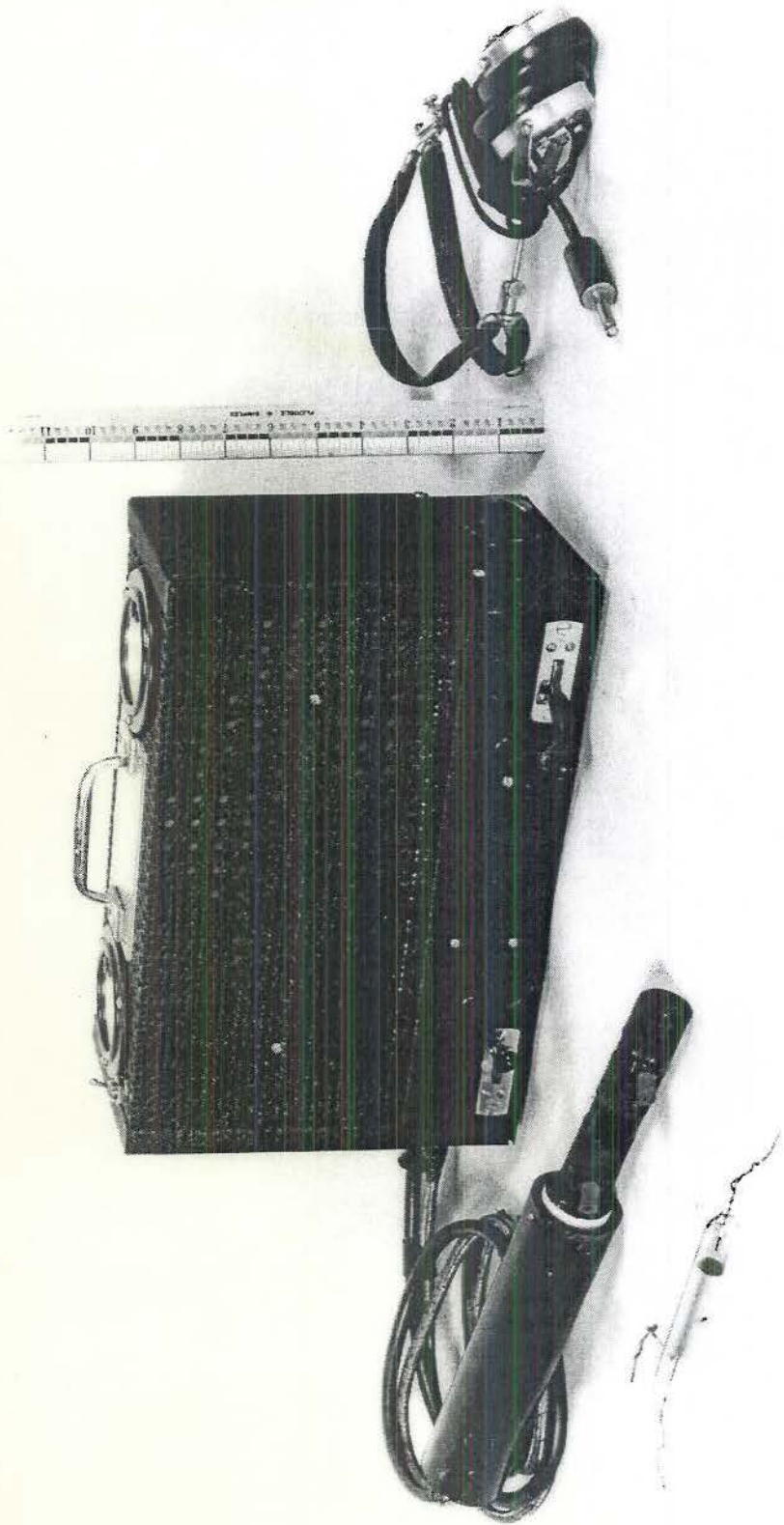


Plate 1

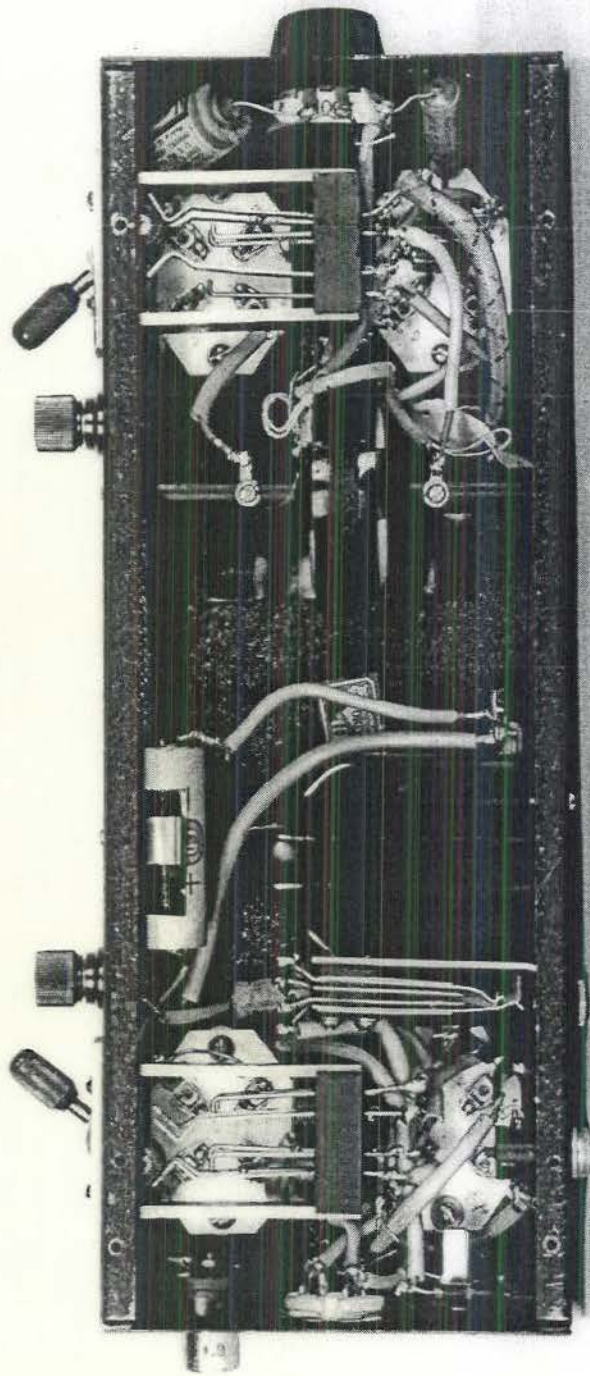


Plate 2

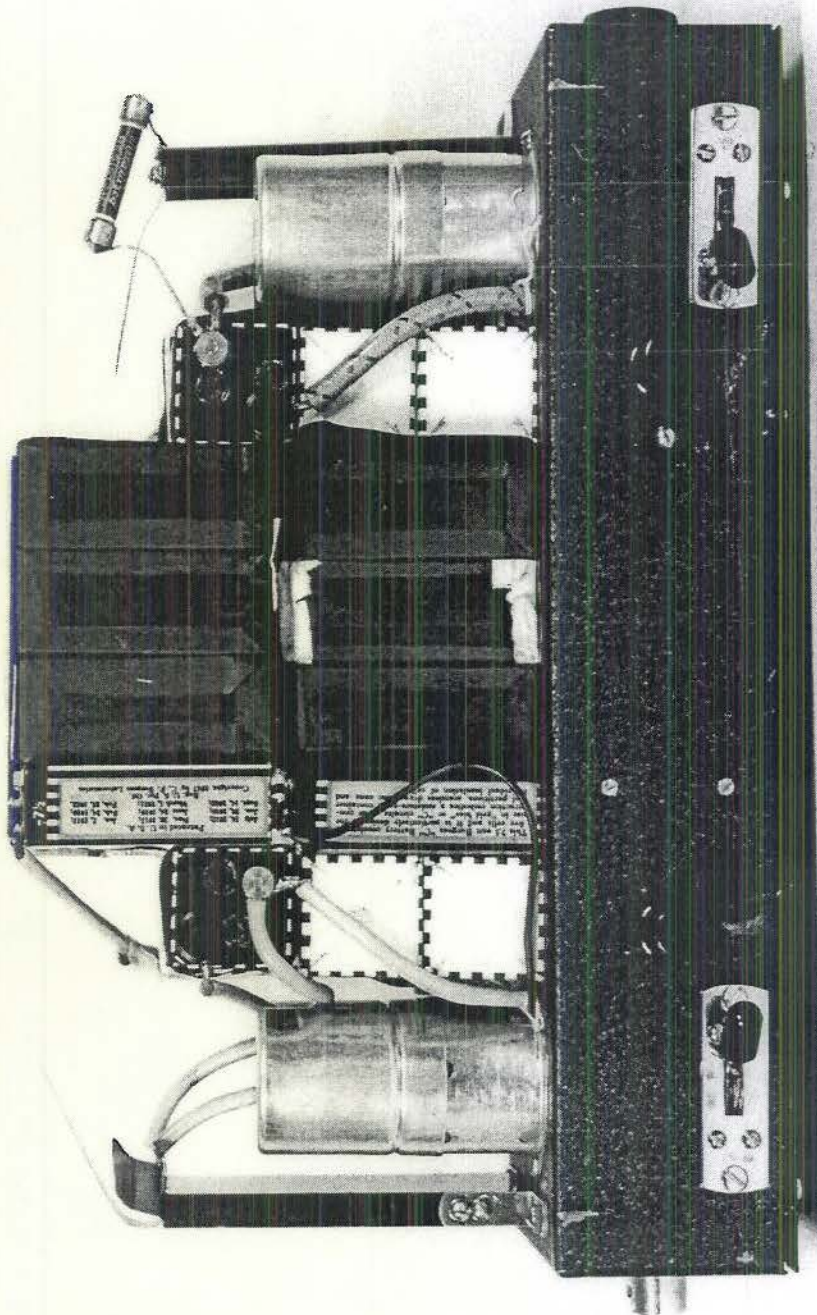
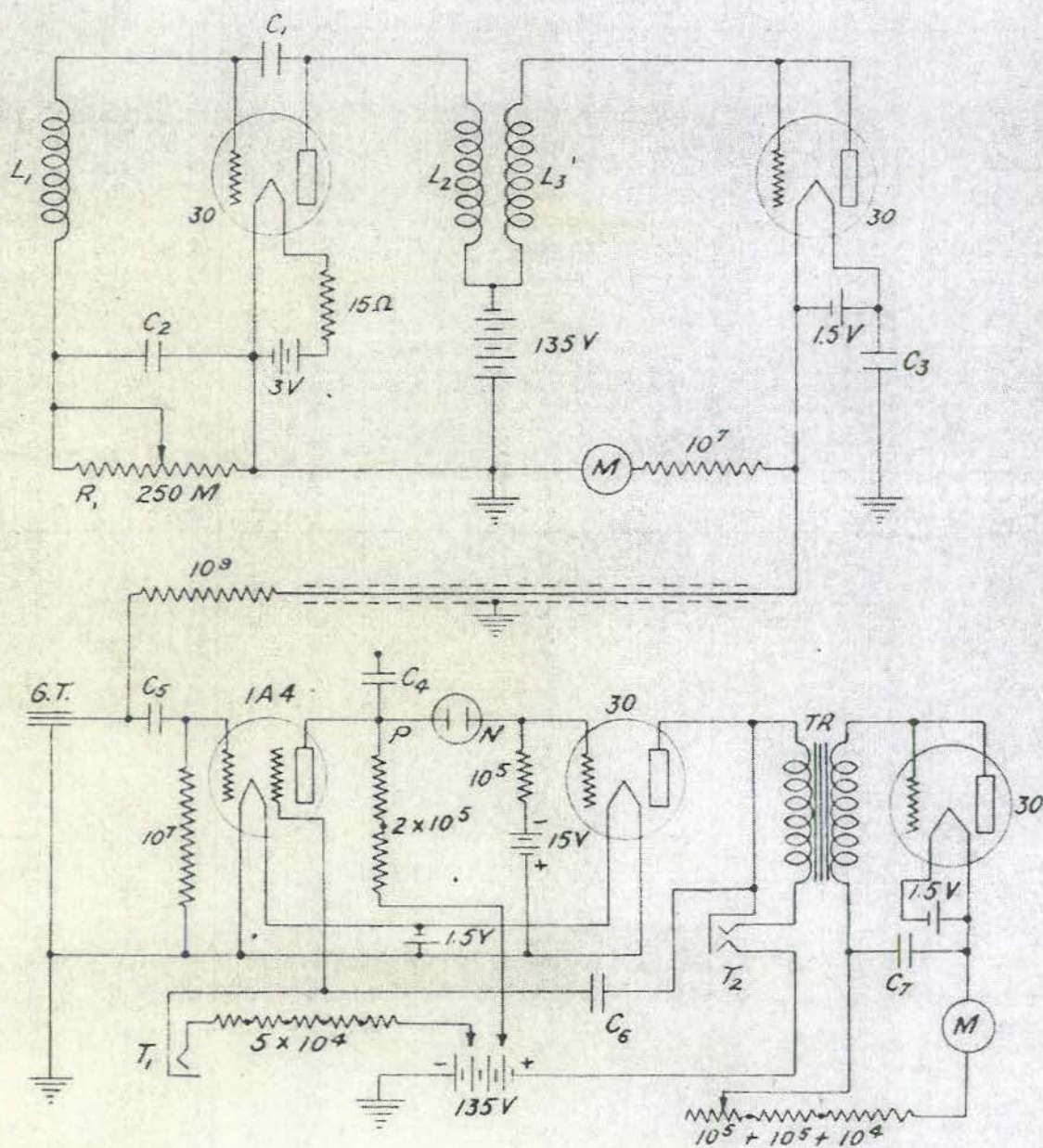


Plate 3

CIRCUIT DIAGRAM FOR PORTABLE RADIOACTIVITY METER

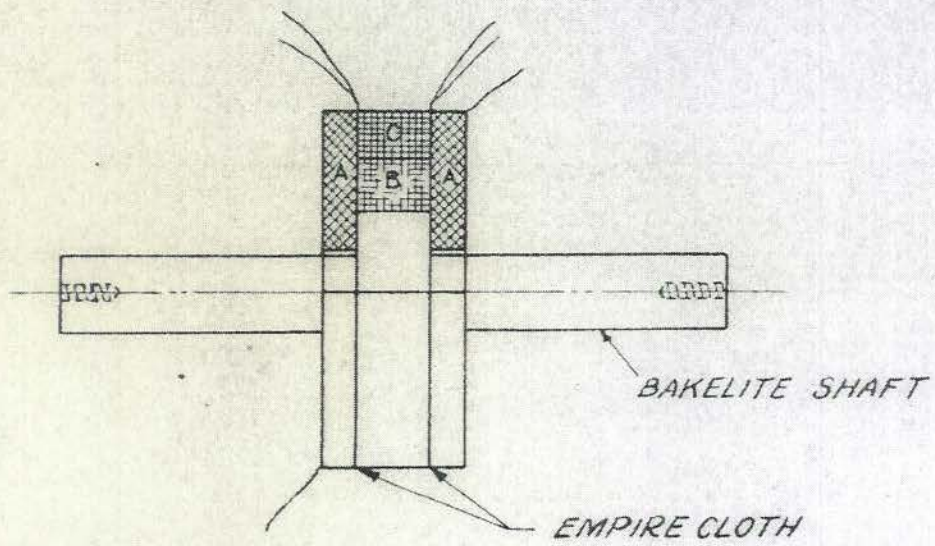


CAPACITANCES

- $C_1 = 500 \mu\text{mf}$
- $C_2 = 0.01 \mu\text{mf}$
- $C_3 = 0.02 \mu\text{mf}$ (OIL VIBRATOR TYPE)
- $C_4 = 0.01 \mu\text{mf}$
- $C_5 = 5 \mu\text{mf}$
- $C_6 = 0.5 \mu\text{mf}$
- $C_7 = 80 \mu\text{mf}$ (MIDGET ELECTROLYTIC)

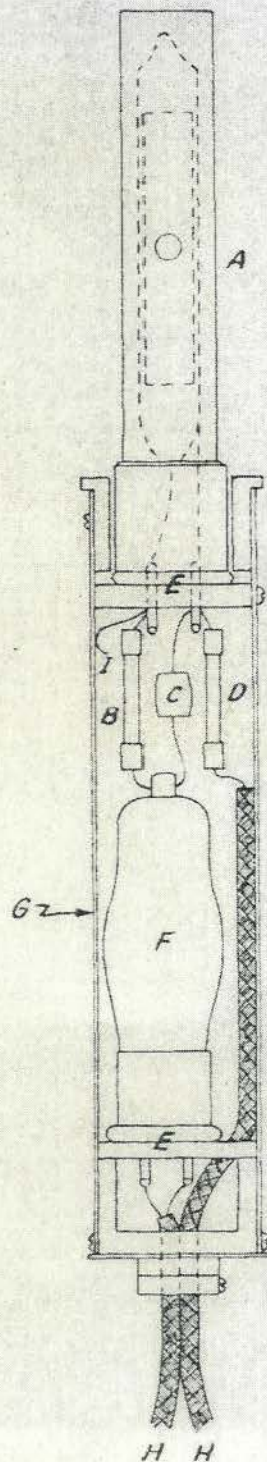
OTHER PARTS

- N = NEON LAMP, GE TYPE CD-1010-C1, 0.04 WATT.
- T_1, T_2 = TELEPHONE JACKS
- TR = OUTPUT TRANSFORMER, 1:6 RATIO
- GT = GEIGER MÜLLER TUBE
- M = 0-200 OR 0-100 MICROAMMETERS
- L_1, L_2, L_3 = OSCILLATOR AIR CORE TRANSFORMER



AIR CORE TRANSFORMER FOR OSCILLATOR

GEIGER TUBE AND EXTENSION HANDLE



- A. GEIGER TUBE.
- B. RESISTOR, 10 MEG.
- C. CONDENSER, 5 MMF.
- D. RESISTOR, 1000 MEG.
- E. ISOLANTITE SOCKET.
- F. TYPE 1A4 TUBE.
- G. BRASS CASE.
- H. SHIELDED CABLE.
- I. GROUNDING SPRING.

SCALE - $\frac{1}{2}$