A PORTABLE DEVICE FOR DETECTING RADIO-MOTIVE ORES

by

Ronald Smith.

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A PORTABLE DEVICE FOR DETECTING RADIO-ACTIVE ORES.

Introduction:

Tremendous interest has been aroused in Canada over the recent discovery of rich radium ore deposits in the Great Bear Lake district. The probability of the location of still further deposits in the neighborhood makes this an opportune time for the development of a practical instrument capable of indicating the presence of radium ore. Prospecting for radio-active ore deposits directly by the detection of the gamma radiations from them has in the past been confined to the use of the electroscope. Satisfactory operation of this instrument in the open is handicapped by several practical difficulties, such as the fragility of its working parts and the necessity of keeping it absolutely dry.

(1) H. Geiger and W. Müller, Phys. Zeits. 29, 839, (1928)
Some subsequent work on the Geiger-Müller tube is described in the following literature.

(2) H. Geiger and W. Müller, Phys. Zeits. 30, 489, (1929)

(3) H. Kniepkamp, Phys. Zeits. 30, 237, (1929)


An instrument is here described that attains all the sensitivity of the electroscope to gamma rays and is moreover conveniently portable and fool-proof in use, requiring no technician to operate.

The Geiger–Müller Counting Tube:

Advantage was taken of the Electron Counting tube developed by Geiger and Müller in 1928 for the purpose of detecting gamma and similar radiations. It was necessary to modify these tubes so that they could be operated on a voltage low enough to be practical for a portable outfit.

Such a tube consists of a hollow metal cylinder and a wire arranged concentrically, the space between these two electrodes being filled with a gas at a pressure of 7 cm. of mercury or less. A high potential is applied across the two electrodes through a resistance of the order of $10^9$ ohms. A two or three stage radio amplifier
enables current surges in the circuit to be detected. (Fig. 1).

When the potential across the Geiger-Müller tube is raised sufficiently clicks are heard in the loudspeaker at irregular intervals. The frequency of these clicks will be greatly increased if a small quantity of radium is placed close to the tube. The residual count, when all radio-active materials are removed from the neighborhood, is due to cosmic rays and stray gamma rays from the earth, a click being heard when one of these passes through the tube.

There is a definite minimum operating potential which depends on the dimensions of the wire and surrounding metal cylinder, and on the gas between the two. Above this threshold there is a voltage range, the breadth of which depends on various variable conditions in the gas or on the inner metal surfaces, in which the count per minute is fairly constant; this count being assumed to correspond to the number of cosmic and gamma rays passing through the tube. Above this range, spurious clicks are produced, the number increasing with the applied potential.

A Low Operating Potential:

The majority of Geiger-Müller tubes used for laboratory purposes contain air at from 3 to 7 cm. pressure, requiring from 1000 to 1500 volts to operate them. As this is nearly prohibitive for field work, it was necessary to develop a tube working on a much lower voltage.
There are three main factors which determine the threshold potential.

1. Diameter of outside metal cylinder.
2. Pressure of the gas in the tube.

The variation of the threshold V with the diameter b of the metal cylinder is given by the formula

\[ X = \frac{2V}{a \log b/a} \]

where X, the electric field at the surface of the wire remains constant for a constant wire diameter a; that is, the less b is, the lower will be V. However the lowering of b is accompanied by a corresponding decrease of the effective area of the tube, thereby decreasing the sensitivity. On this account a diameter of 1/2 to 5/8 inches was chosen as the most satisfactory size. The voltage varied very little with the radius of the wire, fine tungsten or manganin wire being used throughout.

It has been shown that the threshold potential of a Geiger-Müller tube changes with gas pressure in the same way as does the sparking potential of the gas used. Consequently a considerable decrease should be obtained by lowering the pressure of the gas. In this way the voltage was reduced to six or seven hundred volts for air at one to ten millimetres pressure; but spurious clicks

produced at voltages little above the threshold in this region made the tube unreliable for measurement purposes. In addition the sensitivity (count per minute) was very appreciably decreased at these pressures, as Geiger and Müller have already pointed out.

The third variable, the nature of the gas held the greatest promise of giving results. A number of workers have used gases other than air in these tubes successfully, it being found that each gas requires in general a different operating voltage. The lowest potential reported by Geiger and Müller for any gas investigated by them was that for argon. Bosch and Klumb and Schulze have shown however that inert gases have certain distinguishing properties when used in these tubes. Using pure neon and helium they obtained a continuous discharge on raising the voltage above the threshold, as against the rapidly extinguished discharge characteristic of base gases. When a trace of air or other base gas was added, a normal click was produced.

In view of these results a tube was baked out in a good vacuum and pure argon admitted. This gas exhibited the same properties as reported for pure neon and helium. Upon heating the tube again with the argon in it, it was found that, provided the brass had not been thoroughly baked out, enough occluded gas could be driven off

(7) C. Bosch and H. Klumb, Die Naturwiss. 18, 1098, (1930)
(8) W. Schulze, Zeit. fur Physik 89, 92, (1932)
to cause the tube to click normally. The threshold potential was now about 360 volts at one centimetre pressure and moreover the reliable voltage range compared favorably with that for air at 5 cm. pressure.

It was found that if one of these argon tubes was sealed off, its characteristics sometimes changed over a period of time. If the brass had been well baked out before admitting the pure gas, the trace of gas driven off by re-heating as above seemed to be re-absorbed by the metal, the tube developing a tendency to discharge continuously. On the other hand if no de-gassing was done the threshold voltage would sometimes rise after a month or so, apparently owing to gases diffusing out of the brass into the argon. To obtain a condition under which the gas mixture would remain constant indefinitely, a partial de-gassing was first given the assembled tube, which was then filled to the proper pressure with argon containing a small percentage of air. From seven to ten millimetres pressure was found most satisfactory, an operating potential of from 350 to 450 volts being then required. Neon gas, when tried in the same way, showed similar properties, requiring about 50 volts less than argon under the same conditions.

The Complete Portable Outfit:

Having developed a Geiger-Müller Counting tube which would operate on a reasonably low voltage, it was now necessary to construct a complete
portable outfit comprising a tube and all its auxiliary equipment.

A suitable design of the tube is shown in Fig. 2.

![Fig. 2](image)

The outer electrode \( B \), a length of brass tubing \( \frac{5}{8} \) inches in diameter and from one to six inches long, is held in place by a copper wire \( W \) soldered to it and clamped onto the tungsten wire \( T \) sealed into one end of the pyrex glass covering \( D \). The central electrode \( M \), a fine tungsten or manganin wire, is suspended at one end from a glass hook \( G \), fused onto the glass wall, and at the other by a second tungsten wire sealed into the outer case. The final seal off, at \( S \), is made at one end. In this way all side projections are eliminated, allowing the tube to be conveniently handled or packed.

One end (\( T' \) in Fig. 2) is then immersed in paraffin inside a glass container just wider than the diameter of the tube itself, the series resistance (\( R \), Fig. 1) going in with it. This outer covering acts not only as a
protection but also prevents any electrical leakage at the terminal $T_1$, an important factor because of the high resistance ($10^9$ ohms) of $R$. The whole is now enclosed in a hollow cylindrical wooden case, a length of insulated wire connecting this unit to the rest of the apparatus.

The auxiliary equipment consists of a set of ten 45 volt batteries, a two-stage audio amplifier and a pair of ear-phones. The electrical arrangement is shown in Fig. 4, the plate voltage for the amplifier being tapped from the 450 volts supplying the Geiger-Müller tube. Small radio "B" batteries were obtained and they together with the amplifier were mounted in a water-proof case on a standard pack-board, the whole weighing about 55 pounds.

The ear-phones are plugged in, the two leads from the tube connected to their corresponding terminals and the complete apparatus carried as shown in Fig. 5. The tube is mounted on the end of a light handle so that it can
be kept close to the ground.

**Fig. IV.**

**Fig. V.**

**Sensitivity Tests.**

As with all small Geiger-Müller tubes, the number of clicks per minute when all radio-active material is removed from the neighborhood varies considerably from minute to minute. One tube gave the following readings for twenty consecutive minutes:

10, 12, 11, 8, 10, 13, 13, 10, 9, 13, 6, 11, 14, 9, 9, 13, 7, 10, 10, 10

each figure being the number of cosmic and stray gamma rays passing through the tube during that minute. For five minute counts, however, the percentage variations are much smaller, as the following readings obtained from the same tube show:

51, 58, 49, 50

Thus it may be seen that by taking five minute readings only, an increase of three gamma rays per minute through the tube could be definitely detected. In case of doubt as to whether a high count is due to additional radio-active material in
the neighborhood or to statistical fluctuation of the normal count, a longer reading will settle the question.

Tests were made with radium and radium ore. A 53 gram piece of pitchblende from Great Bear Lake containing 60% uranium oxide and about 9 thousandths of a milligram of radium gave a count of 62 for five minutes when six feet from the detecting tube and 88 when three feet away. The zero count (no radium in the neighborhood) was 51.

Eighty milligrams of radium, kindly loaned by Dr. G.W. Prowd of St. Paul's Hospital, Vancouver, could be detected at a distance of 350 feet taking only five minute readings. Results of a test with this standard are shown in Table 1 and the graph in Fig. 6.

<table>
<thead>
<tr>
<th>Distance (feet)</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count (5 minutes)</td>
<td>265</td>
<td>139</td>
<td>99</td>
<td>82</td>
<td>64</td>
<td>55</td>
</tr>
<tr>
<td>Zero Count:</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
It may be seen from the graph that the inverse square law is obeyed within the limits of statistical error.

It is of interest to note that only about five out of every ten thousand gamma rays passing through the tube are detected. This ratio was arrived at from the available data on gamma rays from radium in conjunction with the results of the afore-mentioned test with 80 milligrams of radium.

Other uses for this instrument, besides that of prospecting for radium ore may suggest themselves; for example, the locating of radium needles mislaid in hospitals.

Dr. G.M. Shrum of the University of British Columbia is responsible for the original idea of adapting a Geiger-Müller tube to the purpose outlined in this
paper and has also taken an active part in the development of the complete instrument.
TRIBO-ELECTRIC EFFECT BETWEEN GLASS AND MERCURY.

Introduction:

When a partially evacuated glass tube, containing several grams of mercury, is violently agitated, light is given off which is easily observed in a dark room. The explanation of the production of this light was the purpose of this investigation.

Two possible alternatives were considered:

1. tribo-luminescence between the mercury and glass;
2. discharges in the gas contained in the tube between opposite tribo-electric charges generated on the mercury and glass surfaces.

Tribo-luminescence.

Most solids exhibit tribo-luminescence to some degree, the effect being produced by rubbing or rupturing the surface. Light with a continuous spectrum is emitted, the intensity distribution varying for different materials. No liquids have been reported as showing this phenomenon or as being successfully used as exciters.

1. Karl: Comptes Rendu 146, P. 1104; 1907
W. Kluge: Ann. der Physik 1, 1 P. 1, Jan. 2, 1929.
Tribo-electricity.

The tribo-electric effect is the production of opposite electrical charges on two surfaces of different material when they break contact or are rubbed together. Dawson has investigated the case for mercury and quartz, obtaining a charge of 1 e.s.u./cm.\(^2\) on a quartz plate which had been quickly separated from a clean mercury surface. A potential difference of 350 volts existed between the two when 1.5 millimetres apart.

Thus a spectroscopic analysis of the light in question should decide whether a tribo-luminescent or tribo-electric effect is taking place. If the former is correct, a continuous spectrum should be observed; if the latter, the characteristic spectrum of the gas present in the glass tube should appear.

Experimental Procedure.

Preliminary experiments with various gases and gas pressures resulted in argon at about .4 millimetres pressure being used for the first trials, this gas giving the greatest luminescence of any tried. The kind of glass or purity of the mercury used, within certain limits, had no appreciable effect on this.

A small spectroscope with a long collimator and short focus camera lens for good light.

gathering power was used. A mechanical device for shaking the tubes with a nearly vertical motion enabled the slit to be continuously illuminated. Even so the feebleness of the light made exposures of from 12 hours to 3 or 4 days necessary.

Experimental Results:

A plate taken with argon at .4 millimetres pressure in a pyrex tube showed 26 lines on it, 6 of which were identified as strong lines of the mercury spectrum from 4048 to 5769 Å, 7 as lines in the argon red spectrum, 12 from the argon blue spectrum and one as the Hα line of water vapour.

A pyrex tube containing air at .5 millimetres pressure gave two strong lines which corresponded to two of the first negative bands of nitrogen: 3914 and 4278. Three very weak lines were also present.

A faint line spectrum was obtained from a quartz tube containing an unknown gas and producing a relatively feeble luminescence.

Conclusion:

These results indicate definitely that the light emitted by these tubes is coming from the gases present in them, that is, from small discharges between opposite charges produced on the mercury and glass walls. No evidence of a continuous spectrum being observed at any
time, it is concluded that this phenomenon is purely a triboelectric effect.

The presence of only the first negative bands of nitrogen on the plate from the air tube was explained when practically the same distribution of intensities was found in the spectrum of a weak ring discharge through this tube; that is with the low potential gradients obtained in both cases the first negative bands predominate. The existence of only small voltage differences also explains the greater luminosity of the argon tubes, since argon has a lower sparking potential than air.
A SIMPLE APPARATUS FOR SPUTTERING METALLIC FILMS.

A convenient form of apparatus for cathode sputtering of thin metal films has been constructed. A large bell jar 10 cm. in diameter and 20 cm. tall, with a ground opening (G, Fig. 1) at the top and a ground lip at the bottom rests flat on a plate glass base (B), the joint being made air-tight with stop-cock grease. The top section, T, which is ground to fit the opening G acts as a support for the demountable cathode, C, and also as a connection to the pumping system. An aluminium anode (L, Fig. 2) is bolted to the base B through a hole drilled in it, the gaskets S with thin layers of stop-cock grease serving to make the connection leak-proof and to ease any strains on the glass plate.

As it is essential that no metal be exposed in the discharge chamber other than that actually being sputtered, (the aluminium anode excepted since it does
not sputter appreciably) the tungsten hook supporting the cathode is coated with glass, a small point being left exposed to make electrical contact with the cathode hook. For the same reason there is only a small opening (J, Fig. 1) from the chamber to the pumping system.

The cathode is constructed to suit the requirements of the work to be done. It must have a flat surface of diameter greater than the width of the object to receive the metallic film and held from two to four centimetres above it. Copper cathodes can be electro-plated with many metals with which it is inconvenient or expensive to make a complete cathode. In any case only the one metal being sputtered should be exposed during the discharge.

From 500 to 1000 volts D.C. are required to operate the discharge, although satisfactory work has been done using A.C. voltage. The pressure is adjusted so that the surface to be coated is tangent to the edge of the cathode dark space, i.e. about .04 millimetres of mercury.

Good results have been obtained with this apparatus in silvering, a half-silvered surface on a Michelson interferometer mirror proving superior to those previously prepared by chemical means. Best optical glass may be sputtered in this way, there being no appreciable heating effect if the discharge is run sufficiently slowly.
A SENSITIVE PHOTO-ELECTRIC QUANTUM COUNTER FOR ULTRA-VIOLET LIGHT.

A Geiger-Müller quantum counting tube has been developed that is notable for its great sensitivity to ultra-violet light. Its construction differs in no way from the standard design of Geiger-Müller tube, consisting of a polished tungsten wire .07 millimetres in diameter suspended in the centre of a length of 5/8 inch brass tubing 9 cms. long, the whole enclosed in pyrex glass as shown in Fig. 1.

Fig. 1: T-Brass tube; W-Tungsten wire; Soldered Connection at S.

A sensitive cathode surface was prepared by heating the whole tube in vacuum till some of the zinc in the lump of solder at S evaporated; then when the brass was allowed to cool, the zinc deposited in a thin layer over the inside wall at one end. The tube was now filled with neon at 9 millimetres pressure and sealed off, operating in the dark similarly to other Geiger-Müller tubes.
The specially treated end was sensitive to ultra-violet light of wave-length not more than 3100 Å. and although pyrex glass transmits very little radiation below 2900 Å., the sensitivity seems to be greater than that of the best surfaces investigated by G.L. Locher recently, using a quartz window.

Counts from two different light sources are shown:

<table>
<thead>
<tr>
<th>Source</th>
<th>Distance</th>
<th>Cathode Area</th>
<th>Count/min</th>
<th>Count/min/sq.cm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-luminous 7 metres</td>
<td>.04 sq. cm.</td>
<td>48</td>
<td>60,000</td>
<td></td>
</tr>
<tr>
<td>Bunsen Flame</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 Watt Lamp 7 &quot;</td>
<td>.015 &quot;</td>
<td>45</td>
<td>150,000</td>
<td></td>
</tr>
</tbody>
</table>

Locher gives a value of 188 in the last column for a Bunsen flame, using a tin cathode, although a recalculation from his readings indicates that this figure should have been 1880 instead of 188. His most sensitive surface to ultra-violet light was 15 times as sensitive as the tin cathode, but even this is less efficient than the cathode surface here described.