

or C equal $(bB \text{ minus } aA \text{ over } (a \text{ minus } b))$
 A and B may be computed from the dimensions of the variable condensers.

Now let the potential initially on the system be V , i. e., the potential of the battery used. Let the capacity of the condenser at this position be D . Then we may write

$$Q \text{ equals } V(D \text{ plus } C)$$

Also as above

$$Q \text{ equals } ka(A \text{ plus } C)$$

and

$$V(D \text{ plus } C) \text{ equals } ka(A \text{ plus } C)$$

$$k \text{ equals } V(D \text{ plus } C) \text{ over } a(A \text{ plus } C)$$

The variation of k can thus be determined over the entire range of the scale and deflections can be read as potentials. This gives the charge associated with any position of the leaf (since the capacity of the electroscope is known). The rate of fall of the leaf can then be read as rate of loss of charge. This gives the ionization and consequently the radioactivity measured.

Summary

This electroscope has sufficiently high sensitivity to measure the expected radioactivity in gases. It will detect an activity only twenty times as great as that present normally in the atmosphere and will measure with considerable accuracy an activity but little greater than this.

Its construction is simple and all parts are easily accessible for repairs. It is sufficiently rugged and compact to be used for field work.

Measurements may be made with it more rapidly than with types of apparatus now in use. Recalibrations when necessary may be easily and quickly made.

XXX. SOURCES OF DIRECT CURRENT IN HIGH SCHOOL LABORATORIES

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There are a number of experiments both in the laboratory and in the lecture-room that call for direct currents which must be stronger than those which can be furnished by the ordinary primary battery. Since in many schools there are practically no other sources of direct current than that just mentioned, it was thought that it would not be amiss to call attention to some of the methods of producing direct current and, along with the different methods, mention something of the expense involved in each. It should be

said at the outset that it is not the purpose of this paper to do away with the primary battery since practically all of the principles of electricity can be demonstrated by its use. The history and development of electricity is very closely related to its study, and yet, useful as it is, it has its limitations. Both teachers and pupils are constantly wishing for a good strong current to work with and it is to these that this paper is addressed.

Since practically every school is provided with alternating current it is natural that it should be looked to as a source of power. To make this power available, however, two important changes are involved: that of rendering the current direct, and that of reducing the voltage to a value suitable for use in the laboratory.

Various devices have been made for this purpose, the most common being the motor-generator, the electrolytic rectifier, and the vacuum tube rectifiers; the best examples of the last are the mercury arc rectifier and the tungar rectifier. The so-called rectifiers are all alike in that they take the alternating current and transform it into a unidirectional pulsating current. A single rectifying unit allows one pulsation to pass through and stops or strangles the other, that is to say, the current can pass in one direction but not in the other. When both halves of each cycle are desired it is necessary to combine two or more units.

In the case of the motor-generator we have an entirely different type of change. The A. C. current is sent into an A. C. motor which either by belt or shaft, turns the armature of a D. C. generator which delivers a current of practically constant value. For all uses, for durability, and for cost of up-keep, the motor-generator set is the most satisfactory—the first cost is practically the only cost. If handled properly it will take care of the needs of a laboratory for years and years. The cost of a set installed usually runs from \$700.00 up to \$1000.00 or more depending upon the capacity desired. For a majority of the smaller high schools the price is prohibitive; often times they have not much more than that to expend upon their entire equipment. For this type of school the electrolytic rectifier or Nodon Valve commends itself. Its cost is small and with little care it can be used almost indefinitely. The writer made one for \$3.00 which he used for ten years in connection with classes totaling from 100 to 150 students each year. The supply houses put out one that can be purchased for \$25.00; it is a little more convenient than the home-made type is likely to be.

The Nodon Valve consists of a lead-aluminum cell with suitable electrolyte, usually bicarbonate of soda, which allows the passage

of the current in one direction but not in the other. If a 110-volt direct current be sent through such a cell making the aluminum plate the cathode there is practically no resistance offered by the cell but when the aluminum plate is made the anode an entirely different result is obtained. At the instant the circuit is closed—if it is a fresh-cell and there is little resistance in the circuit—the current rushes through with a strength of several amperes but drops to a fractional part of an ampere in three or four seconds. With the dropping of the current there is a simultaneous rush of the voltage from less than 10 volts up to a value near 80, and in

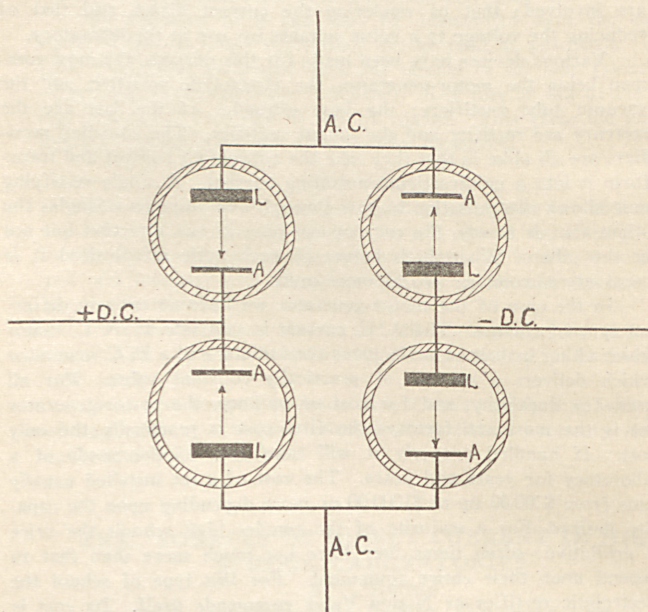


Figure 8

less than a minute it reaches almost 110 which is practically the same voltage it would show on open circuit.

This phenomenon was first observed by Wheatstone about seventy years ago but no use was made of it until approximately fifty years later when Pollak and Groetz, each working independently, conceived the idea of using it to convert an alternating current into a direct current. With a single cell one alternation is eliminated

while the other passes through the cell and is made use of as a pulsating unidirectional current. With four cells it is possible to rectify both alternations thus making the capacity twice as great. In this form, as shown in figure 1, it was placed on the market by a Paris firm in 1904. In practically the same form the Nodon Valve was manufactured and placed on the market in this country two or three years later. While it has not proved to be what some of its early supporters claimed for it there is nevertheless a distinct advantage in its use where more expensive devices cannot be had.

It is possible to get as much as eight or ten amperes at fifty or sixty volts but that strength of current cannot be maintained for an indefinite period without some method of cooling. In ten or fifteen minutes the ordinary cell will not heat sufficiently to cut down its efficiency materially but in an hour it probably will do so. On small currents not exceeding an ampere or two it is not necessary to give it any attention even though the rectifier is in continuous use for two or three hours. Fortunately it is seldom that a heavy current is wanted for a very considerable length of time.

One of the reasons for the lowering of the efficiency due to the rise of temperature is that at the higher temperatures the so-called film on the aluminum plate tends to break down. The theory is that when the aluminum plate is made the anode electrolysis is set up which tends to cover the aluminum plate with a film consisting mainly of aluminum oxide. The length of time needed to build this film depends upon current-intensity. If only a small fraction of an ampere is used it will require from forty-five minutes to an hour; with eight or ten amperes the film appears almost instantaneously, the voltage across the cell rising as has just been mentioned, to eighty in three seconds. In a few minutes the voltage reaches a maximum and the so-called film is completed. The theory offered by Nodon, and later up-held by Burgess and Hambeuchen of Wisconsin, is that the so-called stoppage is due to an ohmic resistance offered by the film. Wilson measured the resistance of the cell and reported it something like 10,000 ohms. The writer made several measurements and obtained values ranging from 7000 to 1100 ohms depending upon temperature of electrolyte and general conditions of the cell. Guthe, Taylor and Inglis, and Cook offered different theories. Cook's theory is worthy of special mention. He held that the resistance of the cell was due to a counter-electromotive force set up by the highly charged anions collecting about the anode and not being allowed to discharge on account of the non-conductivity of the film. This seems a more

plausible theory than the former since its valve effect is evidently connected with making of the aluminum-plate the anode, whereas, if it were nothing more than an ohmic resistance, the film would not allow the passage of the current practically unhindered in the opposite direction

The effect of the temperature of the electrolyte upon the efficiency of the cell was studied and observations were taken over a considerable length of time, varying conditions of cell and electrolyte, varying sizes and shapes of plates, and over a considerable range of temperature. It was found that with an increase of the temperature there was a decided weakening of the film. This resulted in slightly increased current and in a sufficiently lowered voltage so that the power efficiency fell from a value of 50%—usually the highest value obtainable with the electrolytic rectifier—down to as low a value as 30%. Another factor introduced by the high temperature of the electrolyte was the tendency for more of the solute to go into solution. This solute crystallized on the plates when the temperature fell and the presence of these salts had a tendency to destroy the valve effect.

It is possible to keep the temperature down by means of a cooling device but for the greater amount of the work these high-current long runs are not necessary and the use of the Nodon Valve in the laboratory is not greatly impaired. Large currents used for short times and small currents used for long times cause little or no lowering of the efficiency. The rectifier will therefore lend itself well to most uses of direct current in a small laboratory. The only care that need be given it is that of lifting the plates out of the solution when not in use and removing any excess solute undissolved at ordinary temperatures so that the tendency of salts to crystallize on the plates is removed. Sodium bicarbonate solution serves very well as an electrolyte; the chemically pure salt is not essential. It is not necessary to renew it or change the solution very often as there is practically no breaking up of the compound. In fact one charge was used for three years with little or no apparent diminution in the efficiency of the rectifier.

The writer's experience has been that the use of the mercury arc is rather limited. While one can get strong currents at rather high efficiencies from a mercury arc the cost is rather high and, if expense of bulb renewals is taken into consideration, the cost soon approaches that of a motor generator set, which, for all purposes, is much more satisfactory. The mercury arc cannot operate on small currents since considerable current is required to maintain the arc. A few years ago, with the advent of the "movie," the mercury

arc rectifier enjoyed quite a popularity commercially but in recent years it has for the most part been replaced by the motor-generator. Recent experiments, however, show that the mercury arc is particularly fitted for high-tension rectification, and here in turn the large cumbersome and expensive rotary converters may be replaced by the light and comparatively inexpensive arc rectifiers. This very thing is being done today successfully on some of the Swiss and German electric railways.

The use of the tungar rectifier in the laboratory is also limited since it operates best at small currents; it can be made to operate on a few milliamperes. The prevailing type that is being put on the market makes use of only one half of the cycle; this pulsating effect makes the current hard to measure with direct current instruments unless considerable reactance is put into the circuit. This, of course, cuts down the out-put. A type that would deliver sufficient current smoothed out with a reactance so that the current could be read with a fair degree of accuracy would cost approximately as much as a motor-generator. For simplicity of operation, however, it is almost ideal and it is particularly suitable for charging secondary batteries. In the laboratory it can be used for small currents, and for larger currents when the pulsating effect is not objectionable. The fact that it is a lamp socket device, comparatively light and portable, one that can be hooked up anywhere, and one that is free from any care when not in use, is one not to be over-looked.

The common commercial electrolytic rectifier, although requiring considerable care and attention, uses both pulsations. With some reactance in the circuit it gives a fairly constant current, the pulsating effect being almost negligible except for currents near eight or ten amperes. On account of its wider steady-current range suitable for laboratory use, and especially on account of its cheapness, it is recommended for use in the small high school. While it is not as convenient to move about as the Tungar, it is nevertheless portable and can be moved from laboratory to lecture room as occasion demands.

For the larger high school the motor-generator is much more desirable. Although it is not portable the connecting wires can be led to any desired point. The current produced is practically constant since it is subject only to the slight fluctuations of the A. C. voltage.

The question then resolves itself into one of expense. If an amount from \$300.00 to \$500.00 is available, install a motor-generator set; if little or nothing is available, invest a dollar or two in material and construct an electrolytic rectifier.