Laboratory and Shop Notes

A 40-Centimeter Trochoidal Type Mass Spectrometer: Trochotron*

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A LARGE mass spectrometer in which the ion paths are prolate trochoids has been built, following the design principle of Bleakney and Hipple,[1] and has been in operation several months. This "trochotron" uses the theoretically perfect double-focusing properties of crossed uniform electric and magnetic fields. The distance between the source and receiver slits in the grounded plate is 40 cm, while in most other particulars the construction is similar to the prolate instrument described by Bleakney and Hipple. An all-metal vacuum system is employed. An internal voltage divider is used for the aluminum "picture frames" that establish the electrostatic field.

Operation with collector currents as high as 0.3 microampere has been entirely satisfactory for masses up to Ce^{140}, the heaviest element studied extensively. The resolution is approximately one-half the value expected from geometrical consideration using slits 0.020 inch wide and 3 inches long.

Modifications of the apparatus are to be used in separation of stable isotopes in pure microgram quantities and isotopic analysis.

The original instrument was designed and constructed under the direction of W. A. Arnold, J. D. Trimmer, and H. W. Savage.

* This letter was submitted to the Atomic Energy Commission, Oak Ridge, Tennessee, for declassification on April 2, 1947.
1 W. Bleakney and J. A. Hipple, Phys. Rev. 53, 521 (1938).

A Method of Photographing a Cloud Chamber between the Poles of an Iron Magnet*

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THE production of strong magnetic fields in cloud chambers has been accomplished in two ways: by the use of air core coils through which a high current is passed during a short duty cycle, and by the use of iron magnets, magnetized permanently or by means of coils. The pulsed air core coil method is suitable in some applications, but cannot, of course, be used for a counter-controlled chamber. The performance of an iron magnet suffers seriously from the fact that a hole as large as the cloud chamber has to be provided in one of the pole pieces to accomodate the optical system. We wish to propose an optical system which will eliminate the necessity for using a hollow pole piece.

A strip of mirror, about 1 inch wise and inclined at 45 degrees to the plane of the cloud chamber is mounted on a light weight carriage, which also carries the camera (see Fig. 1). After the expansion of the chamber, the carriage

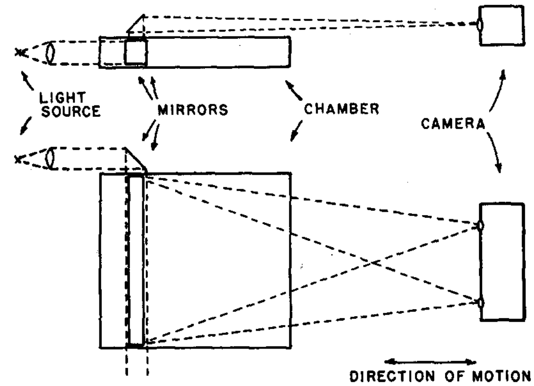

FIG. 1.

moves so that the mirror travels quickly across the chamber, "wiping off" the image. The carriage can conveniently be made to move at a sufficiently high, uniform velocity by means of compressed-air pistons. The film in the camera has to move at an appropriate rate during the stroke. Illumination of the tracks is accomplished by means of the small square mirror mounted on the carriage at the side of the chamber and at 45°, which deflects a parallel beam of light across the chamber below the mirror strip, from a stationary light source. An alternate arrangement can be used, in which the camera is stationary. In this a second, larger 45° mirror is placed on the carriage at the position occupied by the camera in Fig. 1. The second mirror reflects the light into the stationary camera. Such an arrangement, however, requires more space between the chamber and the upper pole piece, and approximately doubles the length of the optical path.

The principal advantage of the system described is that it greatly increases the effectiveness of the iron magnet, both in field strength and in uniformity of field, by allowing solid, flat pole pieces to be used. Only about one inch of gap length is required in addition to that which the chamber occupies. A secondary advantage is that a darker background can be obtained, due to the fact that while one part of the chamber is being photographed, light is not scattered into that region from other parts of the chamber. The light source must give an intense, narrow beam of light which lasts for the order of $\frac{1}{10}$ second. A pulsed carbon arc satisfies this requirement.

Apparatus using the principle described is being constructed for use with the synchrotron. It should also be effective in reducing the weight of cosmic-ray cloud-chamber magnets which are to be flown.

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A Hexade Scaling Circuit

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IT is customary to use the 60-c.p.s. line for the introduction of a time axis into oscillographic records of low frequency phenomena. This relatively high frequency

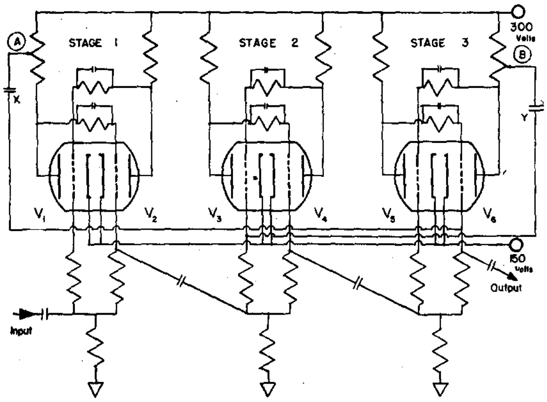

FIG. 1.

PULSE	STAGE 1 V_1	STAGE 1 V_2	STAGE 2 V_3	STAGE 2 V_4	STAGE 3 V_5	STAGE 3 V_6
0	●	○	●	○	●	○
1	○	●	●	○	●	○
2	●	○	○	●	●	○
3	○	●	○	●	●	○
4	●	○	●	○	○	●
5	○	●	●	○	○	●
6	●	○	●	○	●	○

FIG. 2.

becomes inconvenient when the phenomena occur in times of the order of seconds. A much better arrangement would be to provide tenth-second markers on the time axis. Since decade counters are available, one-second marks could be obtained from the tenth-second markers and, as a result, a circuit which scales by six has been developed in order to obtain the tenth-second markers from 60 c.p.s. A time axis can easily be produced which has ten divisions per second and a larger mark at each of the second points.

The basic circuit is a modified Eccles-Jordan trigger or flip-flop circuit. The modification is that used in the Potter four-stage counter decade.[1] In scaling by six, one of the four scales of two stages is omitted. However, the re-setting arrangement is the same. In explaining how the circuit works, it must first be pointed out that the scale of two circuits used are so designed that they are triggered only by negative pulses. Positive pulses dissipate themselves in the low impedance of the conducting tube. It must also be noted that, in order to get scaling by six, it is necessary for each sixth pulse to re-set the hexade to its zero condition.

In the zero state all of the left-hand tubes in Fig. 1 are in the conducting state. Referring to Fig. 2, we can see the state of each tube after the passage of each pulse. The first stage scales the input by two. The second scales the output of the first stage by two. At this point, then, we have an ordinary scale of four. The fourth pulse applied to the input trips the first stage over, its output, in turn, trips the second stage over, and the output of the second stage, in turn, trips the third stage over. The negative pulse coming from A through X (see Fig. 1) arrives at stage three too early to interfere with the action of the negative pulse coming from stage two. The fifth pulse trips the first stage leaving the others unaffected. The sixth pulse must now do three things. It must trip the first stage back into its zero state; it must prevent the second stage from tripping, for it is already in its zero state; and it must re-set the third stage to its zero state. It does this in the following manner.

When the sixth pulse enters the hexade, it trips the first stage. As this stage trips, it develops a negative pulse at A (Fig. 1) which is fed through condenser X into the third stage. This pulse trips the third stage. As it does so, a positive pulse appears at point B (Fig. 1) and is fed through condenser Y into the second stage at a point where it completely annihilates the negative pulse, coming from stage one in the normal fashion, and prevents the tripping of stage two. The sixth pulse has thus passed through the hexade and has left it in its zero condition ready to recycle.

Points A and B (Fig. 1) are made adjustable to facilitate forcing correct operation of the scaling circuit. It was found that the correct position for point A was easy to locate, for with incorrect setting nothing comes out of the hexade; however, the correct position is not critical. The adjustment of point B is likewise not critical; on moving it from one end to the other of the ponentiometer it was found to yield three possible conditions. First, nothing comes out of the hexade. Second, the circuit scales by eight as would normally be expected. Third, the circuit scales by six as we desire. Because of this, it is necessary during the initial adjustment period to set up some means of determining exactly what the circuit is doing. A low frequency generator and an oscilloscope by which Lissajou's figures can be observed serve well for this purpose.

Though the circuit given in Fig. 2 was particularly worked out for scaling 60 c.p.s., it was found that it worked well for input frequencies as high as 15 *kc*. It was also found that it is necessary to use sharp negative pulses whose amplitudes exceed the order of 25 peak volts to

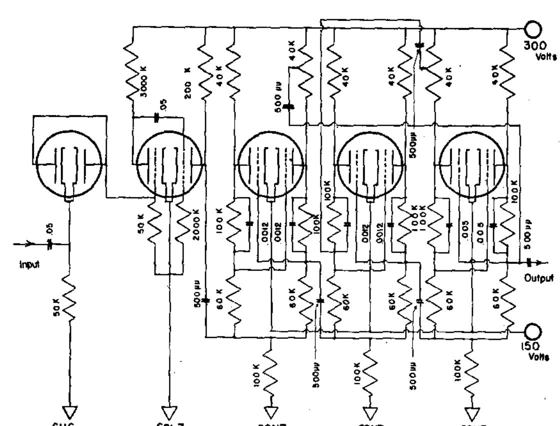

FIG. 3.

trigger the circuit. For this reason a pulse forming the circuit is included in the complete diagram of Fig. 3. The output of the hexade is a sharp negative pulse whose amplitude is the order of 30 to 40 volts. This pulse appeart well on a cathode-ray tube as a time mark. However, is cannot be used to drive a mechanical counter directly.

In the construction of the circuit no effort was made to select parts. All the resistors and condensers were taken from ordinary stock. Their tolerances are ± 10 percent and no effort was made to match them. The circuit did not appear to be at all critical to tubes which were also selected at random. Only the voltages indicated as 300 volts and 150 volts showed some tendency to be critical. It was not determined whether it was the voltages themselves or the ratio of these voltages that was critical. However, it was found that VR tube regulation of these voltages was sufficient to insure stable operation. The total current drawn from the d.c. power supply by the circuit shown in Fig. 3 is .030 amp.

The original circuit has been in use for a number of months. It has thus far exhibited no tendency to change its division figure or be unstable in any way. Several hexades have been built from the circuit in Fig. 2. They have been assembled without undue care in the selection of parts. These were easy to operate and also exhibited good stability.

Deviations of the line frequency from 60 c.p.s. become a major source of time error, and the magnitude of the error introduced depends on the frequency stability of the local power source.

The source of power used for the above described circuit was the mains of the Philadelphia Electric Company. Philadelphia is part of a large load supplied by a number of generating plants and the Conowingo dam. The total load is of the order of 4,000,000 kw and includes the area covered by eastern Pennsylvania, south Jersey, Delaware, parts of Maryland, and the District of Columbia. Because of the large inertia of the system, the frequency over short periods of time, the order of seconds, can be considered constant. For longer times there is a slow frequency drift. The frequency drift of the system is continually corrected by manual adjustment of the speed governors on the generators, and the correction is such that a master clock, running from the mains, is held to within two seconds of Arlington time. The correction is made slowly and the average deviation of the line from 60 c.p.s. is held to within $\pm .2$ c.p.s. or .33 percent. There are times when the peak error may be as great as $\pm .3$ c.p.s. or .5 percent. However, according to the load dispatcher, it is extremely rare and only upon the occurrence of major breakdowns that the error ever exceeds these figures.

By way of a check on the above information a line-frequency record was taken continuously for approximately seven hours of an average work day in Philadelphia, Pennsylvania. This record indicates that for a period of several hours the average error was .1 percent. It also showed peak errors as high as .3 percent for periods the order of five to ten minutes.

Clearing Field Electrode for Cloud Chamber

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In cloud-chamber work it is necessary to provide an electric field in the chamber to remove ions formed prior to the expansion. This is customarily provided by applying a potential between the base of the chamber and some electrode near the top plate, which may take various forms such as a wire gird or Aquadag ring. The customary arrangements do not produce a uniform field and thus clear some portions of the chamber rather slowly. Partially silvering the top plate and applying potential between it and the piston or diaphragm will give a uniform field, but the reduced transparency and rapid tarnishing of the silver is a considerable disadvantage.

Conducting coatings on glass have recently been developed which have high transparency to visible light even with surface resistivities as low as 1000 ohms per square. These coatings are remarkably resistant to humidity and to mechanical and thermal abuse. They are obtainable commercially from several of the larger glass companies.*

We have been using such coated plates for three years for the top plate of our cloud chamber and find them highly satisfactory. Resistivities up to 100,000 ohms per square are satisfactory.

* For example, we have obtained coating plates from the Libby-Owens-Ford Glass Company, Toledo, Ohio and from the Products Development Department, Pittsburgh Plate Glass Company, Pittsburgh, Pennsylvania.

A Resistor Network for the Approximate Solution of the Laplace Equation

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It has long been appreciated that both the two-dimensional and the axially symmetric forms of the Laplace equation could be solved by means of electrolytic tanks; the latter problem can be handled without electrodes of special shape by using a wedge-shaped tank.[1]

It is possible, however, to make a network of resistors capable of solving these problems if some approximation can be tolerated; the resulting boards are considerably more convenient than the corresponding tanks, and they avoid the problems of electrode fouling and probe capillarity, which are annoying in the use of the liquid.

The two-dimensional and axially symmetric forms of the Laplace equation can be converted approximately into the respective difference equations:

$$V_{i-1,j}+V_{i+1,j}+V_{i,j-1}+V_{i,j+1}-4V_{ij}=0, \quad (1)$$

and

$$V_{i-1,j}+V_{i+1,j}+\tfrac{1}{2}\left(1+\frac{r_{j+1}}{r_j}\right)V_{i,j+1} + \tfrac{1}{2}\left(1+\frac{r_{j-1}}{r_j}\right)V_{i,j-1}-4V_{ij}=0, \quad (2)$$

[1] J. T. Potter, Electronics 17, 110 (1944).