arc. The number of divisions on the vernier is 60; hence, as the $\frac{1}{60}$ th of 600" is 10", the smallest reading of this vernier is ten seconds of arc. This vernier, also, at the same time, gives the minutes of arc in this manner: It is divided first into ten parts, which the reader will observe designated by 0', 1', 2', 3', etc., up to 10'. Applying to these divisions the rule, we have the following result: The smallest divisions on the main scale are 10 minutes, and $\frac{1}{10}$ th of 10' equals 1'. Therefore, the main divisions on the vernier read to minutes, the secondary divisions on the vernier read to ten seconds.

We will now proceed to describe a quite recent invention of the writer, which he has named *The Vernier Microscope*, in contradistinction to the *Micrometer Microscope*, described in Article V. This invention consists in viewing through a compound microscope, a very finely and accurately divided scale cut on a glass plate, while the eye-piece of the microscope carries another scale, on a slip of glass, which acts as a vernier to the finely divided scale on the glass plate.

Figure 20 will explain the construction and manner of

the vernier microscope is the simplest instrument which is adapted to this work.

The manner of using the vernier microscope for this determination is as follows: A rod, with flat ends, is obtained of the material whose co-efficient of expansion we desire to know. This rod is inclosed in a brass tube which is so constructed that the whole length of the rod may be cooled down to the melting point of ice, or heated up to the boiling point of water, and yet the ends of the rod are exposed to the operator, so that he can embrace the whole length of the rod with his measuring apparatus. The tube carrying the rod rests in Vs, and while one end of the rod abuts against a firm abutting point, the other end is opposite the rounded end of the glass slide S. At the proper moment this glass is slid against the end of the rod R, and the vernier reading is instantly taken. This measure is repeated several times while the rod is surrounded with melting ice, at which temperature it has remained four or six or eight hours. The ice is now melted from around the rod by passing steam through

vice versa. I have discovered that the converse of this is equally true; that the mechanical rotation of the bar occasions a continuous current of electricity flowing from the center of the bar to the poles, or from the poles to the center, according to the direction of the rotation.

An excited electro-magnet, or a helix of insulated wire through which a continuous current is passed, may be substituted for the permanent magnet.

A continuous current of electricity may also be induced upon a telegraphic circuit by the rotation of the conducting wire in the neighborhood of a permanent magnet, or other body capable of inductive action by the rotation of the permanent magnet in the neighborhood of the conducting wire, or by the revolution of the permanent magnet and conducting wire around each other.

In illustration of my method of inducing a continuous current of electricity upon a telegraphic circuit, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose a bar magnet, N S, Fig. 1, which can be caused to rotate upon its axis *ab* by means which it is unnecessary to describe. A metallic spring, *c*, rests against the center of the permanent magnet, N S. The instrument so constructed may be connected in circuit with a galvanometer, *g*, as in Fig. 1. When N S is caused to rotate upon its axis, *ab*, a continuous current of electricity traverses the circuit, *c S b g c*. The needle of the galvanometer, *g*, is deflected permanently so long as the rotation of N S is continued, and the deflection is reversed when the direction of the rotation is changed.

Figs. 1 and 3 illustrate the combination of a number of rotating magnets to form an electro-magnetic battery for use upon telegraphic lines. In Fig. 2 the battery is arranged for intensity, and in Fig. 3 for quantity. In Figs. 1, 2, and 3, N S N S, etc., represent magnets, which are caused to rotate upon their axes, *ab ab*, etc., the direction of the rotation being the same for all. Fig. 4 represents the manner in which a continuous current of electricity may be induced upon a closed circuit by the rotation of a permanent magnet in the neighborhood of the conducting wire, or *vice versa*, or by the revolution of the one around the other. This figure represents one way in which this part of my invention may be carried into effect, viz., by the rotation of the magnet in the neighborhood of the conducting wire.

N S is a permanent magnet, divided into two halves, N B and A S, which are magnetically united by an iron cog wheel, D, fitting into the corresponding cog wheels, A and B. C is a central support for the axes of the cog wheels, A, B, and D, and it is made of a non-conducting material. When the cog wheel, D, is made to rotate by means of suitable mechanism, rotation is also caused in the permanent magnet, N S, the poles N and S turning in opposite directions.

The rotation of the poles N and S occasions currents of electricity in the neighboring conductor W W'. Since N and S turn in opposite directions, the currents induced by their rotation in W W' are in the same direction, and do not neutralize each other. The rotation of D thus occasions a continuous current of electricity upon the closed circuit W W' g W, the needle of the galvanometer, *g*, being deflected to the right or left, according to the direction of the rotation of D.

The permanent magnet, N S, Fig. 4, may be set in rotation in the interior of a hollow cylinder of copper, so as to obtain the full inductive action of the magnet all around; and the copper cylinders of a number of similar instruments may be united in series for quantity or intensity in an analo-

MAYER'S NEW VERNIER MICROSCOPE.

using this new measuring instrument. On a metallic base, A, are firmly screwed the three upright brass plates, V, V', and P. A scale of thousands of inches, or of hundredths of millimeters, is cut on a glass plate, S, which slides accurately on the guide, *g*, against which it is constantly pressed by the spring, *c*. One end of this glass slide has a neatly rounded abutting point, which is shown in the figure as pressing against the end of the rod, R. The microscope, M, rests in Vs, in the plate, V and V', into which it is firmly pressed by the springs under the clamps, C and C'. The objective, B, is accurately focussed on the scale on S, and thus a magnified image of this scale is formed directly on the scale of the vernier placed at J, in the eye-piece O. By means of the milled head, H, the ocular O may be set at greater or less distances from the objective B, and thus the magnified image of a division of the scale will occupy a greater or less length on the vernier scale at J.

As the scale at J, in the eye-piece, acts as the vernier to the magnified divisions on the scale, S, it is absolutely necessary that the length of a division on the former bears a definite and a very exact relation to the length of a division in the magnified scale S. When the divisions on the scale at S are thousandths of inches, I so adjust the distance of J from B, that 9 of the divisions on the vernier scale exactly equal 10 of the magnified divisions of thousandths of inches. This adjustment having been secured, the microscope is firmly clamped in its Vs, and the vernier is securely fixed in its slot in the eye-piece. We thus have a movable scale and a fixed vernier subdividing the scale exactly like the vernier shown in Fig. 16.

As the units on the microscopic scale are thousandths of inches, it follows that the vernier subdivides these units into tenths; that is, the vernier reads directly to $\frac{1}{10000}$ ths of inches.

By using hundredths of millimeters in place of thousandths of inches, I have succeeded with a similar vernier in reading to the thousandth of a millimeter, which small quantity equals the $\frac{1}{10000}$ th of an inch. This, I believe, is a magnitude far smaller than any ever before read with a vernier. The reader who has taken the trouble to understand this instrument sees that it is very properly called a Vernier Microscope.

The advantages of this instrument of precision are as follows: It is readily formed by any one who has a microscope. The ordinary micrometer scale of thousandths of inches, or hundredths of millimeters, which accompanies every microscope, may be readily converted into a slide like that at S, without injuring it for the uses to which it is usually applied; while, for the vernier at J, may be used an ordinary Jackson eye-piece micrometer. The mounting of the microscope and scale may be readily made by any one having a knowledge of the use of tools.

This instrument is much cheaper than a micrometer microscope, and when once accurately constructed it retains its accuracy; whereas, any measuring instrument which uses a screw is an instrument of precision only so long as we know the pitch and error of each part of the screw. Now, it has been very well ascertained that the errors of a screw, on account of its wear, are not at all constant, and the labor of repeatedly studying its errors is very laborious. Those difficulties in the use of the micrometer screw do not apply to our instrument, for its scales may be very accurately cut by a dividing engine whose errors are known, and which are corrected before each line of the scale is cut.

Having thus obtained scales cut as accurately as possible, we then determine the errors of their divisions and tabulate them for constant corrections to be applied to our measures.

The scale and vernier of this instrument can always be distinctly illuminated, so that very sharp and precise readings can be made.

The "readings" of the vernier microscope can be rapidly made—almost at the instant the abutting point of the slide touches the end of the rod R, or any other body to be measured.

This last mentioned property of the instrument is an important one in all work where a transfer of heat from the body to be measured will cause a considerable error in our measurements. The instrument is therefore well adapted to such work as the determination of the effects of heat on any metal or alloy. The engineer has often to determine the co-efficient of expansion of a special kind of metal, and

the tube, and this current of steam is kept up till the rod ceases to increase in length. The tube with the inclosed rod is again placed in the Vs, and the increase in the length of the rod is measured by taking the difference between this measure and the previous one when the rod was cooled down to the temperature of melting ice. This important practical problem of the determination of co-efficients of expansion will be examined with some detail when we come to describe the exquisite reflecting comparator of our lamented countryman, Joseph Saxton, late of the U. S. Coast Survey Office in Washington.

IMPROVEMENT IN GENERATING ELECTRIC CURRENTS.

By ALEXANDER GRAHAM BELL, of Boston, Mass.

This invention consists of a method and apparatus for inducing a continuous current of electricity upon a telegraphic

PROF. BELL'S IMPROVEMENT IN GENERATING ELECTRICAL CURRENTS.

circuit by the rotatory motion of permanent magnets, or other bodies capable of inductive action.

It has long been known that a straight bar of magnetized steel can be made to rotate upon its axis by passing a current of electricity through it from the center to the poles, or

gous manner to the arrangements shown in Figs. 2 and 3. The currents induced in the copper cylinders, and the currents induced in the rotating magnets themselves, may be thrown into the same circuit, so as to produce a maximum effect.