APPARATUS FOR MEASURING THE HEIGHTS REACHED BY BALLOONS.

For the measurement of the height reached by a balloon several methods have been proposed. One of these is to measure the diameter of the balloon, as seen from the earth, by means of a telescope, and another is to make observations from the extremities of a base of known length; but complicated methods such as these offer special difficulties and are generally replaced by the observation of a barometer placed in the car, while the temperature is carefully noted at the same time.

The formula employed for calculating the height of a balloon with these data is due to the illustrious Laplace. It has been modified by several physicists, and the results that it furnishes have been controlled by observations made upon mountains of which the heights have been measured by trigonometrical processes.

But such verifications, which scarcely exceed 4,500 meters, do not authorize the admission that the figures deduced from the formula will be exact again when applied to balloons that ascend to 17,000 meters, a height that they may perhaps exceed upon subsequent ascensions.

There is here an important question of general physics, and, in order to attempt the solution of it by direct experiment, I have devised and recently had constructed a photographic apparatus to be carried by the balloon, and which, at intervals of time determined in advance, photographs the ground over which it is passing and at the same time fixes upon a sensitized plate the image of an aneroid barometer arranged above a second objective.

This apparatus, which has been elaborated and constructed with the greatest care by M. Gaumont, the superintendent of the Comptoir General Photographique, consists of a wooden box (Fig. 3) suspended beneath the balloon. The ropes that support it unite at a carbine swivel fixed in a ring so as to keep its axis in a sensibly vertical position.

In the figure the apparatus is represented as closed and the button that sets the motive apparatus in operation is seen upon its vertical face. Upon the under side, which faces the earth, there is arranged an anastigmatic objective, O, diaphragmed to f = 20 (Figs. 1 and 2), the principal focus of which is 221 millimeters. Upon the opposite side there is placed a second objective of short focus designed for photographing the aneroid barometer, G, arranged at the proper distance for giving a sharp image upon the same negative.

A clockwork movement, J, in acting upon a bent lever, F, permits the shutters of the two objectives to open abruptly and allow the luminous rays to pass for a period not exceeding $\frac{1}{10}$ of a second.

The two luminous rays simultaneously make an impression upon a photographic film of sensitized celluloid, which, in passing from the magazine, C, winds around a cylinder, B, which is made to revolve by means of a spring contained in a barrel.

In passing from one cylinder to the other the sensitized film presses against a glass, P, so as to present a perfectly plane surface to the luminous rays.

The progressive motion of the film is produced by the action of the same motor, J, which, after freeing the shutters, permits the cylinder to revolve so as to wind over its surface that portion of the film that has been acted upon by the light.

In the center of the negative that reproduces the landscape is situated the image of the barometer.

With such negatives it is easy to determine the height of the balloon at the moment at which each of them was taken.

When we know (1) the focus of the object, (2) the distance of two points located upon the earth and (3) the distance of these two points upon the negative, it is possible, through a simple calculation of proportions, to determine the height of the balloon; and, since the negative gives also an image of the barometer and consequently the pressure, it is possible to deduce therefrom, experimentally, the law that connects the barometric pressure of the atmosphere at various points with the altitude of the latter.

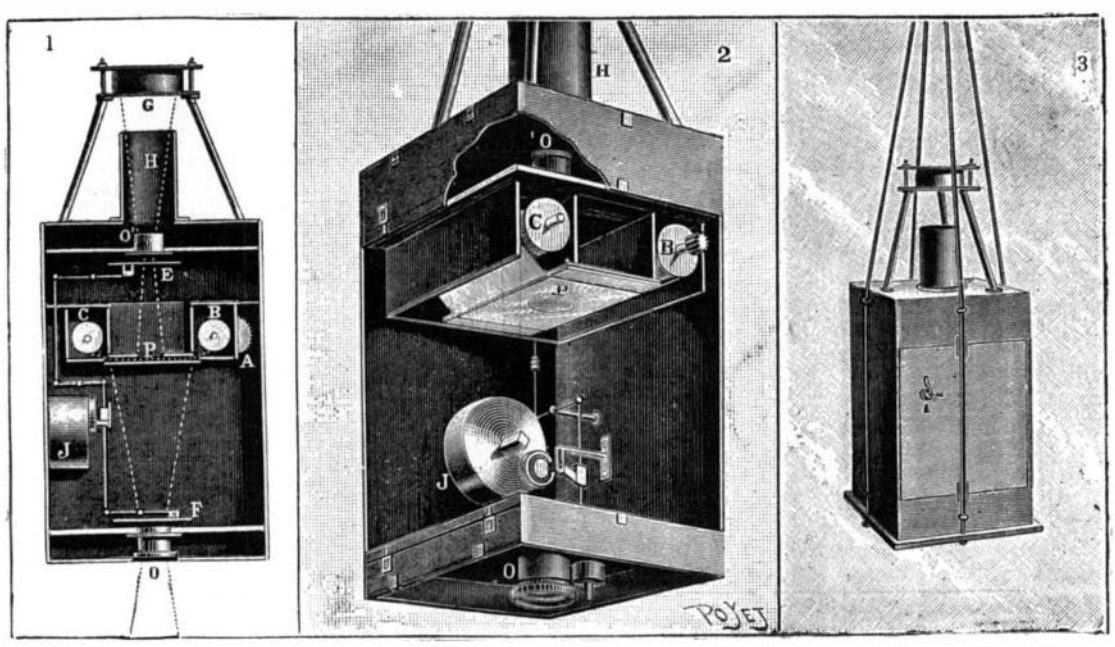
The possible error in the measurement of the altitude thus calculated will depend upon the accuracy of the measurement of the focus on the one hand and of that of the negative on the other, as well as upon an exact knowledge of the distance of the two points selected upon the earth. Now, it is easy to obtain such measurements with great precision.

Various precautions have been taken to assure the perfect operation of the apparatus. Thus, the movements that the strip of celluloid must undergo during its unwinding might modify its dimensions. In order to prevent any errors that might result from this, two parallel lines, the spacing of which is perfectly known, are engraved with a diamond upon the edges of the glass plate, P. The light, upon entering the apparatus at the moment at which the shutters act, photographs upon the film these lines as well as two others that are likewise parallel and at right angles with the first. If, after the development and drying of the negative, there is no perfect coincidence between the engraved lines and their image, the difference is measured and brought into the calculation.

When the apparatus is to ascend to great altitudes at which a temperature of at least −70° prevails (as we have ascertained), it is necessary to protect the mechanism and the barometer against the influence of such extreme temperatures, which would paralyze their motion. To this effect, we have arranged two tubes of thin copper filled with fused acetate of soda in the box of the apparatus previously protected by a covering of thick felt. The soda, in passing back to a crystalline state, disengages a quantity of heat sufficient to assure the regular operation of the motor.

The barometer, G, is fixed above the sunshade, H, opposite the short focus objective, O, arranged at the upper part of the box, which care has been taken to paint white in order that it may be adequately illuminated.

A copper receptacle of the same form as the barometer (and not represented in the figure) contains fused acetate of soda, which, by its contact, prevents the barometer from ceasing operation under the influence of the cold.



Figs. 1 and 2.—SECTIONS. Fig. 3—GENERAL VIEW.

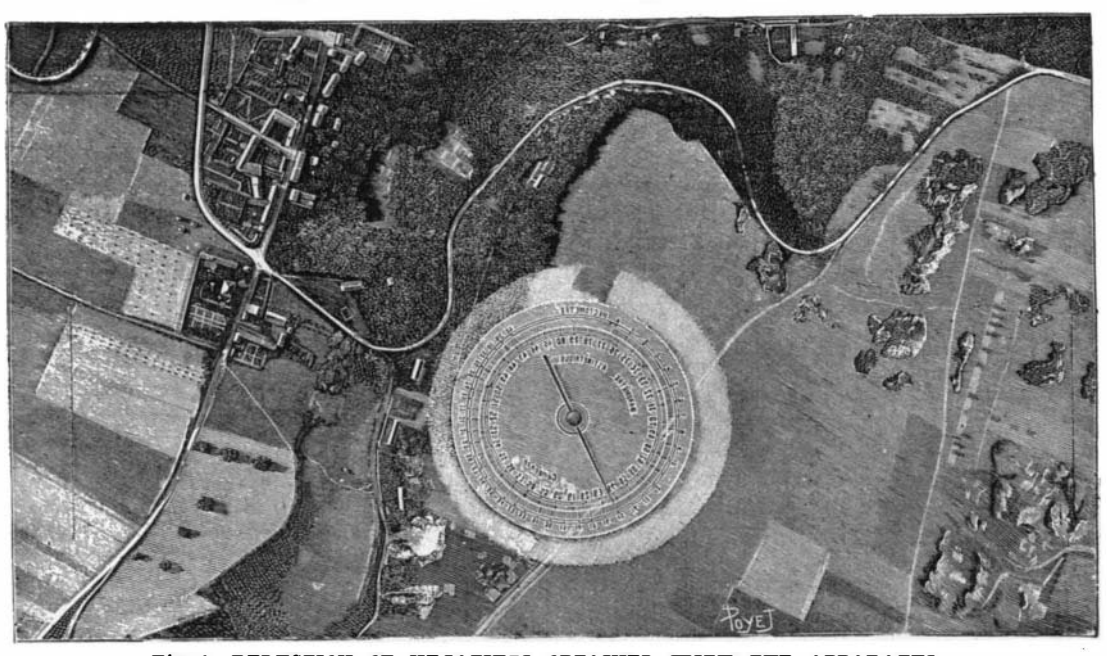


Fig. 4.—REDUCTION OF NEGATIVES OBTAINED WITH THE APPARATUS.

This apparatus was submitted to experiment for the first time on the 21st of last October in an ascension organized by the Commission d'Aerostation Française, for the purpose of testing various automatic apparatus designed for the exploration of the upper atmosphere.

The balloon used was one made of Chinese silk, of 1,700 cubic meters capacity, offered to the commission by M. Mascart on the part of M. Balaschaff. Moreover, Prince Roland Bonaparte was kind enough to defray all the expenses incurred on the occasion.

The balloon, which started from the Villette Gas Works at 12h. 40m., descended at 4h. 26m. at Cossé-le-Vivien, department of Mayenne, after making its trip at a mean speed of 86 kilometers an hour. Despite extremely violent squalls, the start and descent of Messrs. Hermite and Besançon, the aeronauts, took place without accident, but the atmospheric conditions did not permit the balloon to ascend higher than 2,500 meters.

M. Violle's apparatus, which is designed for registering the solar radiation, worked perfectly, as did my photographic apparatus (just described), which, at intervals of from two to three minutes, took 13 × 18 negatives of extreme sharpness. Upon these latter, the houses, roads, railways and fields over which the balloon passed appear with all their details.

Thanks to the kind aid of the director of the geographical service of the army, I have been able to obtain a measurement of the negatives taken during the trip of the "Balaschaff," under conditions of great precision.

Such measurements were made by taking groups of two points situated sensibly upon the same horizontal plane, the distance of such points being about a thousand meters. For the determination of the distance upon the earth of the points selected, maps to a scale of 1-10,000 and 1-14,000 were used.

Fig. 4 gives a reproduction, on a reduced scale, of the sixth negative taken after the start. In the center is the image of the barometer that permits of easily reading the pressure.

The village of Elancourt, the houses of which are seen to the right, along with their gardens and walls, was photographed by the apparatus at a height of 2,250 meters. The various roads, which have very pronounced curves, stand out in white from the dark ground of the fields through which they pass. Elancourt is a village of 620 inhabitants, situated near Trappes, in the department of Seine-et-Oise.

The results obtained in this first trial ascension are therefore very encouraging, despite the insufficient height attained by the balloon.

In order to obtain great precision in the measurement of pressures, I am now having constructed an aneroid barometer which I have so arranged that the needle may make two entire revolutions upon the dial. This instrument will give readings comprised between the pressure of the sea level, say 0·760 meter, and 0·08 meter, or together 680 millimeters Now, since the dial of the barometer is divided into 400 parts, we shall have, for two revolutions of the needle, 800 dial divisions for representing the 680 millimeters of the travel of the apparatus. By means of the photographs that my apparatus thus improved will give, I hope to verify by direct experiment the measurements of altitudes furnished by the barometer in the highest regions of the atmosphere.—L. Cailletet, in La Nature.

CAILLETET'S AUTOMATIC PHOTOGRAPHIC APPARATUS.

OBSERVATIONS have been made recently to determine the extent and cause of the extraordinary deflection of the magnetic needle which takes place over a vast tract of Central Russia. The line selected for observation was one of about 850 miles between Moscow and Kharkov. The widest aberrations are found to exist in the province of Kursk, the capital of which is about 600 miles south of Moscow. In the southeast portion of this province, about 150 miles south of Tim, the needle is deflected more than 96 degrees, and points almost due east and west instead of north and south.