H. KAMERLINGH ONNES. *A device for illuminating scales read by reflexion.*

1. In the physical laboratory at Leiden for many years a method of reading scales with mirror and telescope has been used, in which a small source of light is made to give an intense and uniform illumination to long glass scales. The researches of SISSINGH, ZEEMAN, SIERTSEMA and LEBRET amongst others have demonstrated the convenience of this method. Fig. 1 shows the arrangement, which has been in use for many years for the measurement of low temperatures by means of a thermoelectric couple. This is the first opportunity I have had of describing my method.

Behind the transparent glass scale (as manufactured by HARTMANN and BRAUN) reflectors are placed obtained by cutting a concave mirror into strips [1]) (see figs. 1 and 2). The source of light is placed above the scale and each of the strips throws an image of the source of light upon the reading mirror of the measuring apparatus. When the reading telescope is focussed on the image of the scale the divisions are seen intensely black

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[1]) Originally I cut a broken concave mirror into strips, since these strips are especially manufactured for me by P. J. KIPP & ZONEN, J. W. GILTAY, opvolger, at Delft.

on a very uniformly and brilliantly illuminated-background. The excellence of the illumination obtained in this way has also been noticed by W. H. JULIUS, pag. 53 of his remarkable thesis (1888) he describes how he illuminated his galvanometer-scale by a paraffine-lamp a concave mirror being placed immediately behind the scale and points out the extreme precision with which the readings could be taken.

The method described has many advantages. It is independent of the daylight; the readings can be taken even in a room where the light is very bright, with a telescope magnifying 60 times or more; and scales divided into quarter millimeters might be used and tenth parts of a division still be estimated. Scale and telescope may be placed in the usual relative position, as appears from fig. 1. When desired the source of light may be put close to the reading-arrangement. And lastly the heat given out by the source of light need not be feared as the latter may be of very small size.

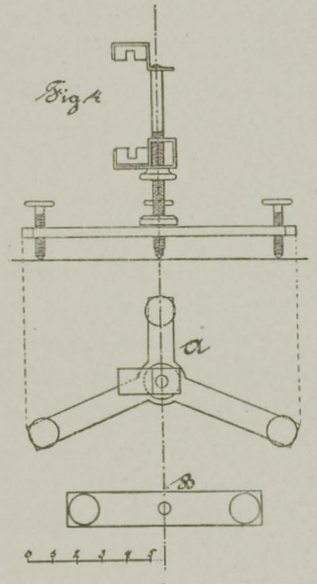
2. If concave strips of arbitrary ellipsoïdal curvature were available, instead of the spherical strips which are so much easier to obtain one could place the light at any distance and illuminate the whole scale by a single source of light of extremely small breadth, placed in one of the two foci of an ellips, the reading mirror occupying the other. The elliptic arc may be imitated to some degree by a certain number of spherical strips. To this end each strip is to be brought into such a position that the image of the source of light which it gives, is thrown in the direction of the reading mirror, and that the strip looks uniformly and brilliantly illuminated as seen from the place of the reading mirror. It is only possible to fulfil the latter condition for each of the spherical strips when the source of light has a certain breadth.

In investigating the connection between the breadth of the source of light required, the angle subtended by each mirror strip and the position and the radius of curvature of this strip, the following points have to be born in mind. A point of the scale is illuminated if the extreme rays, drawn from that point towards the reading mirror when produced backwards towards the illuminating mirror strip, after reflexion on the strip fall within the light emitting surface. If the radiation of the flame is known the intensity of the illumination may be deduced from a consideration of the cones formed by those extreme rays.

Without going into details however it is evident that the broader the source of light the less it matters whether the mirror strip when placed in a certain position has the correct radius of curvature and whether its normal points in the true direction. Moreover it is found that, if the source of light is not too narrow and if the angle subtended by each of the strips not too large, a proper adjustment may be obtained even with strips all of which have the same curvature and that the illumination even in that case becomes very nearly uniform throughout the scale. The radius of curvature of the strips which are used at Leiden is about 96 cMs.; the longest strips subtend an angle of 28° and the length of the chord is therefore 45 cMs. With two strips of that kind at a distance of 3 metres from the

mirror a scale of 80 cMs. may be illuminated by means of an Argand gasburner; for a scale of 100 cMs. three strips are required or two long ones and two smaller ones.

Fig. 2 shows in plan the arrangement of fig. 1 and gives an idea of the relative position of mirror, strips, scale and source of light. In this case a scale of one metre at a distance of 3.2 metres from the galvanometer-mirror was beautifully illuminated by means of a colza-oil flame. This light is suspended at a distance of 54.3 cms. from the mirror strips and of 30 cMs. in front of the scale. Some of the light rays are traced in the diagram. For the sake of comparison the elliptic arc with flame and mirror as foci has been added to the diagram as a dotte curve. The width of the flame is 3.5 cMs., the height of its luminous part from 1.5 to 2 cMs.

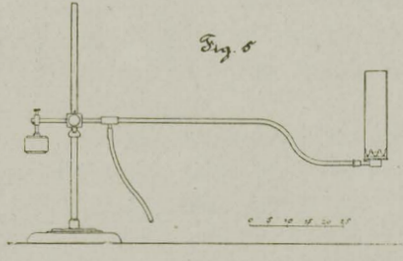


3. In considering some further details we may restrict ourselves to the case in which the scale is horizontal [1]).

It is in general desirable to put the source of light

[1]) For mirror readings on vertical scales and for illuminating cales for other purposes the same method is applied.

above the scale to avoid parts of the scale being covered or the sharpness of the images being spoiled by currents of hot air. The path of the rays will then be according to the diagram in fig 3 (see plate) and the mirror strips must be inclined somewhat backwards. To effect this the mirror strips are clamped between pieces of cork in light, adjustable holders. The construction of these holders is shown in fig 4; fig. 4*a* showing the pattern which is used when a mirror strip is supported by one holder only, fig. 4*b* that which serves when two holders carry one strip. The vertical distances between telescope, illuminating mirror and flame (fig. 3) should be kept as small as possible. In order to prevent the edges of the scale from spoiling the uniform illumination of the background by their dark images the strips should not be placed too near the scale. It is not desirable to use very long strips, firstly, because they are expensive, secondly, because of the inclined position which has to be given to them, and lastly for the sake of the approximation to the elliptic shape which is aimed at. Yet it is advisable to take as few strips as

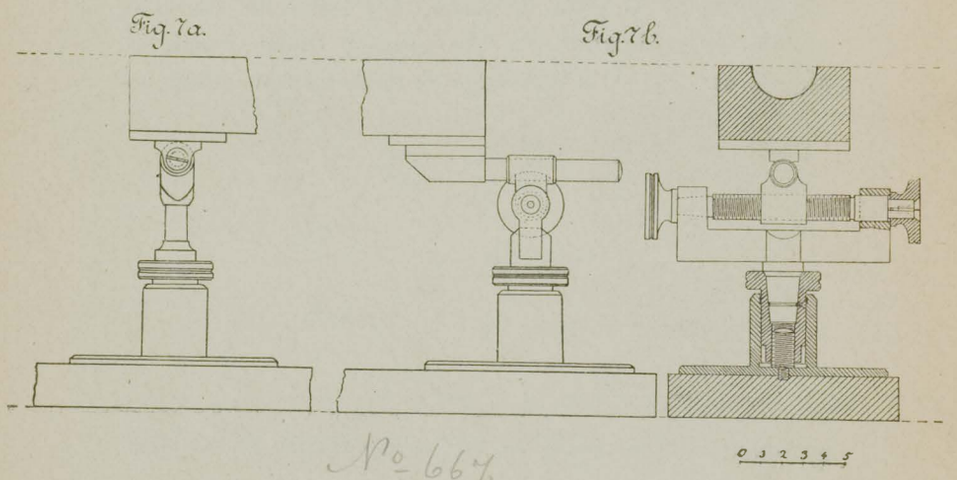


possible, as the edges of the strips disturb by a dark

line the uniform illumination of the background on which the scale divisions are seen.

4. If the radiation from the source of light is of no consequence it is convenient to use an Argand gas-burner. The gas is supplied to the burner through a long arm which reaches over the reading apparatus (fig. 5) in order that the luminous part of the flame may be brought as low as possible above the scale. The foot of the lamp is clamped to the reading table on the side of the observer.

In cases where it is not indifferent, how much heat is given off by the source of light the special advantage of the method is obvious. In fact the inevitable production of heat can be limited to a minimum as only one single luminous surface of very small dimensions is required. To actually reach this minimum may sometimes be of great importance, e. g. for magnetic observations in cellars, where the temperature should



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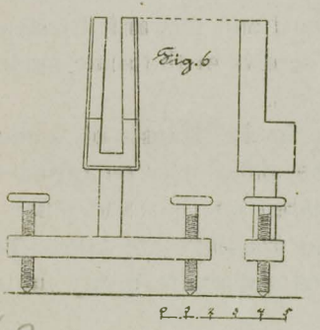
be kept constant. As a source of light which gives little heat I use as a rule a colza-oil lamp consisting of a broad wick in a long trough (fig. 1). There has at yet been no inducement to get rid of the little heat, which this source of light gives off[1]).

According to a personal communication Prof. HAGA of Groningen, in applying the method makes use of an incandescent lamp and does not find this gives any trouble, not even with very accurate galvanometric observations.

5. The reading telescope is mounted on a support which is provided with the necessary adjustments. These supports are also used for the other experiments. The telescope lies in a groove in a wooden beam, which rests on two adjustable brass feet (fig. 7). The foot in front (see fig. 7*a*) allows of an upward and downward motion, a rotation round a vertical axis and a rotation round a hinge with horizontal axis. This hinge which is carefully constructed is fixed underneath the front of the beam. To the end of the beam a brass rod is



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[1]) There was no more inducement to investigate the advantages that according to § 2 might be derived from using strips of another radius of curvature and giving another place and shape to the light source. In all the cases of reading scales with mirror and telescope that occurred, the means present proved sufficient.

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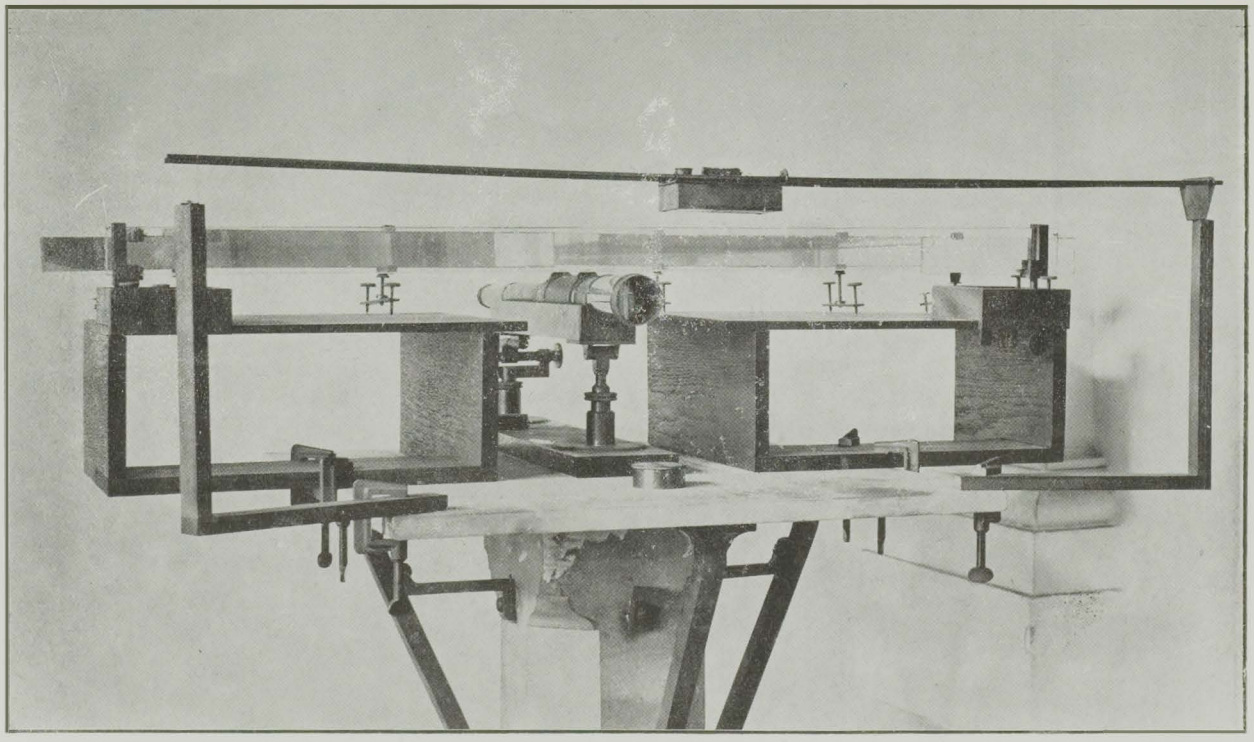

Fig. 1.

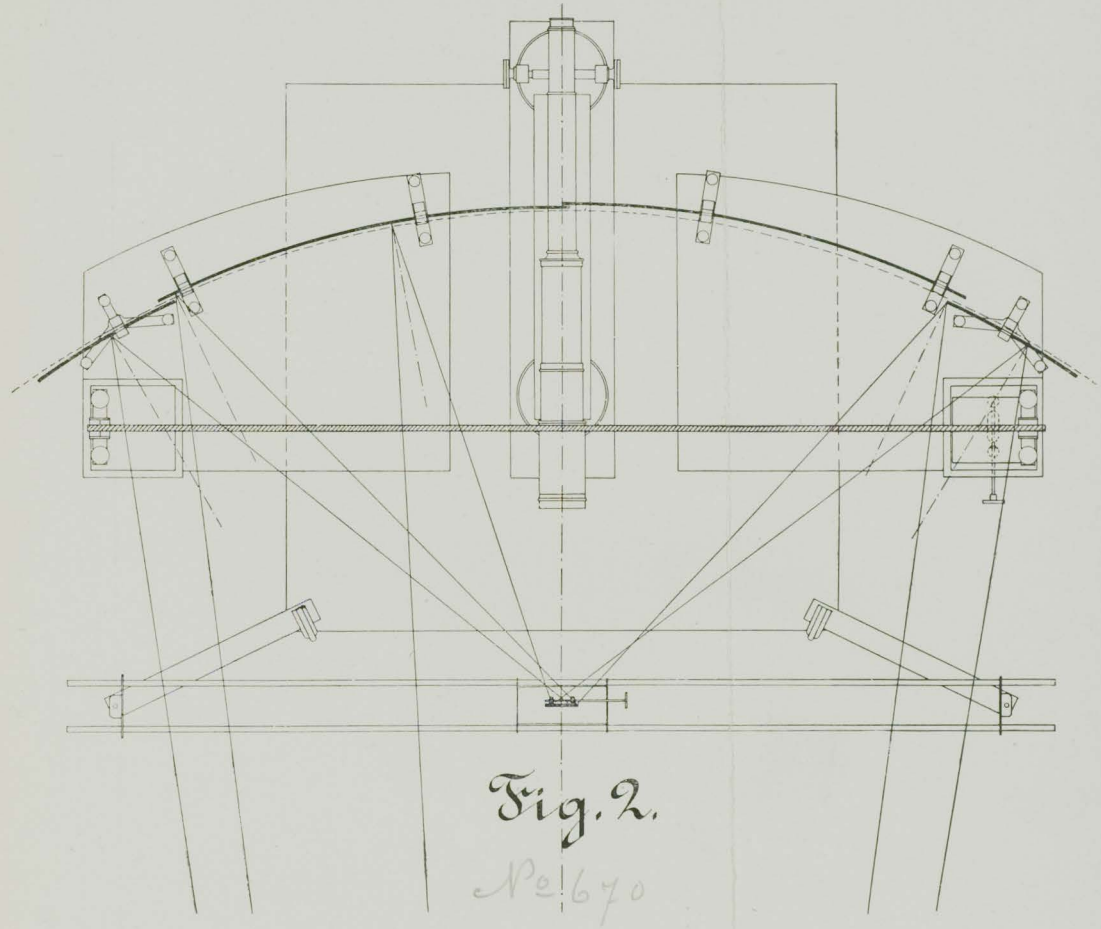

Fig. 2.

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Fig. 3

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attached which slides through an annular brass piece: this piece forms part of the second foot, is movable round a vertical and a horizontal axis and may be adjusted by means of two screws from left to right and up and down.

Only a few more things are required to complete the apparatus. The glass scale is held by two scaleholders which consist of two flexible metal strips lined with cork and are fitted with levelling screws. Both these scale holders with the scale and the mirrorholders with the mirror strips rest on wooden supports of the shape most convenient for the scale length used. These supports as well as the telescope-support are firmly clamped on to a marble slab. The holders are prevented from slipping by being placed in small wooden trays which are fixed on the top of the supports. The bottom of each tray has a fine screw adjustment backward and forward. By means of these screws and the fine screws of the scale holders the scale may be accurately set.

The marble slab as shown in fig. 1 rests on a movable pillar of freestone: the pillar may be raised on appropriate blocks and is placed on the fixed pillar of the magnetic room when the readings are taken. The slab, pillar, blocks and fixed pillar are firmly united by plaster of Paris.

COMMUNICATIONS

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