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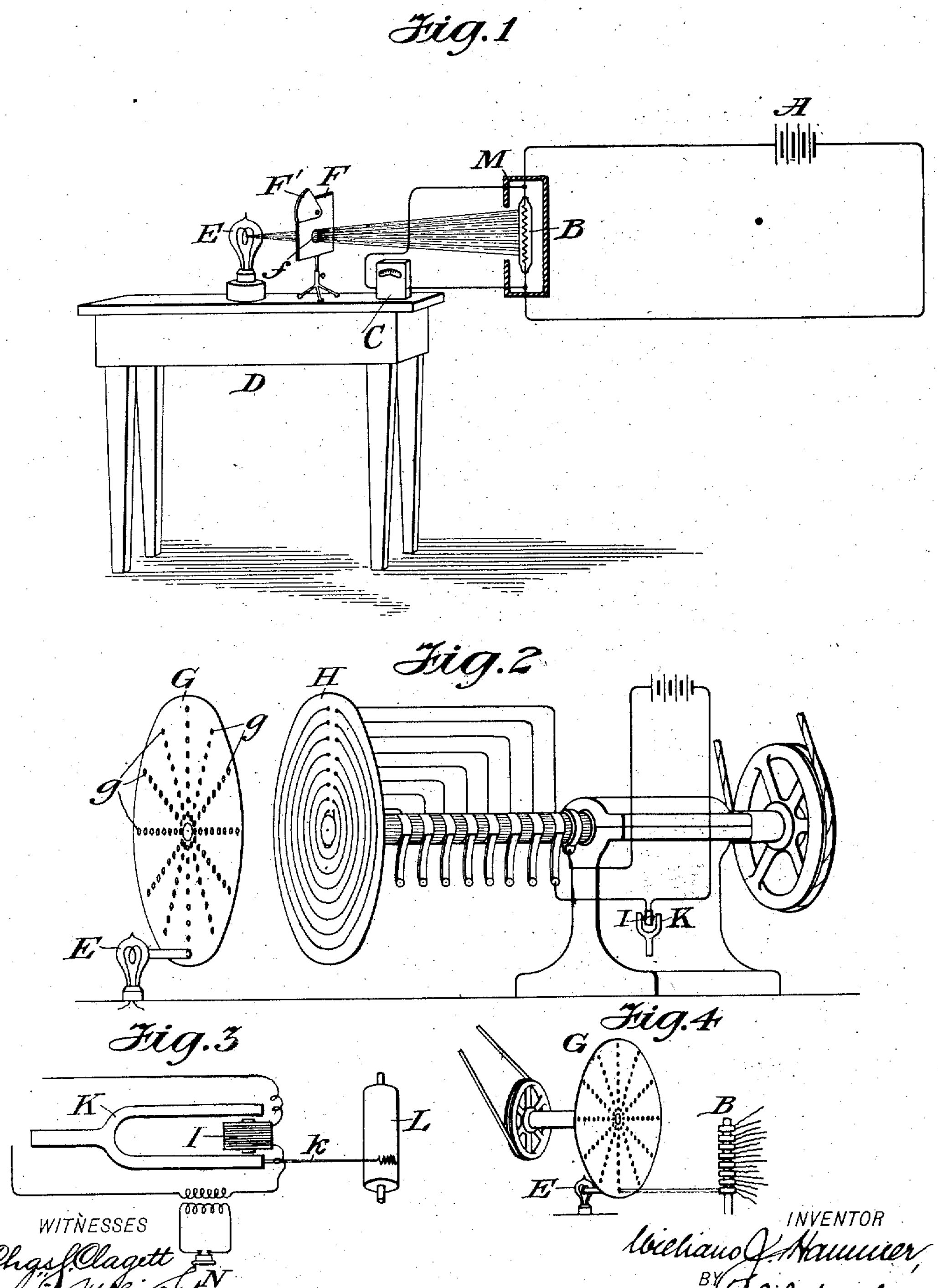
W. J. HAMMER.

METHOD OF MEASURING LIGHT.

APPLICATION FILED OCT. 31, 1906.



WITNESSES

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METHOD OF MEASURING LIGHT.

No. 888,802. Specification of Letters Patent. Patented May 26, 1908.

Application filed October 31, 1906. Serial No. 341,426.

To all whom it may concern:

Be it known that I, WILLIAM J. HAMMER, a citizen of the United States, residing in New York city, in the State of New York, have invented certain new and useful Improvements in Methods of Measuring Light, of which the following is a specification.

My present invention relates to the art of measuring light, and particularly to an improvement in that art by which lights may be compared without introducing the variable physiological factor present when estimating light intensities by the eye, as in the common forms of photometers now in use.

The inaccuracies of the method now in common use and above indicated are well known; in many cases differences amounting to as much as ten per cent. will exist between the estimates made by different observers with the best available scientific means of comparison. Furthermore, the colors of the lights to be compared are of great importance, inasmuch as not only do the colors differ in the intensity of the effect produced upon the eye of an individual, but there is marked variation between different persons in this respect; so that by some observers two lights of the same color may be compared with considerable accuracy, but a change in the color of the standard will render the determination worthless. In addition, the practical impossibility of maintaining a standard light which will not vary from time to time with the pressure of the atmosphere and its specific composition at the place of test, and with the purity of materials used to produce the flame (a flame being usually employed for this purpose), affects the precision of comparison to a greater or less degree.

The common standard of comparison is the now well known "Pentane" lamp; the color of this standard is toward the red end of the spectrum, and to most eyes it shows decidedly pink. Hence when an attempt is made to compare a yellow incandescent lamp, for example, with the standard, the results obtained from different observers are often so discordant as to make them of little use; it has therefore become a practice to have a single observer compare a number of incandescent lamps with the selected standard with great care, so as to make them secondary standards, which when burned at proper voltage will give for a considerable period a substantially unvarying light. Obviously, however, this introduces still further inaccuracies, since the lamps will, in spite of all possible care, differ among themselves, and comparisons made with them will necessarily differ by the personal equations of the different observers. In addition these equations vary in different ways with different persons, being dependent as already pointed out upon physiological factors such as the ocular perception of the individual, varying with fatigue and with physical condition, as is well understood.

All of these difficulties I aim to obviate by the improved method now to be set out; which consists, briefly, in causing the light to be measured to vary a selected physical quantity and measuring the variations so affected; the precision with which the measurement can be effected may be made very great by taking necessary precautions, and is wholly independent of the peculiarities of different individuals, or at least may be made so by proper care. For reasons which will be apparent from a consideration of the present state of the art set out above, I prefer that the quantity to be measured shall be one the variations in which shall not be dependent upon any physiological function for their accurate perception.

Several different ways of embodying the invention are possible. The simplest and best of all those that have occurred to me consists of arranging in an electric circuit a selenium cell of approved construction through which I pass a current, and indicating the changes in the current, due to the action upon the cell of the light selected for test; it being well known that the specific electric resistance of selenium varies over wide limits under the influence of light. In circuit with the cell and the source of current is included any desirable form of electrical measuring instrument. I prefer for this purpose an instrument which will show variation in only one electrical quantity, since in any investigation it is best for well known reasons to employ only one variable at a time; but under some conditions other forms of measuring devices may be used.

In some forms of my invention I have preferred to use sound-waves and to cause these to be affected indirectly by the light-waves; but this, although far more accurate than direct comparisons of light by the eye, is more difficult and more complex to practice and with no compensating advantage.

I am not aware of any existing method of measuring light in which an ascertainable physical quantity is caused to vary by means of light, and the extent of the variation, being capable of direct measurement, is used as a standard of comparison; and to this feature of novelty I desire to make broad claims.

The apparatus here illustrated I believe to be new; it is described and claimed in my application for Letters-Patent Serial Number 341,425 filed October 31st, 1906.

In the accompanying drawings Figure 1 is a diagram illustrating the first of the methods above indicated in my statement of invention, and Figs. 2, 3 and 4, are modified forms in which sound-waves are employed.

In Fig. 1, A is the battery or other source of current which is to be measured and variations in which are taken as indicative of light intensities. The battery is arranged in circuit with a selenium cell B, which is preferably of that form in which the selenium, after being coated upon a suitable conducting support, such as a coil of nickel wire, is sealed in a tube of preferably as nearly perfect a vacuum as can be obtained, the ends of the conducting wire being passed through the glass by means of platinum tips or otherwise; since the current is small, and no great heat is evolved, platinum is not necessarily used.

C is a measuring instrument, in the case illustrated a voltmeter, responsive to small variations of pressure.

I have not illustrated any current-controlling means, since obviously such devices may be employed as the expert may desire, and customarily the current will be regulated by the usual resistances and switches in ways well understood. Preferably the current through the cell should be of as low a value as can be conveniently maintained constant, for several reasons, one of which is that a large current evolves so much heat that the cell is subjected to alternate expansions and contractions which are detrimental; but the most important reason is that for very small currents a proportionately larger variation of voltage is caused by the action of the light upon the cell, rendering the device more sensitive and accurate.

Upon a suitable table D, is arranged the lamp E, to be tested. At F, I have indicated a screen having a hole *f* which may be closed by a slide F^1; in practice it is preferable to place the selenium cell in a light-tight box M (shown partly broken away) having free ventilation, so that the indications may not be affected by exterior light; and inasmuch as the effect to be observed is not detectable by examination of the cell, it is only necessary to open the box at long intervals.

The method of operating the arrangement thus described is substantially as follows: A standard lamp of any desired construction, such as the Pentane lamp referred to in the previous description, is placed in proper position adjacent to the apparatus and lighted, being screened completely from the cell; a small current, preferably a small fraction of an ampere, is then caused to flow in the circuit including the cell, and after it has attained a steady value, the fall of potential around the cell is measured by the volt-meter. After this the light of the standard lamp is allowed to fall upon the cell, and the change in the resistance of the circuit (as indicated by the change in the drop) caused by the action of the light upon the selenium is measured and recorded; this then becomes a "constant" of the particular cell employed. After this, the light which is to be compared with the standard may have its specific effect upon the cell determined in substantially the same way. Obviously the indications of the cell for the first specimens constructed must be calibrated by comparison with the results obtained by photometers, since the measurements of light now in use are purely arbitrary and have no relation to any definite physical quantity; but this relation having been once established in the manner indicated may be indefinitely perpetuated by periodic comparisons of different cells to guard against change.

In Figs. 2 and 3, I show a second means of practicing the method which I have indicated. This consists of a siren-disk G of well known construction in which the rows of holes *g g* bear to each other certain definite relations, such as the notes of the scale. Opposite to, and rotating with this disk (the perforated disk being shown detached for clearness of illustration) is a disk H bearing upon its surface conductors coated with selenium, one for each of the rows of holes *g*. The ends of the conductor go to collector rings rotated with the shaft, the whole being driven at constant speed. In the circuit with the collector rings and source of current supply is a coil I, disposed so as to affect a tuning-fork K provided with a pointer *k*, the amplitude of vibration of which is recorded upon the revolving cylinder L, in the manner of a chronograph. The rows of holes in the siren-disk may conveniently be in the relation to the notes of the octave of a tempered scale, and may each be provided with a similar tuning-fork, which at the normal rate of rotation will respond to its appropriate tone; these being all substantially like the fork K and arranged in a similar way, are not illustrated. Such an organization will enable the observer to conduct a number of tests at the same time, when desired.

The apparatus thus described being brought up to normal speed, which should be maintained as nearly constant as possible, the tuning-fork K will begin to vibrate as soon as the standard lamp is turned on, and the amplitude of its vibrations will be recorded upon the cylinder L; upon turning off the standard and turning on the lamp to be tested the amplitude of the fork's vibration will indicate the intensity of the lamp to be tested, relative to the standard.

A telephone N may be connected in circuit if desired, either directly or inductively, and the note of the fork will then sound in the ear of the observer; an operator with a good musical ear may reach a very close approximation to a correct comparison by the relative intensities of the sounds produced by the two lights; this is, however, open (though in a less degree) to the objections pointed out with respect to visual photometers.

In Fig. 4, I indicate a construction which is cheaper and yet substantially effective. In this figure the cells B are arranged upon a stationary support and the siren-disk alone rotates, cutting off and admitting the light by its rotation.

Having now indicated the general outline of the apparatus which I prefer to use and which by anyone familiar with physical manipulations may be almost indefinitely varied in detail without departing from my invention, I will now proceed to describe some of the precautions which I find it desirable to use in order to effect the measurements to which I have referred with the greatest facility and precision. Obviously the invention will be employed although the arrangements which I am now about to indicate should be omitted; but they add so greatly to the precision of the result that in most cases it will be preferable to employ them.

I have already mentioned that the selenium cell should be inclosed in a vacuum; the reason for this is that the selenium is hygroscopic and when damp there is in such a cell a certain electrolytic action between the selenium and its metallic support which gives rise to an electromotive force in the cell itself, making it to a certain extent a primary battery which may polarize, so that its E. M. F. varies between certain limits, thus rendering its determinations inaccurate by whatever amount of electric effect may be present. In addition the slight heating of the cell causes it to give out gases, changing its internal resistance and again affecting its E. M. F. These deleterious effects are wholly avoided by inclosing the cell in a highly exhausted receiver; and if in the course of this process a current be passed through the cell sufficient to heat it, at the same time continuing the action of the pump, it remains constant for a long period of time. I have also found it of advantage to make the inclosing tube for the selenium cell of fused quartz, which has the property of transmitting some rays which are very largely excluded by glass, and which have a considerable action upon the selenium; this is, so far as I know, entirely new with me.

I do not in this application, claim this construction of the selenium cell itself, which I have found best adapted to my improved method, since it is described and claimed in my parallel pending application, Serial No. 355,902, filed February 5th, 1907.

The second precaution which should be employed is to construct the supporting wire for the selenium of some material which is not readily attacked by the metal, such as nickel, platinum, iron or German silver; nickel being the cheapest non-oxidizable, or substantially unoxidizable metal, is well adapted to the purpose. Brass and copper wire may also be used; but they are objectionable because a selenite of copper is formed between which and the copper a small E. M. F. may be generated, impairing the accuracy and durability of the cell.

Another precaution which should be employed is to standardize the surface of emission of light so that the same extent of surface of the standard and of the light-source to be measured will be exposed to the selenium cell. One of the best methods of accomplishing this is to screen the selenium from the light and pass the portion of light to be measured through a tube the inner surface of which is blackened, of a definite area of cross-section, such as one square millimeter, or in some cases one square centimeter, though in general the latter unit will be found somewhat large. Obviously, however, whatever unit of surface be chosen should be the same for all of the lights which are to be compared. Under some circumstances, as where the average horizontal candle-power of a rotating lamp is to be taken, the larger surface of exposure may be found most convenient.

The circuit in which the cell is interpolated should be of very high resistance, not only because this cuts down the current to a very small value, but because it tends to steady it and make it more responsive to the effect to be measured, while less liable to disturbance from other causes. I have used for this purpose resistance as high as 10,000 ohms; and as the resistances of the selenium cell itself is very high, the total resistance in the circuit may be very large indeed. With a circuit of these characteristics, I have been by special apparatus enabled to start and stop large electrical machinery by passing my hand between the cell and the source of light. Also for somewhat similar reasons the volt-meter or galvanometer employed should be one of large resistance.

There are other methods of employing measurable physical quantities for the purposes set out, and all of these which employ the principles of my invention, I aim to cover by the claims in this and in my other application already referred to.

Having thus described my invention, what I claim and wish to protect by Letters-Patent of the United States is:

1. The new art of measuring light, which consists in causing the light to be measured to vary an ascertainable physical quantity, and measuring the extent of the variation.

2. The new art of measuring light, which consists in measuring the variation in an ascertainable physical quantity produced by a standard light, and then measuring the similar variation produced by the light to be compared with the standard.

3. The new art of measuring light, which consists in causing the light to vary an electric current flowing in a circuit, and measuring the extent of the variation.

4. The new art of measuring light, which consists in causing the light of a standard lamp to vary the current flow in an electric circuit, and measuring the extent of such variation, then causing a similar variation by means of the light to be compared with the standard, and measuring its extent.

In witness whereof I have hereunto set my name in the presence of two witnesses.

WILLIAM J. HAMMER.

Witnesses:
IRVING M. OBRIEGHT,
ANITA BURKE.