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(54) PHOTOMETER

(71) We, BOEHRINGER MANNHEIM G.M.B.H., of Mannheim-Waldhof, Germany, a Body-Corporate organised under the laws of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to two-beam photometers, for the determination of the intensity of a given colour with respect to reflection or transmission of light.

Photometers are known for the measurement of the transmissivity or reflectivity of a sample, in which the light from a light source falling, *via* the sample, on photoreceivers is measured absolutely and compared with the measured light intensity of samples of known colour intensity. The difficulties in the case of this comparison of absolute measurements lie in the time inconstancy of the light source and photoreceivers. For the reduction of these errors, a laborious regulation and stabilisation is normally necessary.

Thus, for example, German Patent Specification No. 1,920,404 describes a reflection spectrometer in which the light source is stabilised *via* a control circuit controlled by a reference photocell. Quite apart from the fact that this method of control is very laborious, instead of the errors due to the light source, there appear the errors due to the second photoelement.

Furthermore, so-called two-beam photometers are known in which the inconstancy of the light source and photoelement is compensated in that, *via* rotating sector mirrors or oscillating mirrors, the light from a light source falls alternately, in rapid succession, *via* the sample to be measured and *via* a definite, regulatable comparative sample, on to the photoelement. Since the same light source and the same photoelement are used for the measurement and the reference, their slow changes compensate each other. The disadvantage of this method is that the rapidly moving mirror systems are susceptible to trouble, must be produced with a high degree of precision and necessitate a considerable additional regulation.

We have now found that the disadvantages of the above-described two-beam photometer, i.e. mechanically moving parts, can be avoided when, from the very beginning, the light, coming alternately from the test sample and comparative sample, is produced by two separate light sources which are alternately switched on and off. This switch rhythm must, of course, as in the case of the known two-beam photometers, be taken into account in the evaluation of the photocurrent and, therefore, requires suitable coupling with a photoamplifier.

As light sources, fluorescent lamps are used, since these can be switched on and off, free of disturbance, in the case of the conventionally used alternating currents with a frequency of 10 - 100 Hz and 10 - 400 V.

As the electronic switch means, there can be used any two-way rectifier circuit which can separate the positive and negative half waves of an alternating current. A two-way diode rectifier or a bridge circuit are especially preferred. If only direct current is available, this must be transformed, for example by means of conventional oscillator circuits, into an alternating current of the desired frequency.

The invention consists in a two-beam photometer, comprising two fluorescent lamps as light sources for the production of measurement and comparison beams respectively, at least one photo-receiver and

an electronic device of known construction for the discrimination between, and measurement of, the measurement and comparison beams as received by the photo-receiver, an indicator device connected to said electronic device, electronic switch means synchronised with the said electronic device for switching the light sources on and off alternately, and a regulating element for controlling the current of the comparison light source to zero belance the indicator device with a sample interposed in the measurement beam or reflecting the measurement beam to the photo-receiver thereby to obtain the relative transmissivity or reflectivity of said sample.

When using the photometer according to the present invention, the sample can be in the transmission or reflection position with regard to the measurement beam and the photoreceiver.

This relatively simple method of compensating or excluding the time inconstancy of the photoreceivers and errors due to mechanically moved parts has hitherto not been used because it appeared impossible, with simple means, to keep two light sources constant over a comparatively long time or to keep deviations practically parallel.

Surprisingly, however, in the case of the photometer according to the present invention, the stabilisation of the light sources is successful, even with the use of simple, known means of the electrical regulating technology.

The disturbing change of the sensitivity of the photometer in the case of one-beam photometers or of those according to the above-mentioned German Patent Specification No. 1,920,404, naturally play no part in the case of photometer according to the present invention since, as in the case of the known two-beam photometers, it is compensated by the comparative measurement.

The principle of the device according to the present invention can be utilised not only in the visible but also in the ultra-voilet range for the measurement of the transmissivity or reflectivity of samples. The wavelength range in which the light source emits especially strongly and which, therefore, is especially suitable for measurement purposes, can be varied within wide limits in known manner by variation of the filling gas and of the filling pressure of the lamp or by coating the lamp with luminiphores. Optical filters placed in front of the light source or a spectral resolution of the light *via* optical prisms or gratings permit the selection of a special light measurement range.

In the following, a reflection photometer according to the present invention, will be explained in more detail. This photometer has been specially developed for the determination of the colour intensities of indicator test strips and, therefore, exhibits special features which, however, do not limit the scope of the present invention.

The making available of an analysis device for test strips which is inexpensive, easy to operate, usable in practically any place and, furthermore, is so light and small that it can be carried, for example, in a physician's bag, satisfies a considerable need. The photometer described in the following and illustrated in the accompanying drawings, which fulfils these requirements, represents, therefore, a preferred embodimental form of the above-described photometer according to the invention.

Fig. 1 shows a schematic arrangement of the optical system;

Fig. 2 shows a schematic arrangement of the electrical system;

Fig. 3 shows a perspective view of the photometer;

Fig. 3a shows a partially cut-away view of the photometer;

Fig. 4 shows an opened sample holder and its fixing on the photometer; and

Fig. 5 shows a circuit diagram of the photometer.

Fig. 1 shows a light source (1) from which a measurement beam passes through a window (2) in a housing and a window (3) in a sample holder (not shown), *via* the sample (5) and again through the windows (3) and (2) to a photoreceiver (6). From the light source (7), the comparison beam passes *via* the window (2), a mirror (8) and the window (2), again to the photoreceiver (6).

Fig. 2 shows, schematically, light sources (1) and (7), from which light falls alternately on photoreceiver (6), which provides photocurrent to an electronic device (9) which amplifies this current, correctly breaks it down into phases with regard to the light sources (1) and (7), compares the two phases with one another and indicates the difference *via* an indicator instrument (10). The alternating current needed by the electronic device (9) is provided by a power supply means (11), a part 11*a* (Fig. 5) of which also supplies the pulsating half wave current which, *via* regulating elements (12) and (13) in which it is converted to square waveform, energises the light sources (1) and (7). The zero balancing of the indicator device (10) and thus the measurement of the deviations of the light intensity by insertion of a sample between light source (1) and photoreceiver (6), takes place by an additional regulating element (14) in

the current circuit of light source (7).

Fig. 3 and 3a show a view of the photometer with a sample holder (4), indicator element (10), the operating knobs of the regulating elements (12), (13) and (14) and the current connection (27).

Fig. 4 shows the opened sample container (4), with a base plate (15), sample guides (16) and (17), window (3), a cover (18) in which a notch (19) is cut out for the protruding part of the sample and a press-on part (20), and the sample holder shoe, with guides (22) and (23) and a pressure spring (24).

Fig. 5 shows the precise circuit diagram of the device in which the elements shown in Fig. 2 are indicated by broken lines. In detail, the references signify:

R_1 — R_{16} resistances,
P_1 — P_6 regulatable resistances,
D_2 — D_5, D_7 — D_{12} diodes,
D_1 — D_6 zener diodes,
T_1 — T_6 transistors,
C_1 — C_6 condensers,
1, 7 fluorescent lamps.

Furthermore, (25) indicates a transformer and (26) an integrated amplifier.

The principle of the electronic switching over and stabilisation of the light sources is briefly described for the switching of light source (1):

On to the connector sockets indicated with 0 and 220 V, there is applied the alternating current necessary for operating, which, *via* diodes D_2 and D_3 serving for the rectification, transistor T_1 and resistances P_1 and R_2 serving for the current strength regulation, energises fluorescent lamp 1. Parallel connected condenser C_1 smooths the current rectified by the diodes so that the fluorescent lamp receives a practically constant voltage during each period in which it is energised. Since this smoothing is not effective beyond the diode D_3, between D_2 and D_3 there is obtained a pulsating half wave voltage for controlling the transistor T_1 by allowing current flow to the base of the transistor during the half waves. The zener diode D_1, together with resistance R_1, provides that the voltage at the base of the transistor during the said half waves is constantly equal to the zener voltage of diode D_1 and drops to zero in the pauses between the half waves, the current passing T_1 to the lamp 1 thus being of square waveform. The base current on the transistor T_1 is so proportioned that the saturation limit is reached. It is thereby brought about that the current flowing through the transistor and the fluorescent lamp is practically independent of mains voltage variations, whereby there is provided a stabilisation of the light source sufficient for the measurement purpose. The switching of the other light source and the electronic device placed in front thereof on the indicating device takes place in analogous manner.

WHAT WE CLAIM :—

1. A two-beam photometer, comprising two fluorescent lamps as light sources for the production of measurement and com parison beams respectively, at least one photoreceiver and an electronic device of known construction for the discrimination between, and measurement of, the measurement and comparison beams as received by the photoreceiver, an indicater device connected to said electronic device, electronic switch means synchronised with the said electronic device for switching the light sources on and off alternately, and a regulating element for controlling the current of the comparison light source to zero balance the indicator device with a sample interposed in the measurement beam or reflecting the measurement beam to the photo-receiver thereby to obtain the relative transmissivity or reflectivity of said sample.

2. A photometer as claimed in claim 1, wherein the electronic switch means switch a source of alternating current having a frdequency of 10 — 100Hz and 10 — 400 V.

3. A photometer as claimed in any of the preceding claims, wherein, with regard to the measurement beam and the photoreceiver, the sample is in a transmission position.

4. A photometer as claimed in any of the preceding claims, wherein, with regard to the measurement beam and the photoreceiver, the sample is in the reflection position.

5. A photometer substantially as hereinbefore described and illustrated and with reference to the accompanying drawings.

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