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INCANDESCENT LAMP AS GAUGING OR COMPENSATING RADIATOR

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The most current radiation source in the visible and near infrared spectral region, used in instrumental engineering and radiometry, is the incandescent lamp. Experience shows that some applications of incandescent lamp are accompanied by phenomena that have hitherto been ignored, in the first place by the change of the spectral distribution of the radiation in the middle and long-wave infrared spectral region in function of the time, during which the incandescent lamp has been switched on.

This phenomenon caused by the gradual warming up of the whole incandescent lamp becomes particularly annoying when using the incandescent lamp as gauging or compensating radiator e.g. in radiation pyrometers, if a thermistorbolometer or another detector sensitive to the middle and long-wave infrared spectral region is used as detector of radiation. The applicability of the compensating method and accuracy of gauging of the pyrometer in case when a direct method is used depends quite critically on the immediate and constant response.

The mentioned phenomenon can be studied by means of a device, illustrated in block diagram in Fig. 1. Fig. 2 and Fig. 4, curve a, illustrates the time dependence of the radiation indicated by the thermistorbolometer and coming from an incandescent lamp sufficiently long heated at a voltage of 11 V and then switched-off. The case is considered that between the incandescent lamp and the bolometer no F-filter or optical system is inserted. After switch-off a sudden fall of radiation and a very slow fall of residual radiation of the warm parts of the incandescent lamp is well obvious. The zero level is given by the noise of the detecting device. If, in addition to this, the visible part of the spectrum of radiation of the incandescent lamp has been filtered off, e.g. by means of a germanium plate, the difference between radiation falling on the detector from the switched-on incandescent lamp and radiation of the incandescent lamp right after switch-off still essentially decreases – see Fig. 3. The residual radiation of the incandescent lamp is in no case negligible and the time constant of rise and after-glow are unacceptably long. They eliminate the possibility of a quick and accurate measurement without further modifications.

To remove this undesirable phenomenon of long time constant of the response of pyrometer compensation it is possible to use a suitable combination of filters between the incandescent lamp and the detector and to filter off in this way the long-wave, variable-time part of the spectrum of the incandescent lamp. One part of the results of measurements carried out for identical heating voltages is indicated in Fig. 4.

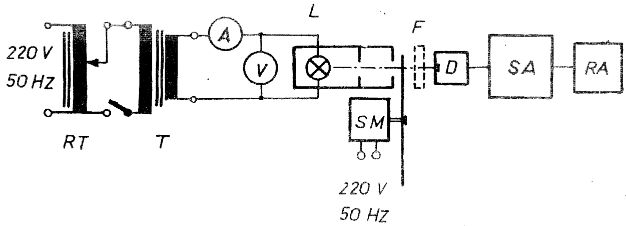

Fig. 1

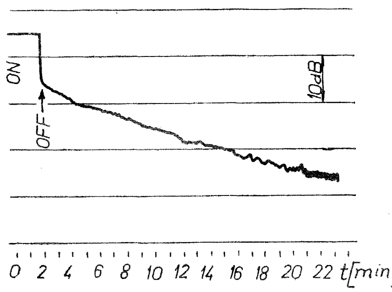

Fig. 2

Before each measurement the incandescent lamp has sufficiently long been heated at the chosen 11 V input and then suddenly switched-off. The results show that to obtain sufficiently short time constant of the response and to reduce the residual signal to an acceptable limit it is inevitable to filter the radiation of the incandescent lamp by means of a quartz plate (Fig. 4, b) or still better by means of a glass plate, a few millimeters in thickness (Fig. 4, c). The filtering plate must of course be cooled in order not to become itself a radiation source. A further possible requirement of filtering the visible part of the spectrum, maintaining at the same time a sufficient radiation signal of the lamp is best met by glass-like selenium as further filter (Fig. 4, d).

A region of about 0.8 – 4.6 μm of the incandescent lamp spectrum is utilized in case of combination quartz – selenium, and about 0.8 – 2.5 μm in case of combination glass – selenium. (Combination with a germanium plate (Fig. 4, e) causes reduction of the signal to a very low level.)

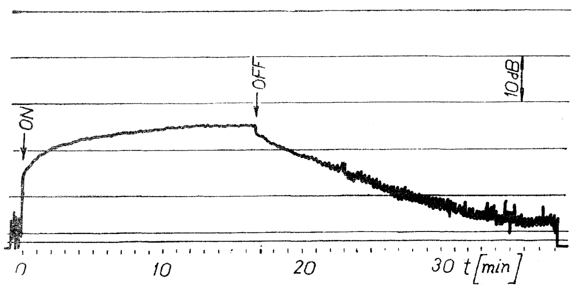

Fig. 3

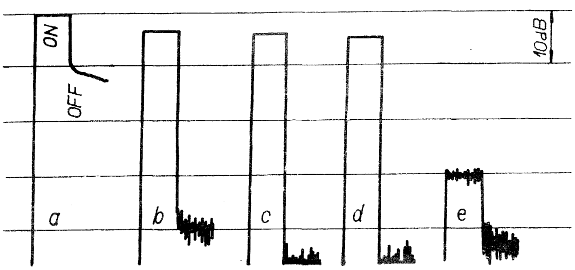

Fig. 4

The spectral distribution of radiation of a sufficiently long heated incandescent lamp under operating conditions is partly illustrated by the curves measured in the region of about 5 – 11 μm. The relative spectral distribution of radiation in this region of a 100 W projection incandescent lamp with glass or quartz bulb closely resemble each other. Only the corresponding measuring slits were different: 0.2 mm for the incandescent lamp with a glass bulb and 0.17 mm with a quartz bulb. Therefore fully shown is here only the quartz bulb case (Fig. 5). Their radiation is comparable with that of a ceramic 1 400 °K radiator of the ÚPT-ČSAV-Brno design, which possesses the properties of a gray body (Fig. 6). These measurements have been carried out on a one-path spectrophotometer IKS-12, which has been modified especially for this purpose [1].

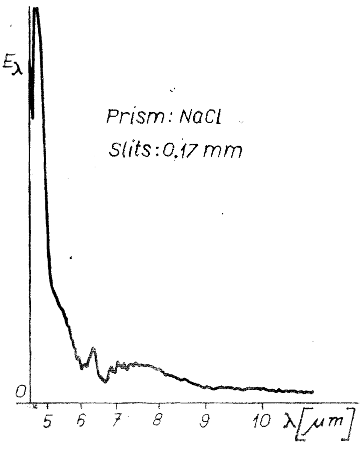

Fig. 5

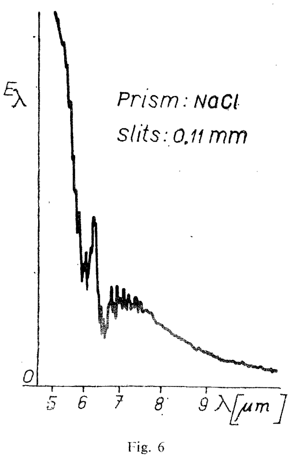

Fig. 6

The deviation E_λ of the recording device of the spectrophotometer corresponds to a certain value $E_{1,2}$ according to equation

$$E_{1,2} = 2\pi h c^2 \int_{\lambda_1}^{\lambda_2} \varepsilon_\lambda \frac{\lambda^{-5} \, d\lambda}{e^{\frac{hc}{kT\lambda}} - 1},$$

where λ_1 and λ_2 are two very near wavelengths determinated by the spectral width of the slits of the monochromator set at the average wavelength λ. In traversing the spectrum these spectral widths change. The emitted spectral output cannot therefore be absolutely compared in the graphs. The deviations also depend on the setting of the image of the radiation source on the slit of the monochromator and its complete covering by the radiation, which with respect to the variety of radiators is not feasible in reproducibly absolute values. Consequently the deviations recorded under the above conditions are relative, for rough information. In the curves of all radiators atmospheric absorption bands are obvious and the comparison shows that in addition to these there are no other absorption bands in the spectrum of a commercial incandescent lamp, nor in that of a tungsten-halogen lamp. The short-wave infrared radiation of incandescent lamps continuously passes into radiation of middle wavelengths though with an intense fall caused by the absorption of the bulb. The incandescent lamp can consequently not be considered as a selective radiator, whose radiation in the middle infrared region is negligible. In case of a commercial incandescent lamp with a bulb of thin glass this can be explained by the continuous fall of transmittance of the bulb in the direction towards middle wavelengths [2]. The bulb of a tungsten-halogen lamp is made of melted quartz, which even at small thicknesses has a sharp absorption edge in the region of 4.6 μm, usually however it heats up to an essentially higher temperature (of a few hundreds of centigrade degrees) than the bulb of a commercial incandescent lamp so that it becomes an intense radiator.

The ratio between the radiation of the filament and of the bulb of the incandescent lamp for individual wavelengths is indicated by the results of measurements made also on the modified IKS-12 spectrophotometer. The measurement was carried out for the above incandescent lamps. The individual wavelengths were set on the spectrophotometer, the measured incandescent lamp was thermally stabilized for a sufficiently long time through heating with nominal input and then instantaneously switched-off. The whole time course of one measurement for a glass bulb is illustrated in Fig. 7 for the wavelength 5.2 μm. In the further examples of the measured curves for the wavelengths 2.6, 3.3, 5.17, 5.6, 7.25 and 9.8 μm (Fig. 8) only important portions

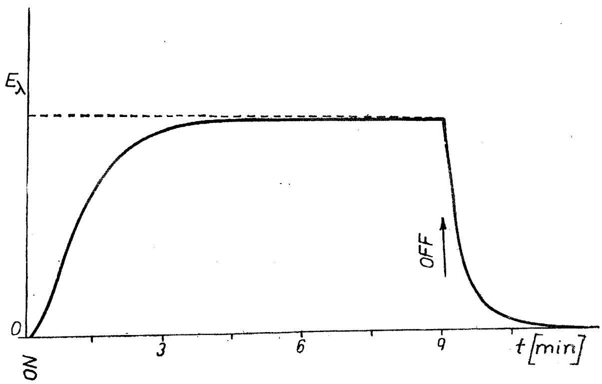

Fig. 7

of the time course of radiation in the region of the switched-off incandescent lamp have been selected. After switch-off the deviation suddenly falls to a certain value given by the ratio of the filament radiation to that of the bulb and then, from the value determined only by the radiation of the bulb slowly falls to zero. The curves of the quotient of radiation of the filament and bulb in function of wavelengths, obtained by the above method are in Fig. 9 and in Fig. 10 concerning an incandescent lamp

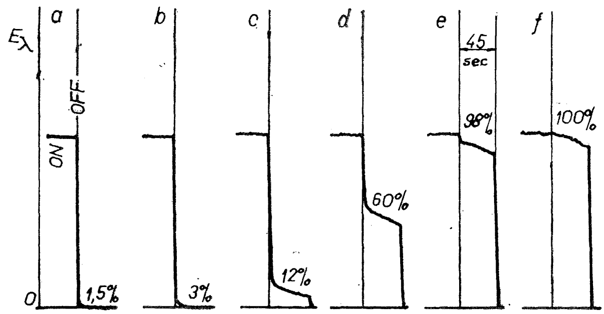

Fig. 8

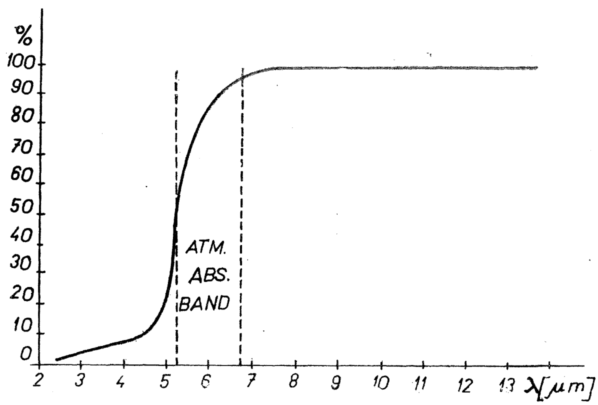

Fig. 9

with glass bulb and an incandescent lamp with quartz bulb respectively. During all measurements the incandescent lamp with a glass bulb was placed in a housing with air holes for air circulation, the incandescent lamp with quartz bulb was placed in a housing with slight forced air flow by means of a fan. With an intense cooling of the bulbs the quotient of their radiation falls proportionally.

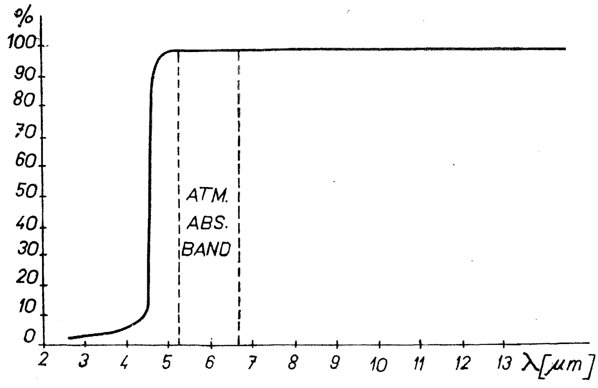

Fig. 10

The measurements show that for the case of a gauging or compensating incandescent lamp the quartz bulb renders no advantage over glass bulb. On the contrary, the sharp absorption edge of quartz at the wavelength of 4.6 μm increases the share of radiation of the bulb still in the region in front of the atmospheric absorption band, while in case of a glass bulb this transition moves into the region of the atmospheric absorption band. On the other hand from the above it is obvious that the glass bulb on the incandescent lamp partially transmits the radiation of the filament up to the region of 6 μm (however apparently also in dependence on the glass material used).

The spectrophotometric measurements as they have been carried out do not give a complete illustration of the energetic distribution of the radiation between the filament and the bulb, since on the slit of the monochromator a larger part of the filament and a relatively poor part of the bulb is imaged. They prove however that the total output of the infrared radiation in the middle and long-wave infrared spectral region, emitted by the whole bulb, is remarkably large.

The above measurements fully justify the requirement for filtering the radiation of a gauging or compensating incandescent lamp with the use of detectors responsive in the wavelengths over approximatively 3 μm, otherwise the long time constant of the response of the radiation of the incandescent lamp to a change of the heating current and the considerable inaccuracies caused by the non-uniform heating of the bulb cannot be avoided. When the middle and long-wave infrared spectral region of the incandescent lamp cannot be filtered off, it is necessary to heat the incandescent lamp sufficiently long – 10 minutes and even more – at the desired input before measurement.

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Shrnutí

ŽÁROVKA JAKO KALIBRAČNÍ NEBO KOMPENSAČNÍ ZÁŘIČ

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V článku je popsáno měření reakce celkového záření žárovky na změnu žhavicího proudu v závislosti na čase. Je poukázáno na některé způsoby filtrace záření žárovky, které časovou konstantu reakce propuštěného záření zkracují na minimum. Dále je uvedeno spektrální rozložení záření žárovky v porovnání s keramickým zářičem v blízké a střední infračervené oblasti spektra a popsána metoda pro přibližné stanovení poměru záření vlákna a baňky žárovky v závislosti na vlnové délce.