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LETTER TO THE EDITOR

Photo-electric temperature measurement by line reversal

An image of the incandescent strip of a tungsten striplamp is focussed in the centre of a gas-flame containing sodium vapour. This first image together with the flame are focussed on the slit of a spectral apparatus. In the continuous spectrum of the strip the yellow sodium line is usually visible then. It is well known that the line is brighter than the adjacent continuum if the temperature of the flame is higher than the brightness temperature of the background. If the flame temperature is lower the line is less intense than the continuum and appears as an absorption line. We can make the temperatures equal by varying the flame temperature (or the background brightness) until the line is indistinguishable because of its having the same brightness as the continuum. This is the principle of "temperature measurement by line reversal". In fact it amounts to a comparison of

a) the brightness temperature of the background, i.e. the brightness temperature of the strip minus corrections due to the light losses by reflections at the striplamp window and at the first lens, and

b) the true temperature of the flame, provided that the considered part of the flame has the same temperature all over.

In our case the last-mentioned condition can be sufficiently fulfilled as the measurements concern the homogeneous region a few cm above the small blue cones in the quiet flame of a burner with a grid. Another condition is that the sodium content of the flame is of the right order of magnitude: if the content is too small the accidental error in the measured temperature will become large; if it is too large the measurement yields the temperature of the outer zone of the flame only (the sodium light from the inner part of the flame not being able of reaching the spectral apparatus because of selfabsorption).

With visible spectral lines *visual* adjustment to disappearance of the line is possible. The method is easy and is often used; however, in routine measurements it becomes fatiguing. With ultraviolet lines the *photographic* observation remains possible. To that purpose one takes a series of spectrograms with different background temperature; this procedure requires much time. In both cases, and especially in the latter, the *photo-electric* method is preferable in the long run. Following Alkemade's suggestion [1]) we have arranged the photo-electric measurement as follows. The sodium line, obtained in a prism spectrograph with very narrow entrance slit, is imaged four times enlarged on a narrow exit slit by means of an additional lens. Near the additional lens there is a small mirror, mounted above the coil on the vertical rotating axis of a moving-coil milliammeter. The yellow lightbeam is reflected by the mirror; consequently the vertical spectral lines shift horizontally across the vertical exit slit when the mirror rotates, i.e. when the electric current in the milliammeter changes. We feed the meter with a 25 c/s alternating current. As a result the spectrum with the sodium line vibrates across the exit slit. The amplitude of the vibration is controlled by the current. The line passes the slit 25 times in either direction, making a total of 50

passings per second. The intensity of the light that leaves the slit is measured by means of a photomultiplier (RCA 1P28). When the latter is connected to a cathode ray oscillograph with synchronized time base, the screen will show the intensity profile of the line (broadened by the spectrograph and by the exit slit). This method is convenient for checking the slit widths and the optical adjustment (without striplamp) and for determining the vibration amplitude. The method is less convenient for measurement of the temperature (with striplamp), the intense continuous spectrum

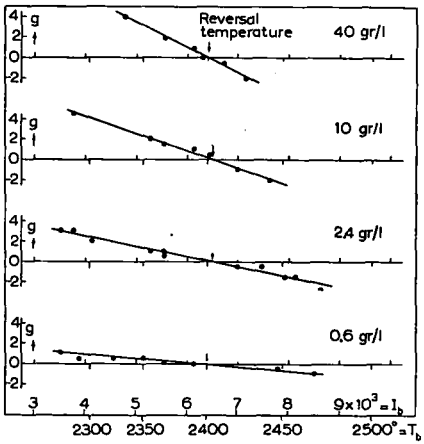

Fig. 1.

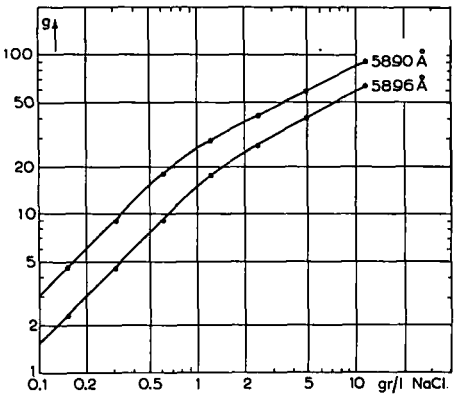

Fig. 2.

Fig. 1. Line reversal in a flame: line intensity minus background intensity, as a function of the background intensity.

Abscis: I_b = spectral radiance of the background (erg sec^{-1} cm^{-2} $sterad^{-1}$ $Å^{-1}$).
T_b = brightness temperature of the background (°K).
I_b and T_b both at 5890 Å.

Ordinate: Deflection g of the a.c. galvanometer, proportional to the intensity difference of line and background, again at 5890 Å.

In these measurements a NaCl solution was sprayed into the central part of the flame. The NaCl content (0.6–40 gram NaCl per litre solution) has no perceptible influence on the measured temperature. The temperature of the (acetylene-air) flame is found to be 2400 or 2405 °K.

Fig. 2. "Curves of growth" of the components 5890 and 5896 Å of the Na doublet.

Abscis: NaCl concentration in the sprayed solution.

Ordinate: Deflection g of the galvanometer, proportional to the line intensity, no background being present.

The horizontal distance of the curves is the ratio of the emissivities of the Na atoms at 5890 and 5896 Å; this ratio is practically 2. The vertical distance of the curves is the measured doublet intensity ratio, which decreases from 2 at low Na contents (with small selfabsorption) to $\sqrt{2}$ at high contents (with strong selfabsorption).

causing at the reversal point much noise in the oscillograph image; in our measurements this noise was about 4 times as large as the noise at the top of the line profile without background. For measuring the temperature it is preferable to connect the multiplier to a 50 c/s alternating current galvanometer [3]), synchronized with the 25 c/s mirror movement. Figure 1 shows results of galvanometer measurements.

In the outer zone of a flame the temperature usually drops because of mixing with adjacent air of room temperature. Using high sodium contents throughout such a flame we found the reversal temperature to be 50 to 75° too low. In order to eliminate this outer zone effect we surrounded the flame with an independently fed tubular flame in which no sodium was introduced. In other words we came to use a broad flame of which only the central part was coloured. With this flame the points of fig. 1 and 2 were obtained. In consequence fig. 1 shows the same reversal temperature at all sodium contents.

In addition we made some measurements without the striplamp. The intensity of the Na emission line was measured as a function of the concentration of the NaCl solution which was sprayed into the flame. Both the oscillograph and the a.c. galvanometer showed proportionality of intensity and concentration below $\frac{3}{4}$ gram NaCl per litre solution. With stronger solutions we found an increasing shortage due to self-absorption: see fig. 2. This refers to the strongest component of the doublet, i.e. 5890 Å. Evidently the limit $\frac{3}{4}$ depends on the activity of the sprayer [2]).

We intend to compare some visible and ultraviolet lines on their suitability in this photo-electric temperature measurement, and to investigate the constancy and reproducibility of flame temperatures with a view to the possible use of flames as temperature standards [4]).

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