Note regarding the article by T. G. Kyle, "An error in the Ångström pyrheliometric Scale", Tellus, vol. 19, No. 2, 1967

By ANDERS ÅNGSTRÖM, *The Eppley Foundation for Research*

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In this article Mr Kyle has drawn attention to an error which is supposed to occur in the measurements with the K. Ångström compensation pyrheliometer. The poor thermal conductivity of the blackening applied to the receiving strips of the pyrheliometer has the consequence that equalizing the temperature of the back surfaces does not strictly equalize the temperature of the front surfaces, the front temperature of the illuminated strip being slightly higher than that of the front surface of the strip heated from within by the electrical current.

The error is without doubt worth some consideration and the present author has consequently drawn attention to it repeatedly at the meetings of the Radiation Commissions, and most recently at a meeting at Brussels in May 1966. I derived, in fact, a mathematical expression for the effect, already in an early article in *Meteorologische Zeitschrift*, 1914 (Heft 8), with the title "Das Ångströmsche Kompensationspyrheliometer und die pyrheliometrische Skala" (later reprinted in *Astrophysical Journal*, 1914). My expression for the error was given in the form:

$$\frac{W}{J} = 1 - \frac{\delta b}{k} = 1 - \varepsilon. \qquad (1)$$

Here J is the sun radiation which we intend to measure, W is the corresponding heat produced by the compensation current, δ is the convection constant at the front surface, b the thickness of the blackening and k the conductivity of the same substance. The expression is identical with that derived by Kyle, and I drew from it the same conclusions as those presented by him, after having introduced approximately the same probable values for the symbols.

To these previous results it seems now appropriate to add some remarks.

1. The deficiency of our knowledge concerning the thickness and the conductivity of the blackening causes a considerable uncertainty as regards the actual value of ε. If we accept the value 0.5 per cent as a probable one, we find that it suggests a difference between the Smithsonian (1913) and Ångström scales of 2.0 + 0.5 + 2.5 = 5.0 per cent, where 2.0 represents a probable value for the edge effect and 2.5 is the correction to the Smithsonian scale of 1913 announced by Abbot and Fowle. The value 5.0 per cent is evidently in very good accord with the value 4.9 derived by me in the case that no scattering from the solar aereole influences the measurements. As the effective opening of the Ångström instrument is slightly larger than that of the Smithsonian standard, we find in practice a difference between instruments representing the scales, which is less than 4.9 per cent. The ratio is influenced to some extent by the turbidity (see Ångström & Rodhe, *Tellus*, vol. 18, No. 1, and also Ångström, *WMO Bulletin*, July 1965).

2. In the case of the Ångström standard the blackening consists of a thin layer of platinum black, on which is superposed a layer of lamp black. Strictly we ought to replace b/k by a factor γ in eq. (1) where:

$$\gamma = \frac{b_2}{k_2} + \frac{b_1}{k_1}, \qquad (2)$$

in which k_1 and b_1 refer to the soot and k_2 and b_2 to the platinum black. As b_2 undoubtedly is small compared with b_1 and k_2 large compared with k_1 we need here only to consider the effect of the soot, as has been done by Kyle and me.

3. It seems probable that the value of δ is not quite constant. It may vary slightly with the position of the instrument. (It is probably slightly larger when the tube is vertical than when it is in the horizontal position.) It may also be slightly dependent on the opening angle, in the sense that a larger opening angle will correspond to a slightly larger convection than a small one. The possibility of a variation of δ with such parameters as solar height and open-

ing angle introduces considerable difficulties, when we aim at an accurate evaluation of the influence of the aereole on the pyrheliometric measurements.

4. In the case of the modification of the Ångström pyrheliometer introduced by the Eppley Laboratory the original blackening is replaced by Parsons' black. The thickness is here much greater than in the original type but the conductivity is also greater. Still the combined effect in the Eppley type may be considerably larger than that suggested above. As, however, the Eppley pyrheliometers have all been calibrated with the aid of instruments of the original construction, it seems justified to assume that practically no extra error is introduced through the effect of the new blackening procedure. The whole problem has for some time been under the attention of the Eppley Laboratory.