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CLARENDON LABORATORY

Atmospheric Physics

Comparison of ozone spectrometers using sunlight and standard lamps

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1. Introduction.

At the present time the only satisfactory way of comparing two ozone spectrophotometers is to bring them together at the same place and make simultaneous measurements with the two instruments on sunlight. This is inconvenient and expensive. For some reason, which at present is not known, comparisons of two instruments by sunlight and by a standard lamp may give appreciably different results, up to about 0.02 in N. (Dobson 1965) A similar difference has been found by Hamilton and Walker (1967). It would seem that this disagreement between the results on the sun and on the lamp must be caused by some defect in the spectrophotometer, and "The Directional Effect" discussed by Dobson (1965) might be the cause. In view of the great importance of being able to compare two instruments accurately, using the light of the standard lamp, this question is considered further below.

2. History of the design of the instrument.

In the original design of the instrument only the 'C' wavelengths were used, and stops were placed about halfway between S_1 and P_1 which limited the top and bottom of the incoming beam of undispersed light so that all the light which passed between these stops could pass clear through to the final slit S_5.

When it was decided to use the additional wavelengths A,B and D, thick 'Q' plates were fitted near slits S_1 and S_5 which displaced the apparent positions of these slits and so varied the wavelengths. With the stops as originally placed, the incoming beam of light from S_1 moves up and down on prism P_1 as Q_1 is moved from the A to D wavelengths. It was therefore decided to omit the stops between S_1 and P_1 and to use the top of P_1 to limit the top of the beam of light and the top of P_2 as the other stop, since the light should be undispersed at both these positions. However, as shown by Dobson (1965), the two wavelengths of a pair are NOT cut off in exactly the same way by the top of P_2, but as the line of light from the traverse lamp (see test 10 of "Adjustment and Calibration") is moved upwards on prism P_2 the longer wavelength of a pair is cut off before the shorter wavelength, leading to a very large change in dial reading for such light.

3. Recent Tests.

Tests have recently been made on Instrument No.1 in which the lower edge of the incoming beam from S_1 to P_1 was limited by a temporary stop about halfway between S_1 and P_1, as in the original design, and the position of the stop was adjusted so that for the 'C' wavelengths no light quite reached the top of prism P_2. (As pointed out above, the position of this stop must be different for each pair of wavelengths.) Tests with the 'traverse lamp' showed that there was now no 'directional effect' and both wavelengths of a pair were cut off at the same place (as was to be expected) while the dial reading remained nearly constant as the 'traverse lamp' was moved, sweeping the line of light over the full extent of the prisms. See Fig. 2.

4. Cause of the 'Directional Effect'.

If the left hand side of the instrument were an exact mirror image of the right hand side, then the top of prism P_2 should cut off both wavelengths of a pair at the same place, (just as at the top of P_1), and the fact that it does not do so shows that the two sides are not mirror images of each other. A suggested cause of this defect is that the lenses are not achromatic. It is difficult to see how a want of achromatism in the main lenses L_1 and L_2 should cause trouble, but a non-achromatic lens at L_3 will form images of P_1 at slightly different places in the region of P_2 according to the wavelength. It thus seems that this is a possible cause of the 'Directional Effect'.

5. Suggested further tests.

Two tests of the above views are possible:- (a) to replace the present quartz lens at L_3 by an achromatic lens in two instruments and then see (1) if the 'directional effect' disappears, and (2) whether two instruments can be compared equally well by the sun and standard lamp; (b) to fit stops to two instruments to prevent any light of, say, the 'C' wavelengths reaching the top of prism P_2 (as in para. 3 above), and compare the instruments on the 'C' wavelengths, using sunlight and the standard lamp.

The last test is very easily done without any extra expense, but even if it shows that the 'directional effect' is the cause of the differences found in comparisons using sunlight and the lamp, it does not solve the problem of comparing all instruments by standard lamps. The second test may not be successful, but if it is, it would be no great problem to replace the lens at L_3 by an achromatic lens in all instruments.

The comparison of different ozone instruments which was reported by Dobson (1965) had to be made in the winter, since the extra instruments were only available then. This meant that the sun was always low and the dial readings were far up on the scale, whereas the lamp readings were near the low end of the scale. If similar comparisons are made in the future they should preferably be made during the summer at various values of μ and therefore with dial readings distributed over the scale.

References

Dobson, G.M.B. 1965. A critical examination of the accuracy of the ozone spectrophotometer. Oxford. Clarendon Laboratory, Atmospheric Physics Memorandum No. 65.7.

Hamilton, R.A. and Walker, J.M. 1967. The determination of the extraterrestrial constant of a Dobson spectrophotometer. London, Met.Office Sci.Paper No. 27.

Fig. 1.

Sketch showing the positions of the stops between S_1 and P_1 as in the original design. The results shown in Fig.2 (a), (c) are obtained with both stops removed; in (b), (d) with lower stop in position.

Fig. 2.

(a) and (b). Percentage galvanometer deflections to show the positions of the cut-off for 3114A (full line) and 3324A (broken line). (a) with no stops between S_1 and P_1, using tops of prisms P_1 and P_2 to limit beam. (b) with temporary lower stop shown in Fig.1 cutting off light which would have reached top of prism P_2.

(c),(d). Dial readings corresponding to (a),(b) respectively. As the 'traverse lamp' is moved parallel to the length of the instrument the line of light moves up and down on prisms P_1 and P_2.

Note that in (a) and (c) there is a large difference in the position of the cut-off and in the dial reading when the line of light is near the top of prism P_2.

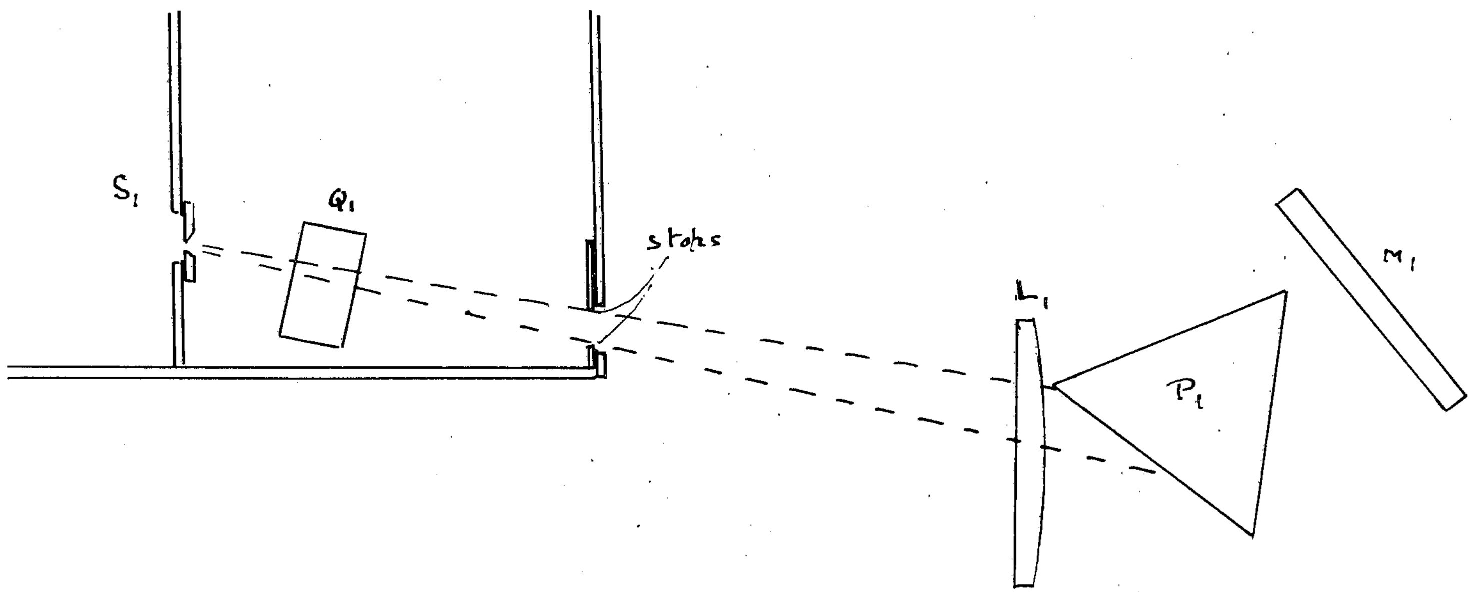

Fig: 1

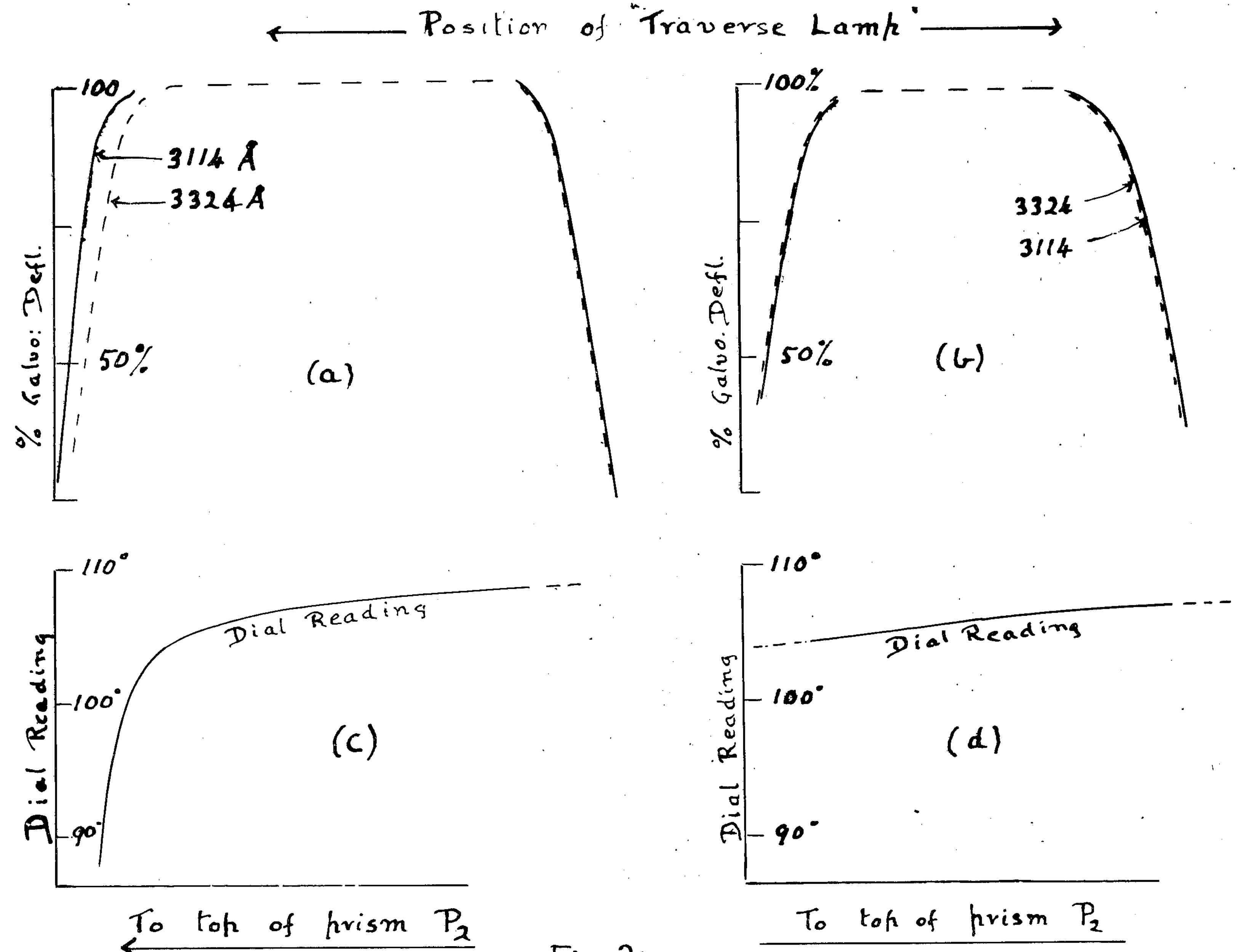
Position of "Traverse Lamp"
100
3114 Å
3324 Å
50%
% Galvo: Defl.
(a)
100%
3324
3114
50%
% Galvo. Defl.
(b)
110°
100°
90°
Dial Reading
Dial Reading
(c)
To top of prism P_2
110°
100°
90°
Dial Reading
Dial Reading
(d)
To top of prism P_2

Fig: 2.