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A crystal diode meter circuit for Dobson Ozone Spectrophotometer

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ABSTRACT. In Dobson Ozone Spectrophotometer, the amplified a.c. component of the photomultiplier output is rectified by means of a rotating commutator for indication in the meter. An attempt has been made to replace this mechanical rectifying device by means of a simple crystal diode circuit with satisfactory results. With this, a sharp minimum in current value, and not a reversal of the meter current, indicates null point. Studies have been made to see its workability in different spheres of spectrophotometer operation.

1. Introduction

The Dobson Ozone Spectrophotometer (see Ref.) manufactured by M/s R. & J. Beck Ltd., London, is used in many parts of the world as the standard equipment for estimating atmospheric ozone. The electrical part of the instrument utilizes a photomultiplier, which, along with the a.c. amplifier, produces an a.c. voltage output proportional to the difference between two spectral intensities. A rotating commutator, driven by the shutter motor is used to rectify this a.c. output for indication in the d.c. micro ammeter. An attempt has been made to replace this mechanical rectifying device by means of a simple crystal diode arrangement with satisfactory results. The present paper describes the results of the study of the workability of this rectifier in various spheres of spectrophotometer operation.

2. The Rectifier

This consists of four Philips germanium crystal diodes OA81 in bridge configuration, connected to the amplifier circuit as is shown in Fig. 1. This bridge circuit has the advantage of giving full wave rectification requiring no transformer and leaves the meter terminals floating. Thus it is capable of replacing the commutator without any further change in the original circuit as will be evident from Fig. 1.

3. Rectifier characteristics

Because of the simple ohmic contacts, the commutator gives a d.c. output linearly proportional to the input a.c. voltage down to the very low current values. The diodes, however, show noticeable nonlinearity in the low current region. In fact, the short circuit d.c. current at very low level bears a parabolic relation (Torrey and Whitner 1948) with the input a.c. voltage. And because the diode internal resistance is current sensitive in a complicated way, it is difficult to relate the output to the input by any simple relation that will be valid over the entire operating region.

The transfer characteristics shown in Fig. 2 have been obtained experimentally by feeding 60 c/s sine-wave voltage V at A in Fig. 1 after replacing the valve DL92 and 6·8 K by dotted resistances. The parameter R represents the meter shunt and i the meter current. Evidently V which is proportional to the intensity can be found out from the measurement of i and R for a given super H.T. setting and thus intensities can be compared.

In actual practice, when the diodes are used in the photomultiplier circuit, any measurement involving knowledge of the absolute value of i or V is likely to be extremely limited in its accuracy because of the highly nonlinear characteristics in the low current zone and also due to the fact that the diode output is not entirely due to the difference in two spectral intensities as will be clear from the subsequent discussion. Nevertheless, if the operation be confined to the linear portion of any curve, a difference method may be used for finding out an unknown light intensity in terms of two known intensities by applying the following formula—

$$(L_1 - L_2)/(L_2 - L_3) = (V_1 - V_2)/(V_2 - V_3) = (i_1 - i_2)/(i_2 - i_3)$$

where L = Light intensity

V = Corresponding a.c. voltage output

i = Corresponding meter reading.

4. Null Method

Normal ozone observation can, however, be made by null method that involves no knowledge of V, i, or R. Here, however, a sharp minimum in the current indicates the null rather than the current reversal as in the case with commutator.

Fig. 3 shows the approach towards null at various hours of a day for λλ A and D conditions and indicates the degree of resolution attainable near null. The following observations can be made in this connection —

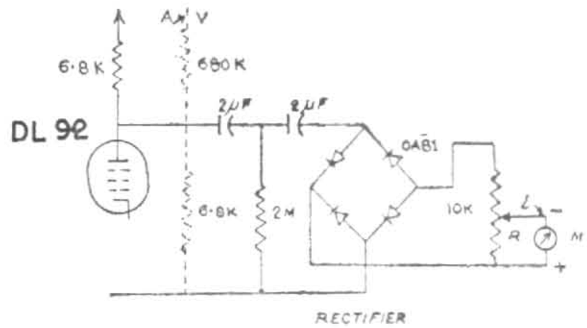

Fig. 1. Rectifier and its testing circuit

(*a*) The current at null is never zero. This is because any variation in photomultiplier current due to either noise pulses or minute fluctuations in spectral intensities passes through amplifier-rectifier channel and appears as the d.c. current in the meter. In the case of commutator, however, only that component of a.c. voltage which has a frequency equal to the chopping rate is rectified by the commutator. Thus the base current in that case is zero. However, the finite base current at null point serves to bias the diode such that the operating point is located in the steeper part of the characteristic curve and thus sharper null is achieved Further, with high standing current, diode internal resistance is lower (Torrey and Whitner 1948) so that insertion loss is minimum.

The base current, as discussed above, may be changed by changing super H.T., meter shunt, absolute value of spectral intensity and its fluctuations.

(*b*) The approach curves become flatter with weaker light. Further, they are asymmetric, the slope being steeper on the lower side of the null. This may give rise to a tendency to record a slightly higher dial reading than the actual value at null. This is particularly relevant in the case of λλA where such asymmetry is more prominent.

(*c*) Higher the value of the shunt resistance, sharper is the approach to null. This is because with higher resistance, the characteristic curves become steeper as is evident from Fig. 2.

(*d*) For greater accuracy in determining the null point, a quick plotting of the current values on either sides of the null may be done, but with a little practice such plotting is hardly necessary in view of the sharpness of approach to null.

Table 1 gives a comparison between the typical dial readings obtained on different occasions with commutator and diode while making observation with clear zenith sky at New Delhi. It will be evident that the two sets of readings tally very well.

TABLE 1
Comparison between the dial reading by diode and commutator

Date	Time (IST)	Wavelength	Dial reading with	
			Commutator	Diode
26-3-64	12-30	λλA	54·5	55·5
		λλD	6·6	7·0
28-3-64	12-16	λλA	50·6	51·0
1-4-64	10-18	λλA	62·8	64·0
		λλD	4·9	5·0
	12-30	λλA	54·0	55·0
		λλD	6·5	8·0
4-4-64	10-30	λλA	59·0	58·0
		λλD	9·5	10·0
	12-15	λλA	57·6	57·0
		λλD	13·5	13·3
	16-30	λλA	138·0	140·0
		λλD	58·4	57·0
14-4-64	12-00	λλA	58·6	60·0
		λλD	10·6	11·0

6. Wedge calibration

The wedge can be calibrated by the normal method of cutting some fraction of total light with the help of wedge so that the current comes back to the same value as when a known obstruction, *e.g.*, rhodiumised plate is put in the light path. Typical wedge calibration curves drawn by means of diodes are shown in Fig. 4 where $\triangle D$ has been plotted against the mean dial reading D. They show remarkable degree of correspondence when compared with such curves drawn with the help of commutator.

7. Wave length calibration

The Q-settings of the ozone spectrophotometer can be performed for different wave length conditions in the usual way by changing $Q_1=Q_2$ on either sides of the expected value and noting the dial reading at null for each $Q_1=Q_2$ value setting. Fig. 5 shows the plotting of such dial readings for λλ D setting, under clear zenith sky near noon.

From the graph,

$$Q_0=(108\cdot2+111\cdot9)/2$$
$$=110\cdot05.$$

Expected value of $Q_0=109\cdot20$.

8. Umkehr observation

Fig. 6 shows the Umkehr curves plotted for morning as well as evening for λλD. It has been observed that when the sun's zenith angle goes beyond about 85°, the light becomes faint enough to make the diode arrangement insensitive and

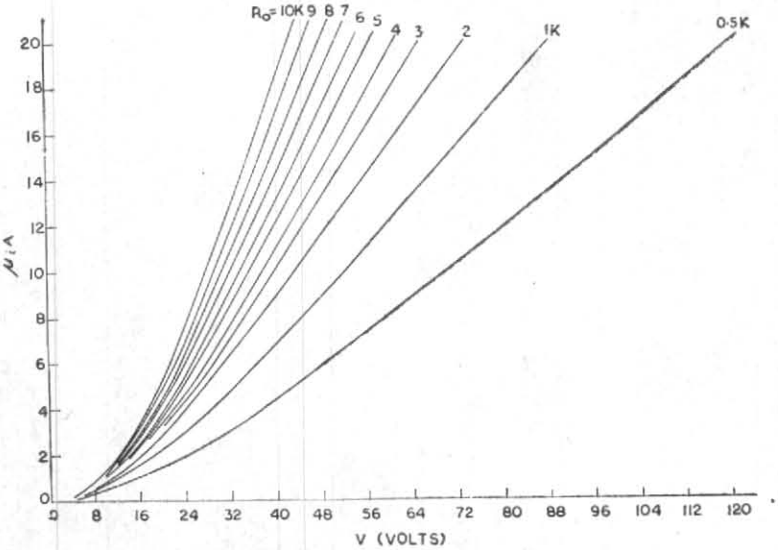

Fig. 2. Rectifier characteristics

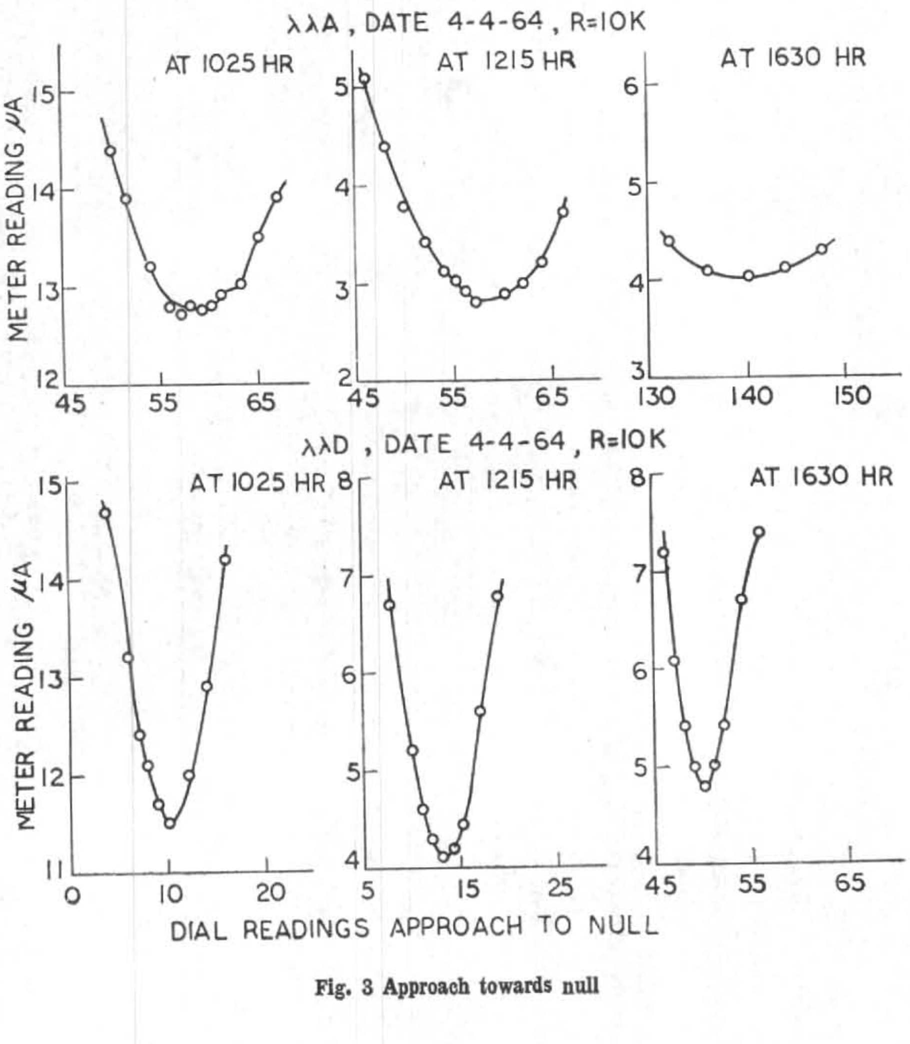

Fig. 3 Approach towards null

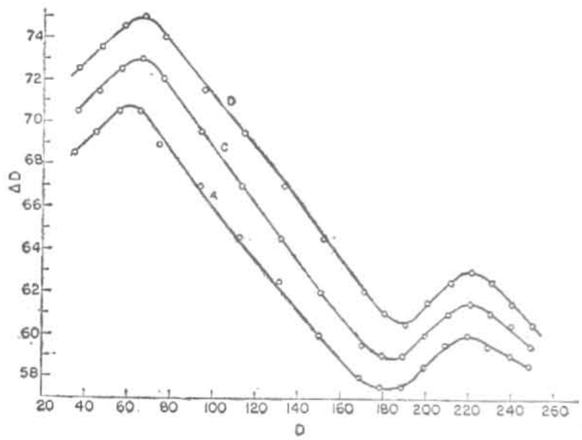

Fig. 4. Typical wedge calibration curve
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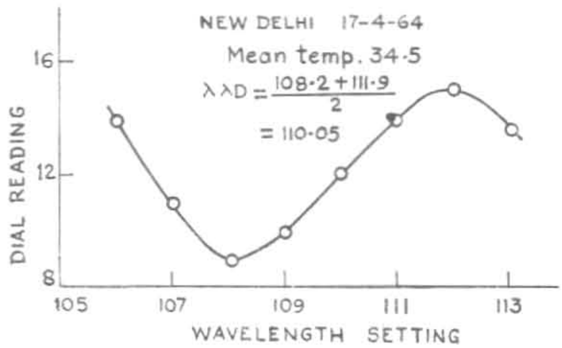

Fig. 5. Wave length calibration

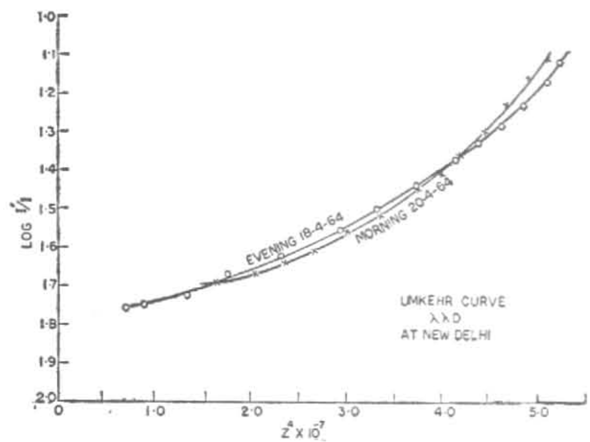

Fig. 6. Umkehr curves drawn with the help of diodes

no observation can be continued beyond this angle either in the morning or evening. With λλA, the observation fails still earlier. It is hoped that with the help of some additional amplification of the signal, Umkehr observation can be extended beyond $Z=90°$. Work is progressing in that direction at present.

9. Discussion

It will be evident from the above studies that the diodes are capable of replacing the commutator in almost all the different spheres of spectrophotometer operation. These have practically infinite life with no maintenance problem. Sensitivity is good because the rectification always takes place exactly when a.c. voltage passes through zero and hence the full a.c. cycle produces the current in the same direction. In commutator this condition is approached only when the phase of commutation is accurately fixed at zero voltage —an operation difficult to achieve in practice. Current stability with diode is found to be much better because of fixed phase of rectification. This is of very great help particularly during wedge calibration. Since no moving part is used, there is no wearing out or source of dust (*e.g.*, carbon particle from brushes) in the instrument. Thus the diodes promise to be a cleaner and much trouble free device for use with the Dobson Ozone Spectrophotometer.

10. Acknowledgement

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