

## FORMATION OF RAINBOWS IN A VERTICALLY PROJECTED SEARCH-LIGHT BEAM

1. A ceilometer constructed in the Instrument Workshop at Poona has been under test since about the middle of June to study its performance under field conditions. The high pressure mercury arc (BH6, 900 watts, 60,000 lumens) of the ceilometer has been in continuous operation during this monsoon. The vertically projected beam from the mercury arc is visible at night as a slightly divergent column of light, its brightness decreasing uniformly from bottom to top (Fig. 1a). Because of varying atmospheric turbidity, the brightness of the column of light arising from scattering has been found to undergo variations from day-to-day. On account of the elongated shape of the mercury arc, the cross-section of the beam is not circular but pencil-shaped. When there is low cloud the illuminated portion appears as an elongated patch. Often several layers of clouds can be seen moving across the column of light.

2. Observations of the search-light beam on nights when light or moderate rain was falling have revealed an interesting feature which is reported in this note. Watching the beam from a distance of about 100 yards one sees two bright bands of which the upper one is brighter than the lower (Fig. 1b). Both these bands reveal spectral colours. The upper and brighter band is reddish at the bottom and violetish at the top; the lower and fainter band is reddish at the top and violetish at the bottom. The space between these two bands is comparatively dark and under favourable conditions the

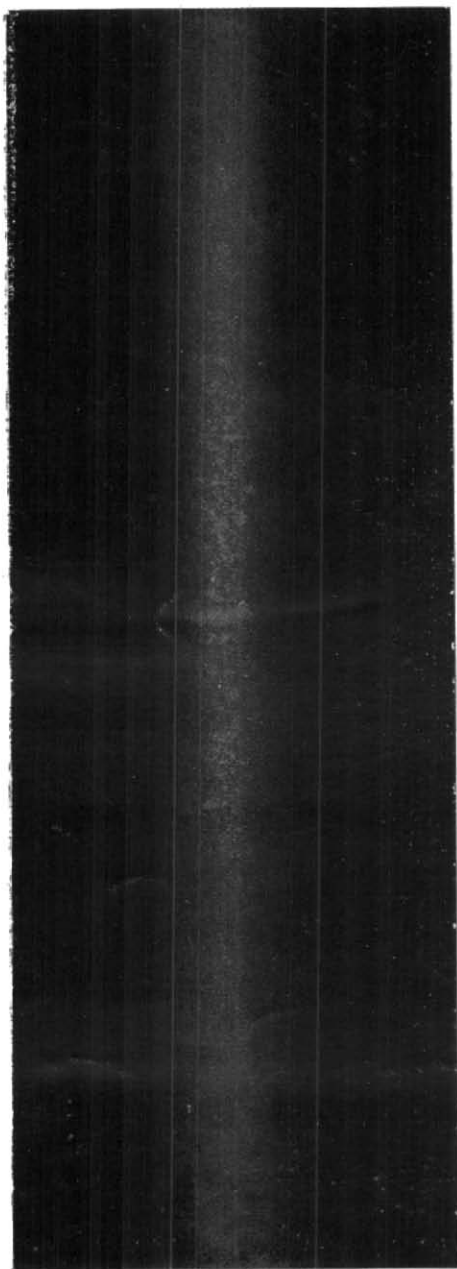


Fig. 1(a)

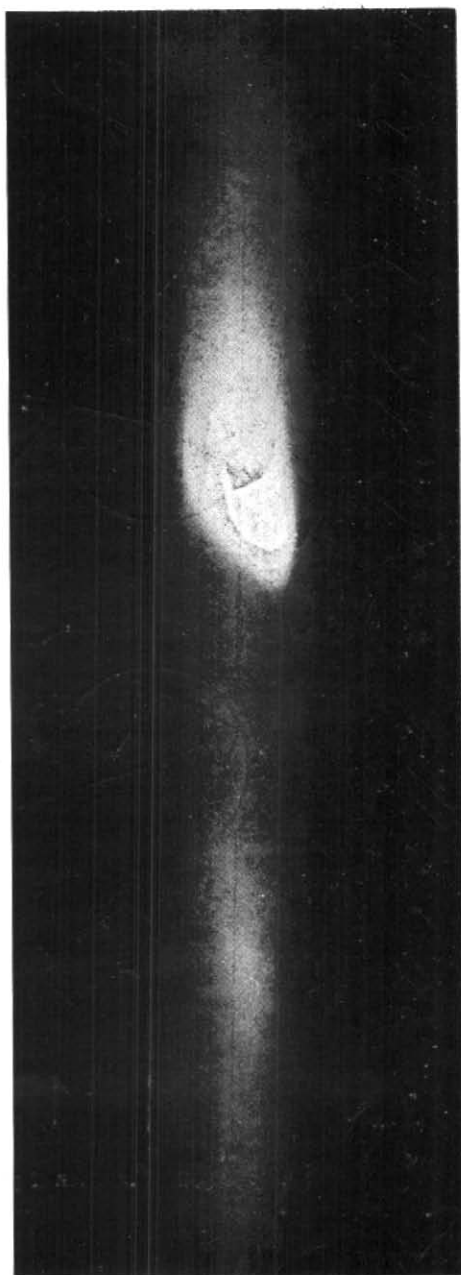


Fig. 1(b)

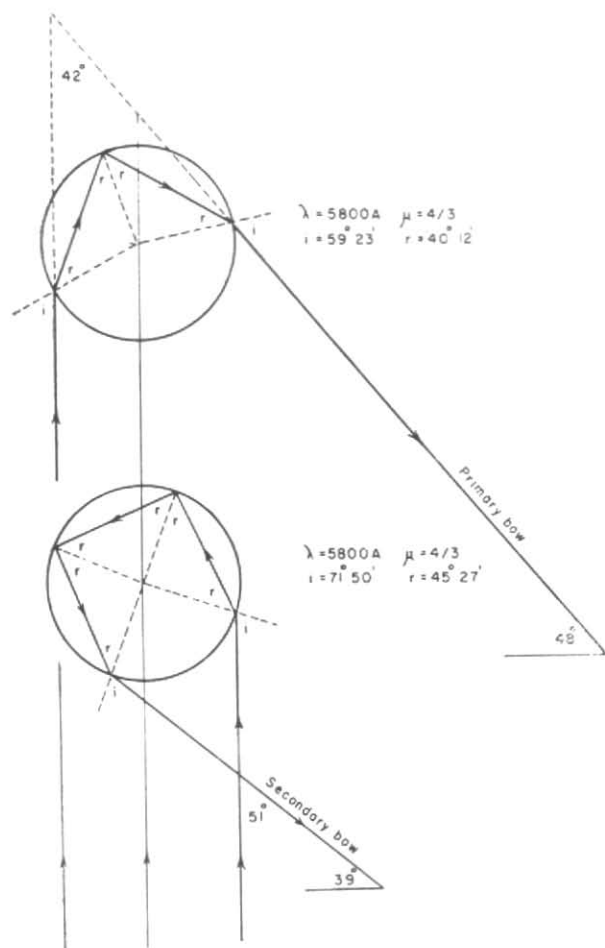


Fig. 2. Formation of primary and secondary rainbows

contrast between it and the parts of the beam above and below it is striking. These observations immediately suggested that this is a case of formation of rainbows, the upper band being the primary bow and the lower one the secondary bow. With the help of an alidade the angles of elevation of the two bright bands were measured from the place from which the photographs reproduced in Figs. 1(a) and 1(b) were taken. The angles of elevation were found to be approximately  $50^\circ$  for the upper band and about  $40^\circ$  for the lower one. It may be mentioned that no special care had been taken to adjust the search-light beam to be perfectly vertical so that a small error in the verticality of the beam cannot be ruled out.

3. According to the geometrical theory of formation of rainbows explained in standard text books, the angles of deviation of the Descartes ray for  $\lambda=5800 \text{ \AA}$  and  $\mu=4/3$  are  $\pi-42^\circ$  for the primary bow and  $2\pi-129^\circ$  for the secondary bow. As can be seen from Fig. 2 the corresponding angles of elevation for the primary and secondary bows for a parallel vertically projected beam are  $48^\circ$  and  $39^\circ$  respectively. The measured angles are in satisfactory agreement with these values. From the geometry of the problem it is clear that while the secondary bow appears at a higher elevation than the primary bow in the case of natural rainbows formed when sunlight is refracted by falling raindrops at a distance, the primary bow has a higher angular elevation than the secondary when these are formed in the vertically projected beam of search-light.

4. The striking features of the observations reported here are the brightness of the primary bow, the sharp cut-off of illumination at its bottom edge and the comparatively dark column between the primary and secondary bows. All these features are best noticed when the rain drops are falling steadily without being disturbed by wind. When the rain is blown about by wind, various streaks and striations of illumination are noticed. These arise from non-uniform spatial distribution of the drops

(including regions temporarily free from drops) in the small section illuminated by the beam. When it is raining rather heavily, the sharp cut-off of illumination below the primary bow is not at times so conspicuous presumably due to the distortion of the bigger drops from spherical shape.

5. As is well known the primary and secondary bows have no fixed location in space but their angles of elevation will be the same irrespective of the location of the observer. There is a possibility that in the actual working of a ceilometer while it is raining, the scanner might "see" the rainbows and mistake them for cloud. Assuming a distance of 1000 ft between the search-light and the scanner, the primary bow will correspond to a height of about 1110 ft and the secondary bow, if recorded, to a height of about 810 feet. Examination of the ceilometer records of Santacruz for the months of June and July 1959 together with the corresponding records of the self-recording rain gauge showed on several occasions a characteristic trace beginning at about  $48^\circ$  elevation and extending upwards for a few degrees. These traces could be associated with spells of rainfall of light intensity as judged from the rain gauge records.

6. Even in the case of the rotating beam ceilometer in which the scanner is kept fixed facing vertically upwards, the primary and secondary bows will be visible to the scanner when the beam makes angles of  $48^\circ$  and  $39^\circ$  respectively with the horizontal. It may also be mentioned that although rainbows formed in the search-light beam are not visible to the naked eye during day time, the scanner will be able to "see" them both during day and night.

7. The photographs reproduced in this note were taken with a Rolleicord camera of aperture F/3.5 on Agfa Isopan film with an exposure of about 2 minutes.

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