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Visibility at the Colaba Observatory, Bombay

S. M. MUKHERJEE AND C. S. KARVE.

(*Received 11th October, 1948.*)

ABSTRACT. Special observations of visibility were taken from the electrometer tower of the Colaba Observatory, about 50 feet from the ground, with a Bennett visibility meter at seven specified hours between sunrise and sunset, almost daily during November 1936 to March 1939. Seven objects situated at different distances in different directions from the observatory were used and the data from these observations are discussed for monthly variations. For hourly observations on selected days and nights, fourteen objects at different directions and distances and five city lamps towards north, were mainly observed with the Bennett and a Wigand meter. Typical hourly observations are discussed and shown diagrammatically. Wind and associated visibility are statistically analysed.

1. *Introduction.*

Special eye observations* of visibility were made with measurements of atmospheric electric elements at the Colaba Observatory from the middle of 1935 to 1936. These data were published elsewhere.[1] During this period the main features of the variation of visibility were observed. The data of subsequent study with a visibility meter are presented in this paper.

2. *Observations.*

The bulk of the data was collected from the observations during 6 to 7, 8 to 9, 10 to 11, 12 to 13, 14 to 15, 16 to 17, and 18 to 19 hours Bombay Mean Time (B. M. T.), taken almost daily except when the visibility meter was out of order.

The data with regard to each of the seven visibility objects collected in different hours of the day are grouped according to disc numbers 0-3, 4-6, 7-9, 10-12, 13 and above. The percentage frequencies of each of these groups for all the seven objects in different months and of those, associated with different wind directions for the Truncated Peak, White Building and the city lamps for the dry and wet periods are worked out and discussed in sections 6(*a*) and 6(*b*) respectively.

The visibility of objects corresponding to disc numbers 0 to 3 is designated as bad or poor, 4 to 6 as fair, 7 to 12 as good and 13 and above as excellent.

*C. S. Karve used some of these observations for his thesis presented for the M.Sc. degree of the Bombay University.

3. *Relation between Wigand and Bennett meter disc numbers and International Code Figure for Visibility.*

TABLE I

Visibility Code figure.	Visual range (meters).	Wigand disc number required to render an object invisible at different distances.								
		Distances of the objects in meters.								
		50	200	500	1,000	2,000	4,000	10,000	20,000	50,000
0	50									
1	200	6	1							
2	500	10	4	1						
3	1.000	12	7	3	1					
4	2,000	13	10	5	3	1				
5	4,000	13	12	9	5	3	1			
6	10,000	14	13	12	10	7	3	1		
7	20,000	14	14	13	12	10	7	3	1	
8	50,000	14	14	14	13	12	10	7	4	1

In table I is shown the relation between the Wigand meter disc number and the international visibility code figures in practical use, calculated from the relation

$$L = 66l \left[\frac{1}{14 \cdot 3 - a} - 0 \cdot 06\right]$$

where L = the visual range and l = distance of the visibility land mark, and a = the Wigand disc number required. The different distances are those adopted as limiting distances in the international code of visibility. In table II are given the data of simultaneous observations, during day and night, by the Wigand and the Bennett meters to show the relation between their disc numbers.

TABLE II

Wigand meter reading.	Average Bennett meter reading (day).	Average Bennett meter reading (night).
0	0	0
1	1	1
2	2	3
3	3	3
4	4·1	4
5	5·2	4·9
6	6·2	5·9
7	7·2	6·9
8	8·3	7·9
9	9·4	8·9
10	10·6	9·9
11	11·7	10·9
12	12·8	11·9
13	13·9	12·9
14	15 to 21	14 to 21

4. *Visibility land marks.*

Particulars of land marks observed at specified hours during day time are given in table III.

TABLE III.

No.	Object.			Azimuth.	Approx. distance (miles.)
1	Kennery Island and Light House	..	..	180° (S)	13
2	Truncated Peak of a Hill	..	..	42° (NE)	22
3	Tower of Bombay Secretariat Building	..	..	30° (NE)	2·5
4	White Building on Malabar Hill	..	..	334° (NNW)	4·1
5	Sunk Rock Island	..	..	(E)	2
6	Afghan Church	..	..	23° (NNE)	0·7
7	Highest Peak of Karanja Hill	..	..	(ENE)	8

The back ground of the White Building was the wooded Malabar Hill and of the rest, the sky. Besides the White Building, thirteen additional objects—black against sky back ground, at different directions (N to S), distances (4 to 25 miles) and heights (70 ft. to 2000 ft., a. s. l.) observed every hour on selected days.

For the purpose of night visibility, a few street lamps were chosen in the area from the Malabar Hill upto the centre of the city. These were of about 100 c.p. each, as far as possible isolated and at distances of about 3½ to 4 miles from the Observatory. The revolving lamps of the Kennery Light House to the south was also used.

5. *A few noteworthy features of visibility at Bombay.*

In winter, heaps of smoke are carried by sea breeze over the eastern hills to a height of about 800 to 1500 feet from the ground by evening time. In the pre-monsoon and hot months March to May, these characteristics are somewhat the same as in the winter months. The conspicuous difference lies in the fact that as the season advances, the sea breeze becomes stronger and the duration of the land breeze gets shorter. Occasionally a kind of haziness develops and persists on a few consecutive days in this season. Similar haziness continues for some days continuously before the onset of the south-west monsoon. This is followed by a period of exceptionally good visibility all-round, probably the best visibility in the year, for a week or two immediately before the commencement of the monsoon. This transition from poorer to better visibility takes place rather abruptly indicating the sudden advance of monsoon air over Bombay. This is followed in a week or two by cloudy weather and rainfall.

6. *Discussion of results.*

(a) *Monthly variations.*

January to March.—In January the visibility of the White Building on the Malabar Hill (NNW) is poor almost every morning due to settling of smoke from the land area by weak land breeze and formation of mist or haze. Maximum obscurity of the object occurs soon after sun rise and is rapidly dispersed by convection by about 9 hours and the residual turbidity is cleared after onset of the sea breeze which generally commences shortly before mid-day. By afternoon, the visibility is invariably good. The distance of the Secretariat Tower (NE) is not far enough to give the details of diurnal variation of visibility of this object. Nevertheless, the variations are almost similar to those of the White Building with this difference that the frequency of occurrence of mist and poor visibility is less, by about 30%, than that of the White Building. Consequently, there are a few occasions of fair and good visibility on some mornings. The Truncated Peak (NE) of the hill is either invisible or faintly seen on the majority of mornings (on about 60% of days). On some days (about 20% occasions) the object can be clearly seen in the morning. As the day advances, the visibility deteriorates and by afternoon, this is almost always invisible. The reason for this variation is that the land-wind at night pushes the smoke haze away from the object into the sea and, with the onset of the sea breeze, the sea haze and smoke from the mill area and the harbour are moved into the mainland, and by afternoon, sufficient smoke haze collects and completely obscures the object. Noticeable deterioration starts by about 10—11 hours approximately coinciding with the time of onset of the sea breeze. So far as the Karanja Hill (ENE) is concerned, there are very few occasions of poor visibility (say 5 to 10%) and these are not confined to morning hours alone but are distributed over the day. Good visibility predominates in the day and there is no marked variation of visibility of this object. In the case of the Kennery Light House (S), poor visibility predominates in the morning and good visibility in the afternoon, the transition from bad to good visibility being clearly marked by 13 to 14 hours, about 3 hours after the onset of the sea breeze at Colaba. Apparently smoke haze which spreads over the sea due to land breeze takes 2 to 3 hours to move past this object after onset of the sea breeze.

In February and March, the variation of visibility of all the objects is nearly the same as in January. However, as the season advances the frequency of mist and bad visibility becomes less, and less probably due to decreased stratification of the atmosphere and shorter duration of the land breeze. In March, the Truncated Peak is always invisible.

April and May.—In the case of the White Building, bad visibility in the morning is to be observed on still fewer occasions, about once in 3 days in April and once in 10 days in May. Otherwise, good visibility prevails throughout the day. The visibility of the Secretariat Tower and the Karanja Hill continues good practically in all the hours of the day. The Truncated Peak is practically invisible in these months. Variation of visibility of the Kennery Light House is nearly the same as in January.

November and December.—The variations of visibility of the White Building in November and December are nearly similar to those in April and March respectively. For the Secretariat Tower, visibility is good in November except for a few occasions of bad visibility due to morning mist. The conditions in December and February are nearly the same. Visibility of the Truncated Peak in the morning in November is good on about 80% of days and bad visibility is rare in contrast to conditions prevailing in other months of the dry period. Frequency of bad visibility increases with advance of the day,—the transition being marked once at about 9 to 10 hours and again at about 13 to 14 hours. Conditions in December closely resemble those in January. In the case of the Karanja Hill the visibility is almost always good in these months. In November visibility of the Kennery Light House is nearly always good. In December frequency of good visibility of this object increases from about 40% in the morning to about 95% in the afternoon.

October.—The visibility of the White Building and the Secretariat Tower, of the Kennery Light House and the Truncated Peak and of the Karanja Hill are nearly similar to those in November, January and December respectively for these objects. In October, the conspicuous increase in bad visibility of the Truncated Peak occurs by about 16 hours instead of about 10 hours in January.

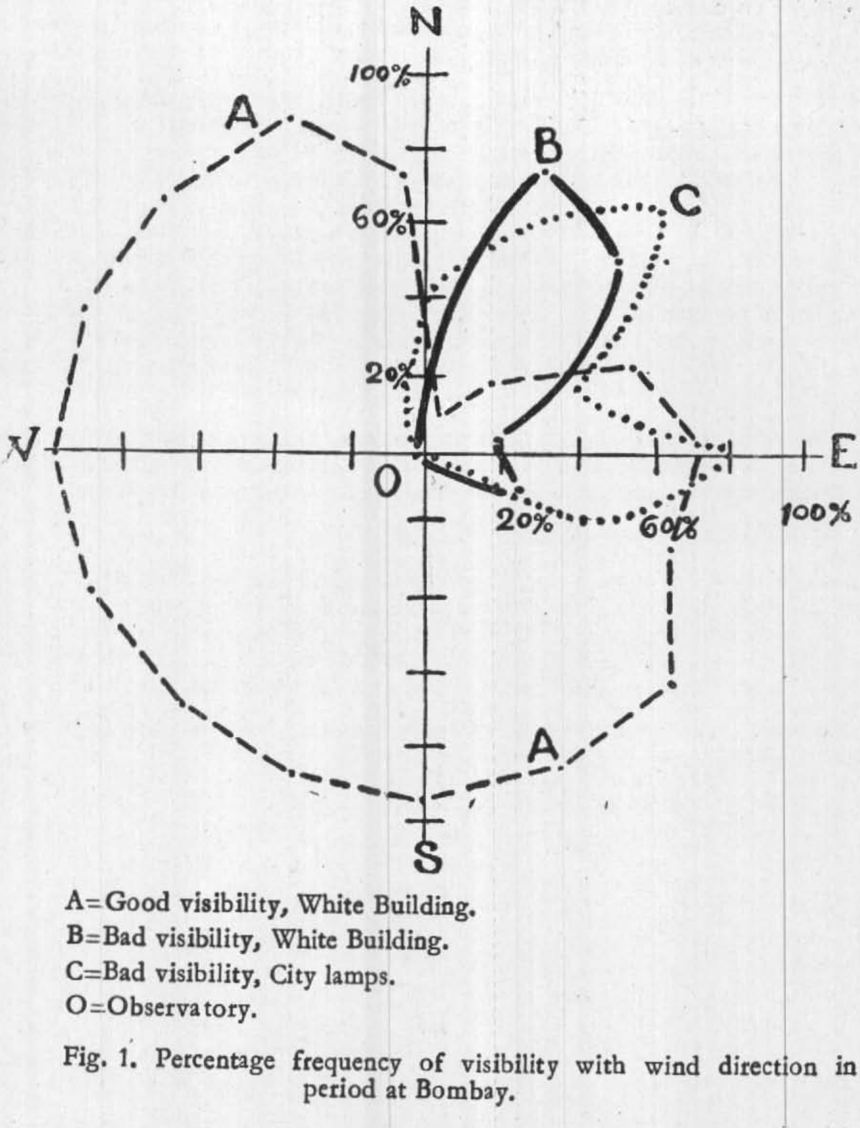
June to September.—During monsoon visibility of the White Building does not vary systematically and good visibility is most frequent. Frequency of good visibility somewhat decreases from June to July, apparently due to increase of rainfall, and increases thereafter. Visibility of the Secretariat Tower is nearly always good. The Truncated Peak is always invisible except on about 8 to 10 days in June corresponding to days of exceptionally good visibility prior to burst of the monsoon. The Kennery Light House is practically invisible in July. In June and August the visibility is bad on the majority of occasions. In September the object is visible on as many occasions as it is invisible. So far as the Karanja Hill is concerned, visibility in June and July is good on about half the number of days. In the remaining days, it is bad or fair. In August and September visibility is good on most of the days. There is no marked diurnal change.

The lowering of visibility in different hours of the day in the monsoon is mainly due to rainfall. Even without rain, change in concentration of the monsoon haze is, to a certain extent, responsible for the change of visibility in this season.

(b) *Statistics of wind and associated visibility.*

The distribution of percentage frequency of good and bad visibility of the White Building and bad visibility of the city lamps with different directions of wind in the dry period, is shown in figure 1. This is similar to the variation of visibility of these objects in the wet period but almost opposite to that of the Truncated Peak in the dry period. The Truncated Peak remains almost invisible in the wet period.

Good visibility at night also follows nearly the same characteristics as those of the near objects during the day time.



A=Good visibility, White Building.
B=Bad visibility, White Building.
C=Bad visibility, City lamps.
O=Observatory.

Fig. 1. Percentage frequency of visibility with wind direction in dry period at Bombay.

(c) *Hourly variations of visibility on selected days during November to May.*

November 6, 1936.—On this day the visibility of objects in different directions varied widely. The visibility of the different objects, except those towards south, became a minimum at varying times between 0700 and 0930 hours B. M. T. With the near objects towards the north the visibility was good all the time after 0900 hours B. M. T. In the case of the more distant objects between north and east-south-east, the improvement progressed at a much slower rate while the objects towards the south and south-south-east gradually deteriorated in visibility and the minimum was reached between noon and 1 p. m. With the veering of wind from north-west to north-north-west and associated strengthening, the visibility of objects towards north-east, east and east-south-east became gradually worse due, no doubt, to conveyance of smoke, which was carried westward by the north-easterly breeze, to the region between the Observatory and the mainland. The visibility of objects in other directions showed some improvement. The variations of visibility at the different hours with the associated changes of wind are shown in figure 2. The azimuths, the distances in miles and the heights in feet of the objects are shown against the relevant curves.

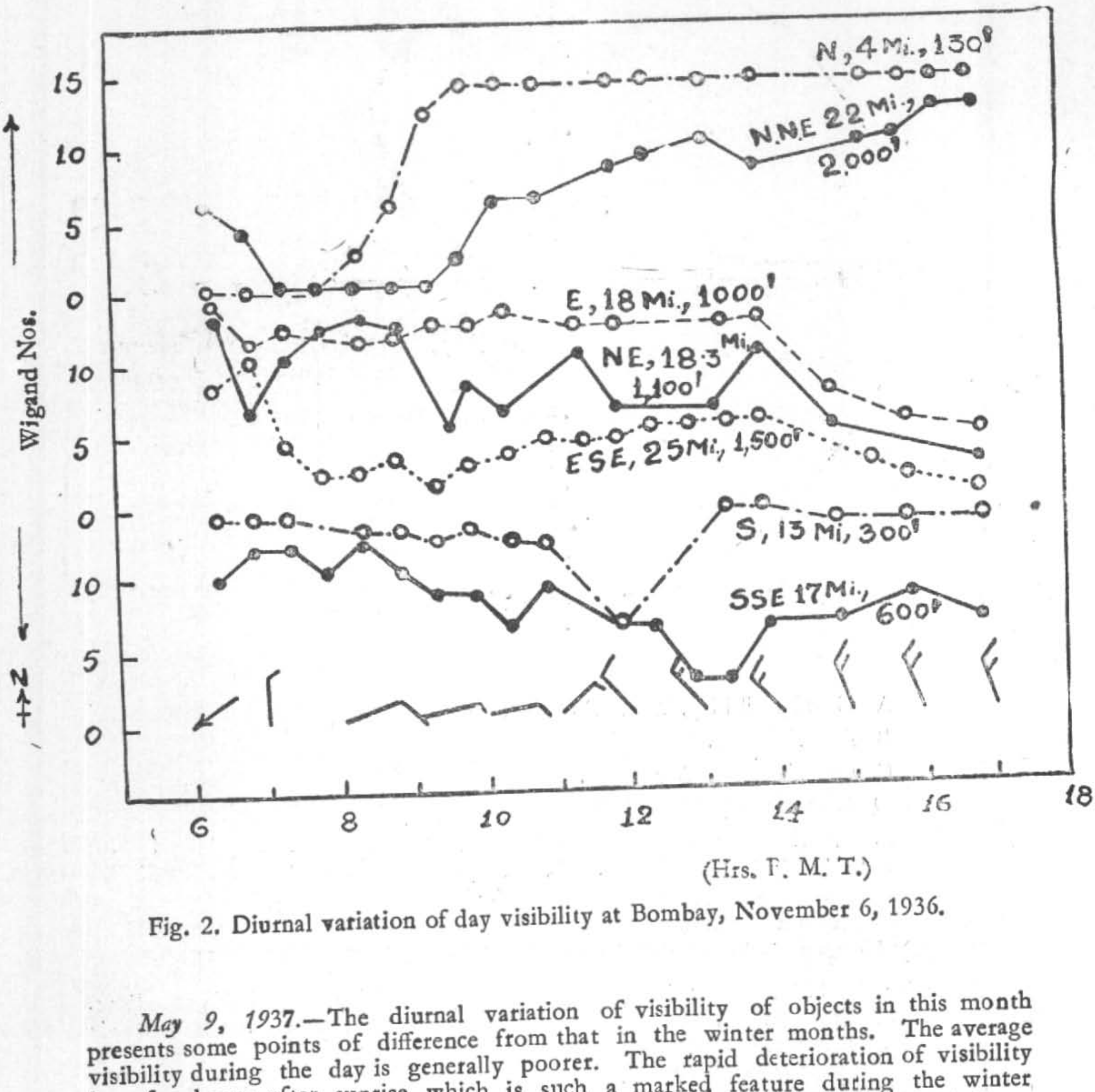


Fig. 2. Diurnal variation of day visibility at Bombay, November 6, 1936.

May 9, 1937.—The diurnal variation of visibility of objects in this month presents some points of difference from that in the winter months. The average visibility during the day is generally poorer. The rapid deterioration of visibility in a few hours after sunrise which is such a marked feature during the winter months is practically absent. The visibility of the hills towards the north-east and east does not improve to the same extent as in the afternoon hours of December or January. The afternoon increase of visibility is, however, common to this month and to the winter months. These peculiarities of visibility are connected with the diurnal variation of wind and vertical temperature lapse-rate. As the season advances, the duration of land breeze gradually decreases and for the major part of the day the wind remains some westerly to north-westerly in direction. The night inversion of temperature which is present on almost all days in December and January is very feeble or absent in May.

Both the relative and absolute humidities are also higher in May than in winter months. This causes the appearance of haze in the direction of the hills towards east and north-east.

The visibility curves and associated winds are shown in figure 3.

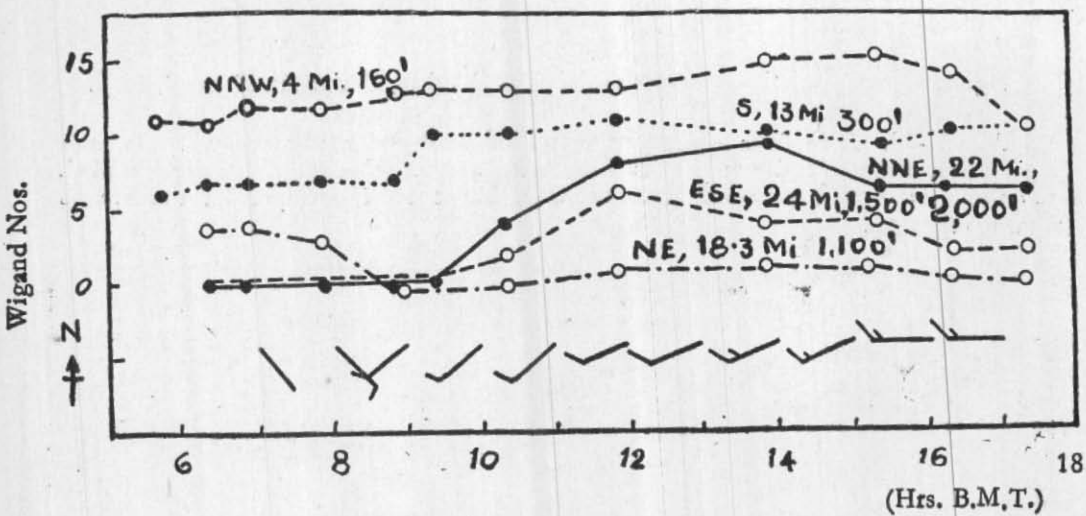


Fig. 3. Diurnal variation of day visibility at Bombay, May 9, 1937.

(*d*) *Hourly variations of visibility during selected nights during November to May.*

December 29 to 30, 1936.—The effect of land and sea breezes on visibility is shown distinctly by the observations made on this night and reproduced in figure 4. The sequences of deterioration of visibility with incidence of weak land breeze by about 2000 hours, subsequent improvement with further change in direction and velocity of wind followed by further deterioration, due to early morning mist, are clear.

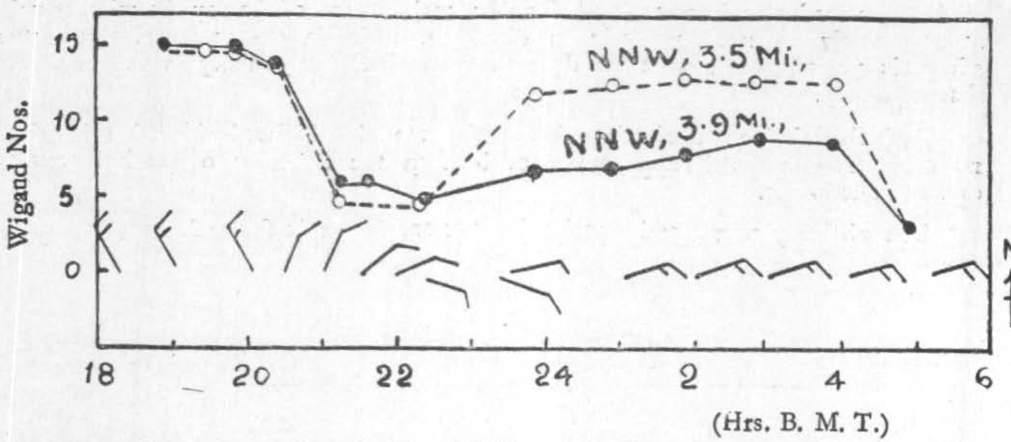


Fig. 4. Diurnal variation of night visibility at Bombay, December 29 to 30, 1936.

May 21-22, 1938.—The alternating effect of land and sea breezes which is such a prominent feature in dry months is practically absent in most of the days in May, as on rainless days in monsoon, when the wind blows continuously from the sea as shown in figure 5.

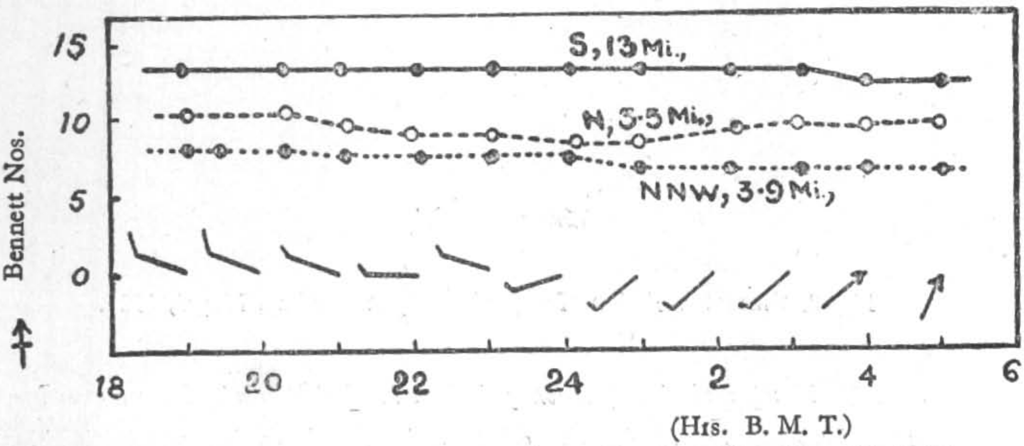


Fig. 5. Diurnal variation of night visibility at Bombay, May 21 to 22, 1938.

Hourly observations of visibility and wind during a large number of individual days and nights in different months during 1936-38 were taken. The above examples are a few out of them and typify the characteristics of visibility and wind at Bombay.

The investigation was carried out under the direction of Dr. K. R. Ramanathan. To him and to the members of the staff of the Colaba Observatory who helped us substantially in the observations during specified hours of the day, our best thanks are due.

REFERENCE:

1. Mukherjee, S. M., *J. Univ. Bombay*, XI, part III, (1912).