a fall in the illumination of the objects under study finds a natural explanation on the basis of the principles of the quantum falling on each element of area of the retina to put forward a rational explanation of the observed facts on any other basis. If the optical image formed on the retina is to be transmitted without loss of detail to the visual cortex, the number of quanta of energy falling on each element of area of the retina and actually absorbed by it and passed on to the visual centres in the brain should be such that each cone in the area under consideration can function fully and effectively. This would obviously not be possible if the flux of illumination falling on the retina is too small, or if the absorbing power of the retinal pigments is inadequate to capture all the incident light-quanta, and make them available for visual perception. The fact that photopic vision can adjust itself to very high levels of illumination is an indication that the visual pigments present in the retina are not capable of absorbing more than a very small percentage of the incident light-quanta. If, in addition, the retinal illumination is itself of low intensity, not more than a small fraction of the cones in the retina can actually be functioning in any small interval of time—such as, say, one-hundredth part of the second—and a dropping off of the visual acuity to very low values is then inevitable. A simple calculation which takes account of the number of light-quanta incident on the retina during any such small interval of time and the number and spacing of the receptor-elements, *viz.*, the cones present in the area shows that this explanation is sustainable.

## SQUALLS IN INDIA

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IN the design of buildings, bridges, chimneys, dams, light-houses, transmission poles, etc., the engineers have to take into account various aspects of destructive winds. The need for information on such winds in different parts of the country is on the increase.

From the point of engineering the destructive winds can be classified into two types—(*i*) winds associated with squalls which are transient local phenomena lasting for a couple of minutes and (*ii*) winds associated with large-scale phenomena like cyclones and depressions that last for a longer time affecting a wider area.

Here we shall consider only the squalls. Technically a squall is a sudden increase of wind speed by at least 3 stages on the Beaufort scale, the speed rising to force 6 (39 to 49 km.p.h.) or more, and lasting for at least one minute. In Assam and Kashmir there is no observatory equipped with anemograph to record squalls. The present study therefore refers to the rest of India for which 7 to 13 years data are readily available for a fairly good network of 25 stations given in Table I. It may be pointed out that the conclusions based on these short period data are tentative and intended to give only a very broad picture of the outstanding features of squalls.

### DISTRIBUTION OF SQUALLS

From the distribution of mean annual number of squalls (Fig. 1), it is seen that a maximum of 50 to 70 squalls occur a year in S. Kanara and Kerala while a minimum is observed in Rajasthan and Gujarat and east of the Western Ghats over Deccan plateau. A large part of North India and the Coastal Andhra Pradesh also experience such small number of squalls, less than 20 per year.

In India squall is mainly a hot weather phenomenon. Over 60% of the annual squalls occur during the months March to September. It can be seen from Fig. 1 that certain regions experience practically all the squalls during a couple of months. For instance, the Punjab experiences as much as 80% of the total annual squalls during the period March to July. With the approach of the cold weather season the frequency of squalls rapidly decreases all over the country. During the months December and January, frequencies of squalls are negligibly small.

### DIRECTIONS OF SQUALLS

Squalls may approach a place from any direction. On certain days they have been reported with directions diametrically opposite from two stations situated a few kilometres apart. Further there have been instances when the same place experienced two or more squalls on the same day from different directions. Despite these vagaries it seems from an analysis of the directions of squalls that during the pre-monsoon and monsoon seasons squalls tend to blow from a particular direction depending upon the region. From the wind roses of squalls given in Fig. 2(*a*) for the pre-monsoon period (March to May), it can be seen that the general directions of squalls in N. India differ considerably from those in S. India. They are mainly west north-westerly in N. India becoming north-easterly in S. India after a clockwise change. A careful study has revealed that these general directions are fairly comparable with the prevailing winds in the afternoons at 3 km.a.s.l. To depict this curious relation the stream lines of the afternoon winds at 3 km. for the typical month of April are superposed on the wind roses in Fig. 2 (*a*).

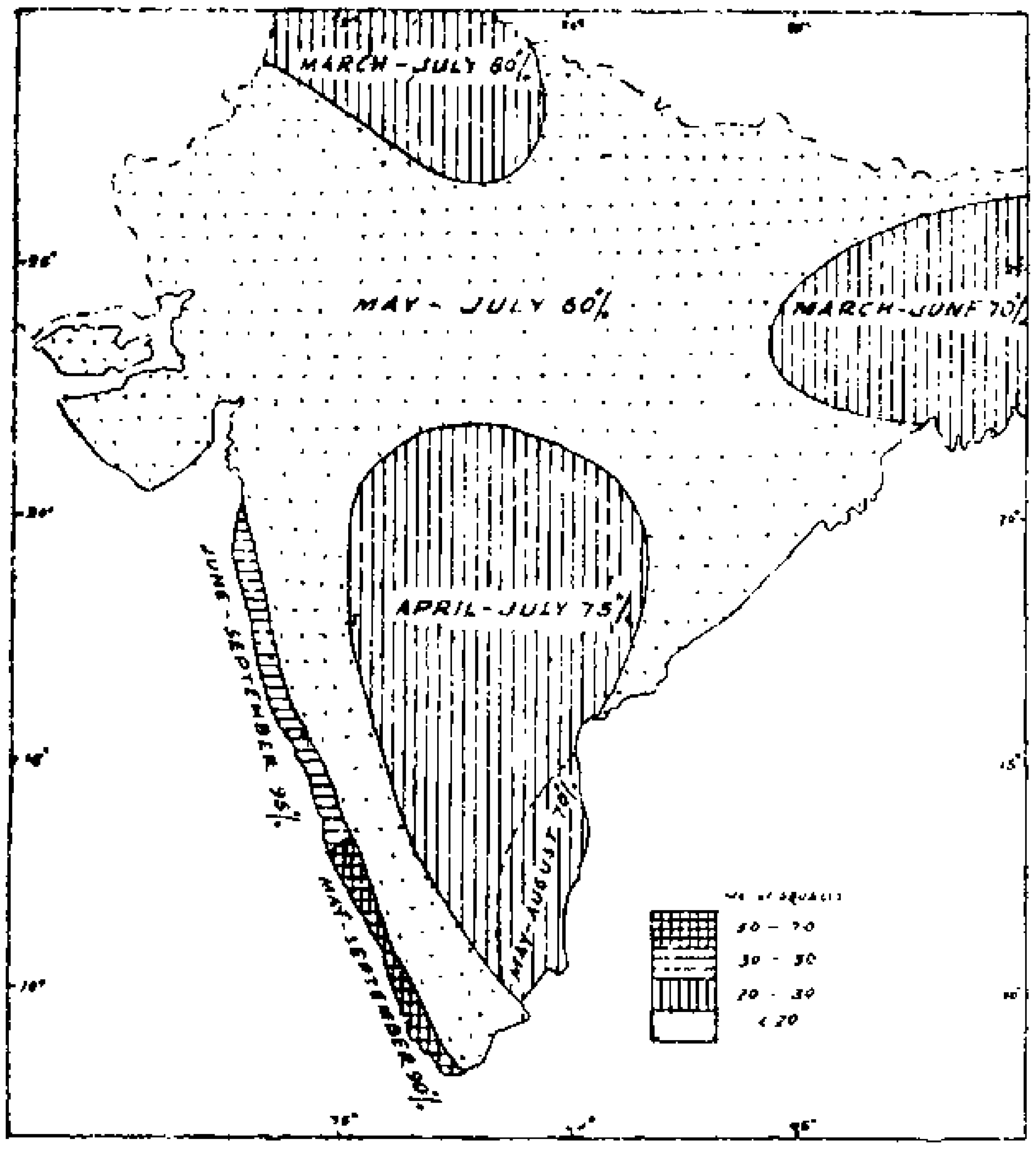


**FIG. 1.** Mean annual number of squalls and their period of maximum frequency %.

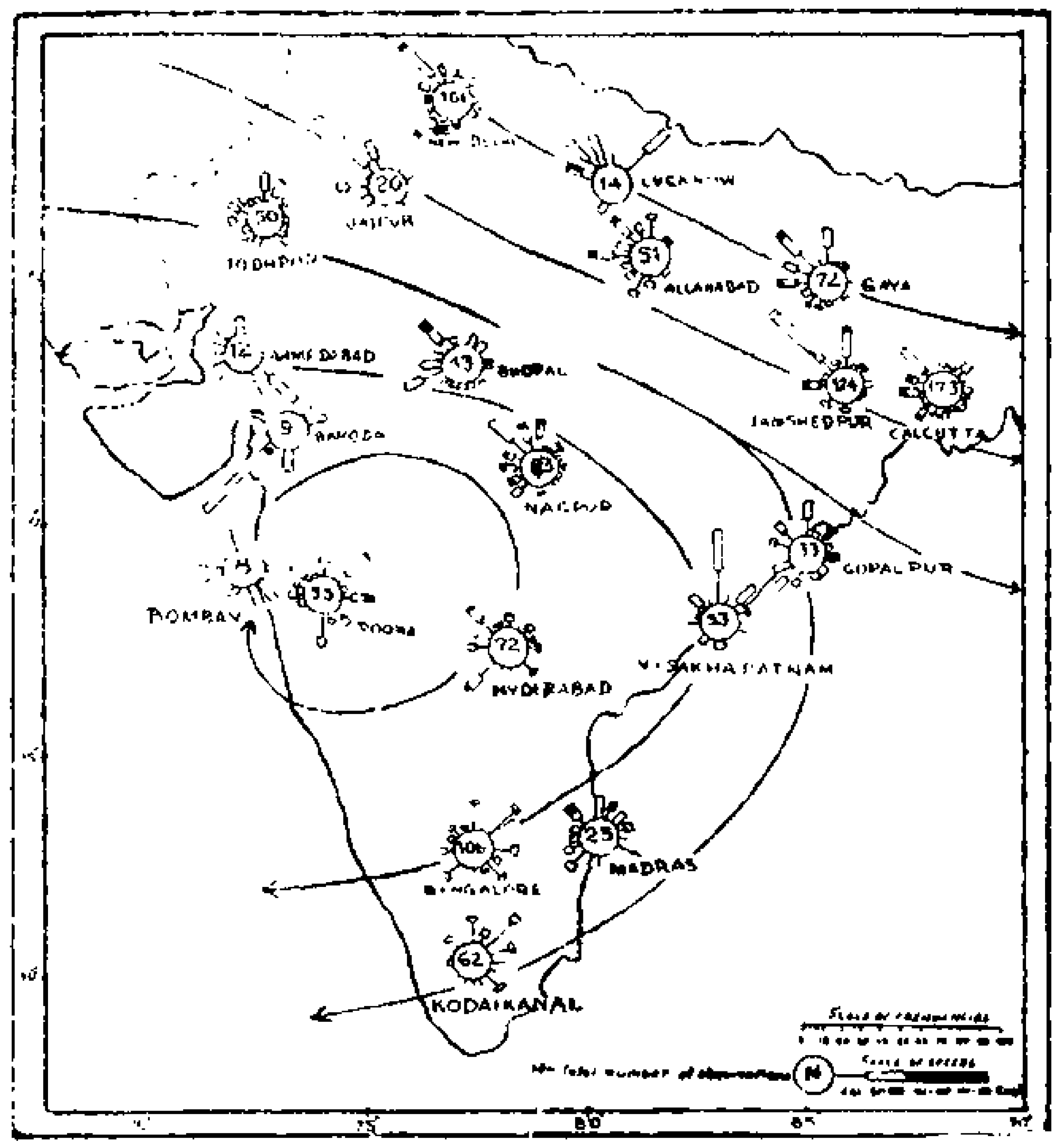


FIG. 2 (*a*). Wind roses for squalls in pre-monsoon season and stream flow of afternoon winds at 3 km. a.s.l.

During the monsoon season (June to September) the general directions of squalls over S. India are mainly westerly [Fig. 2 (*b*)]. Over the Punjab, Rajasthan and U.P. they are mainly north to north-easterly. Squalls are very variable in direction in Bihar and Bengal. For the months October to February the squalls are too few in number to give a useful indication of their general directions. Even for the pre-monsoon and monsoon seasons discussed above it may be remembered that complete reliance cannot be given to the mean directions of squalls for want of long period data. But the relation between the mean directions of squalls and the upper wind directions indicated by the available data for the pre-monsoon period seems to be an important aspect which, when confirmed with the help of more data, may help us to get an idea of the general directions of squalls over regions where actual observational data may not be available.

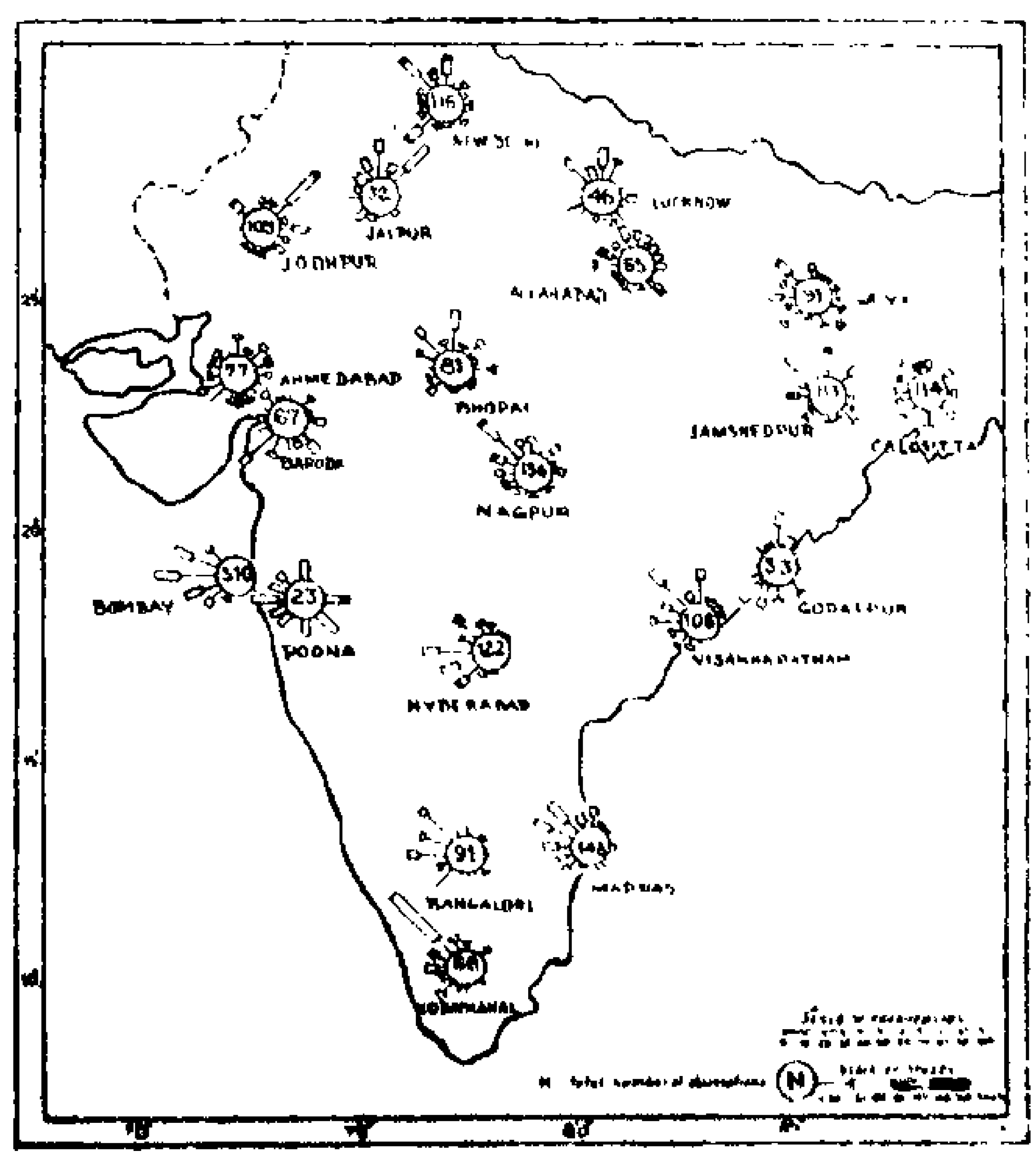


**FIG. 2** (*b*). Wind roses for squalls in monsoon season

### Maximum Gust Speed

In Table I are given the maximum wind speeds in gusts associated with squalls at all the stations. The highest wind speed so far observed is 163 km.p.h. at Allahabad, on 21 March 1950. A large part of the Gangetic plain is vulnerable to such violent squalls whereas in the west coast of the Peninsula squalls have not so far exceeded a speed of 97 km.p.h.

**Table I**

*Statistics of squalls in India*

| Station | | Latitude °N. | Longitude °E. | Height of Anemograph above ground (metres) | Period of data | Maximum wind speed in gust (km.p.h.) | Frequencies of Squalls of different wind speeds (km.p.h.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 141–160 | 101–140 | 60–100 | <60 | Total |
| New Delhi | .. | 28° 35′ | 77° 12′ | 19·8 | 1948–1960 | 159 | 1 | 12 | 182 | 110 | 305 |
| Jaipur | .. | 26° 49′ | 75° 48′ | 18·3 | 1950–1960 | 144 | 1 | 0 | 36 | 19 | 56 |
| Lucknow | .. | 26° 45′ | 80° 53′ | 13·7 | 1954–1960 | 119 | 0 | 3 | 33 | 29 | 65 |
| Jodhpur | .. | 26° 18′ | 73° 01′ | 18·3 | 1948–1960 | 151 | 2 | 6 | 102 | 48 | 158 |
| Allahabad | .. | 25° 27′ | 81° 44′ | 12·2 | 1948–1960 | 163 | 1 | 7 | 70 | 54 | 132 |
| Gaya | .. | 24° 45′ | 84° 57′ | 13·9 | 1951–1960 | 127 | 0 | 5 | 78 | 92 | 175 |
| Bhopal | .. | 23° 16′ | 77° 21′ | 11·7 | 1952–1960 | 111 | 0 | 3 | 66 | 68 | 137 |
| Ahmedabad | .. | 23° 04′ | 72° 38′ | 14·8 | 1953–1960 | 109 | 0 | 2 | 27 | 65 | 94 |
| Jamshedpur | .. | 22° 49′ | 86° 11′ | 15·5 | 1951–1960 | 150 | 1 | 15 | 156 | 82 | 254 |
| Dum Dum | .. | 22° 39′ | 88° 27′ | 20·0 | 1949–1960 | 147 | 1 | 11 | 144 | 96 | 252 |
| Alipore | .. | 22° 32′ | 88° 20′ | 26·5 | 1948–1960 | 124 | 0 | 7 | 186 | 119 | 312 |
| Baroda | .. | 22° 18′ | 73° 15′ | 21·9 | 1948–1960 | 90 | 0 | 0 | 28 | 52 | 80 |
| Saugar Island | .. | 21° 45′ | 88° 03′ | 15·5 | 1951–1960 | 119 | 0 | 4 | 105 | 42 | 151 |
| Nagpur | .. | 21° 06′ | 79° 03′ | 15·6 | 1950–1960 | 137 | 0 | 9 | 131 | 118 | 258 |
| Gopalpur | .. | 19° 16′ | 84° 53′ | 9·7 | 1951–1960 | 109 | 0 | 2 | 48 | 31 | 81 |
| Santa Cruz | .. | 19° 07′ | 72° 51′ | 15·1 | 1953–1960 | 93 | 0 | 0 | 53 | 69 | 122 |
| Colaba | .. | 18° 54′ | 72° 49 | 25·9 | 1948–1960 | 97 | 0 | 0 | 218 | 314 | 532 |
| Poona | .. | 18° 32′ | 73° 55′ | 39·6 | 1948–1960 | 119 | 0 | 3 | 65 | 24 | 92 |
| Visakhapatnam | .. | 17° 43′ | 83° 14′ | 12·2 | 1948–1960 | 120 | 0 | 1 | 77 | 104 | 182 |
| Hyderabad | .. | 17° 27′ | 78° 28′ | 18·5 | 1954–1960 | 145 | 1 | 4 | 80 | 109 | 194 |
| Meenambakkam | .. | 13° 00′ | 80° 11′ | 25·0 | 1951–1960 | 136 | 0 | 2 | 120 | 86 | 208 |
| Bangalore C.O. | .. | 12° 58′ | 77° 35′ | 19·2 | 1949–1960 | 106 | 0 | 1 | 51 | 156 | 208 |
| Bangalore F.O. | .. | 12° 57′ | 77° 38′ | 16·1 | 1954–1960 | 84 | 0 | 0 | 50 | 121 | 171 |
| Kodaikanal | .. | 10° 14′ | 77° 28′ | 15·2 | 1948–1960 | 93 | 0 | 0 | 54 | 84 | 138 |
| *Cochin | .. | 09° 58′ | 76° 14′ | 12·8 | 1943–1952 | 93 | 0 | 0 | 104 | 609 | 713 |

* Anemograph maintained by the Cochin Port Trust.

From the heights of anemographs given in Table I it can be seen that the heights to which these winds refer vary from station to station. At present there is perhaps no accepted factor by which one can reduce these wind speeds to a common height. The observed values may perhaps be fairly applicable up to a maximum height of about 30 metres above ground in general.

### Frequency of Gust Speed

From the point of design engineering, information on maximum wind speed alone is of little use because the high winds of destructive nature observed over a region may be a very rare phenomenon occurring once in 50 or 100 years which may be more than the normal life period of the proposed structure. In that case, from the point of economy, structures will have to be designed to withstand the maximum wind that is expected to occur within their normal life period. Even in the case of structures so designed, their life period will be shortened if the structures are subjected frequently to severe stress and strain by strong winds. In view of this the engineers are required to take into account not only the maximum wind speed but also the frequencies of less violent winds that can bring about early fatigue to different parts of a structure.

Therefore in Table I are given the frequencies of squalls of wind speeds 141 to 160, 101 to 140, 60 to 100 and less than 60 km.p.h. This shows in the first instance that winds above 140 km.p.h. are rather a rare phenomenon confined mainly to the north of lat. 22° N. and occurring at the most twice in about 10 to 12 years. Less violent winds of the order of 101 to 140 km.p.h. occur about once in every year in the Punjab and Bengal. Elsewhere their frequency is much less, the west coast of the Peninsula remaining altogether free from such squalls. This part of the Peninsula experiences annually about 10 to 15 squalls within the speed range 60 to 100 km.p.h.

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