Journal of Scientific & Industrial Research

A—GENERAL

THE COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH, NEW DELHI

THIS ISSUE

A: GENERAL

Raindrop size measurements at Delhi and Khandala during south-west monsoon

Criteria for design of windmills for low to moderate wind velocities

B: PHYSICAL SCIENCES

Simultaneous action of organic inhibitors and anodic polarization on the corrosion of iron

Fries rearrangement of phenolic esters

Soap flotation of vermiculite

C: BIOLOGICAL SCIENCES

Terramycin and growth

Oxalate content of plant tissues

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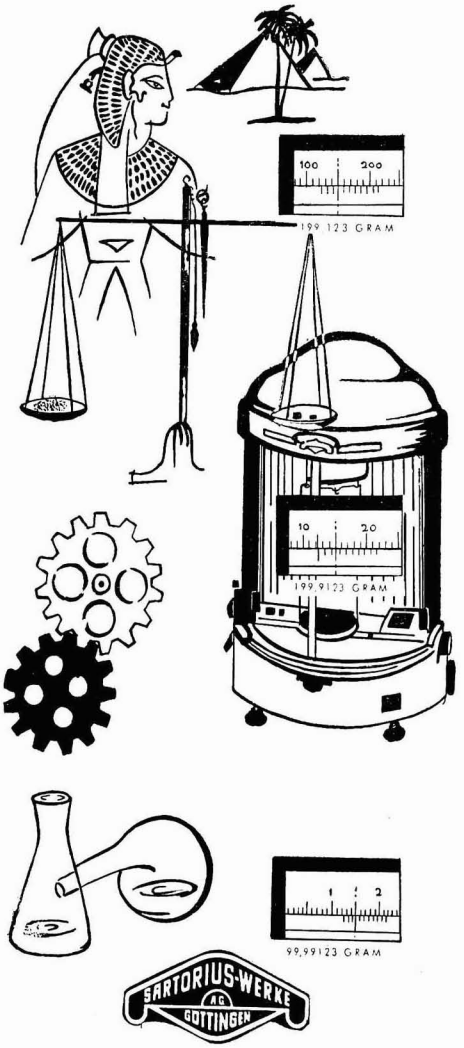

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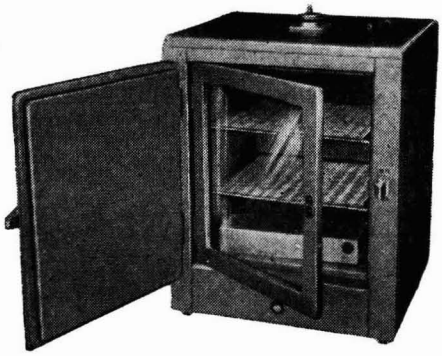

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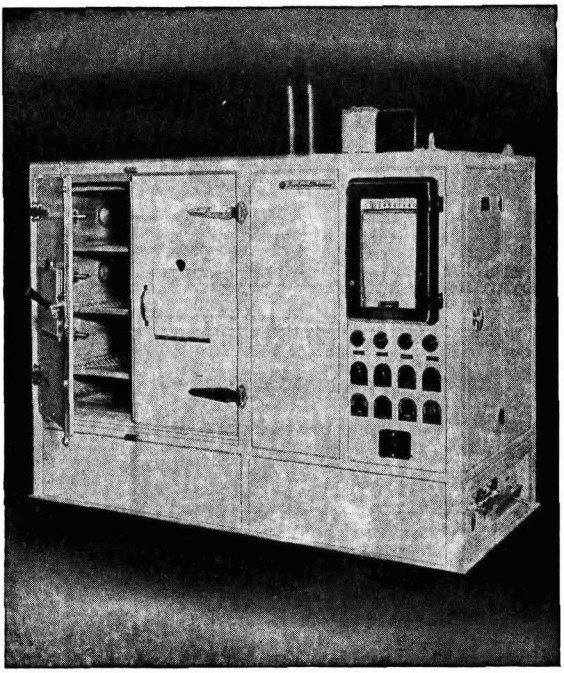

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Current Topics

EXPANSION OF DEFENCE RESEARCH

WITH A VIEW TO COVERING NEW FIELDS AND ALSO raising the present level and scope of defence research, a chain of laboratories is being set up in the country under the Defence Science Organization. One of them, at Jodhpur, was declared open by the Defence Minister in May last; this laboratory is equipped to carry out investigations in respect of weapons and equipment under conditions of dry heat, assessment of conditions in arid zones, desert physiology and effect of environment on service personnel. Another laboratory will be set up at Mussoorie to undertake research on food and other problems relating to the health and efficiency of personnel operating in high altitudes and cold climates. A Gas Turbine Research Centre, recently established at Kanpur in collaboration with the Council of Scientific & Industrial Research, will undertake studies on fuel efficiency and performance of gas turbines under tropical conditions. The existing laboratories will be expanded and equipped for research in aeronautics, electronics, metallurgy, etc. It is also proposed to expand the Defence Science Laboratory in Delhi into something like a Defence Science Institute to train personnel for defence research.

These developments will be widely welcomed. The emphasis in defence research so far has been on inspection and modification of equipment to improve operational efficiency under combat conditions. Expansion was obviously called for, but the pace and direction of expansion have necessarily to be determined by the availability of manpower, research facilities and finance. There is an evident appreciation of all these factors in planning the programmes of development.

During the past few years, a number of research laboratories have been established in India and shortage of personnel with the qualifications, skills and outlook necessary for creative research is being felt everywhere. The emphasis on the training of personnel for defence research is a wise step, but an enterprise of this type will have to be given sufficient time to become productive, and there is the obvious difficulty because of the diverse fields of research and development involved. For immediate needs, therefore, facilities available in university laboratories and research institutions may have to be utilized. There is ample scope for 'contract' research in the defence field and collaboration between civilian and military research is not only desirable, but also necessary. The Defence Science Conferences have in the past surveyed the fields for collaborative research and shown that the scope is indeed large.

The expansion programmes under consideration imply that adequate funds would become available for research and development. It is understood that the present allotment for the Defence Science Organization is less than one quarter of one per cent of the defence budget. Defence research and development have a claim for priority. There is apparently need for greatly increasing the budget allocation. In U.K., the amount earmarked for this purpose is of the order of 10 per cent, and allocations in other countries would not be very different. While the percentage figures are not sacrosanct they are indicative of the importance attached to science in the defence field. Development of research results, to which attention must necessarily be given, implies expenditure which far exceeds that on research and the forward course of defence science will be assisted by appraising fully the research, development, testing and evaluation programmes, and matching the requirements by adequate finances.

TIMBER RESOURCES & UTILIZATION

TIMBER SHORTAGE IS A SERIOUS PROBLEM ALL OVER the world — a problem accentuated by excessive forest exploitation during the last World War — and has formed the subject of discussions at International Conferences convened by the U.N. Food & Agriculture Organization in 1947, 1949 and 1954. The timber resources of India are accepted to be slender, but the demand for timber has been progressively increasing with the rising population and

planned industrial development. The Planning Commission has included timber among the five important raw materials requiring development for the formulation of plans for augmenting resources and rationalizing utilization has acquired high priority. The Symposium organized by the National Buildings Organization in May last to discuss problems on Timber and Allied Products in their varied aspects is of more than ordinary interest.

The area under forests in India forms only 21·6 per cent of the total land area, and this is low in comparison with the world average of 29·1 per cent. The present trend has been to bring more land under cultivation and afforestation is not likely to contribute materially to the expansion of the forest area. The *per capita* consumption of timber in India, which is 1·4 cu. ft, is exceedingly low and the world average is nearly twenty times this quantity (24·6 cu. ft). Timber consumption is known to increase with industrialization and industrialized countries are also great consumers of wood. A timber famine apparently exists in India and a major national effort is called for to remedy the situation.

It is clear from the papers presented and the discussions held at the symposium that while the scope for any substantial enhancement of timber production is limited, that for rationalizing timber use is large indeed. The conservative attitude of users to rely on a few well-known timber species for their requirements has greatly aggravated the shortage of timber. Only a few out of the fifty or more species known to yield durable or moderately durable woods are exploited for structural purposes. The timbers from about ninety secondary species can be rendered strong enough for structural use by preservative treatment, and the utilization of these and also of bamboos and other plant materials available from the forests for particular purposes demands urgent consideration. The development of wood-based industries, like plywood and fibre board industries, provides a means for utilizing inferior woods, scantlings and chips which are at present wasted or burnt as fuel. For instance, in plywood manufacture, only the veneers from the more valuable wood species are used on the outside and peeled sections from poorer classes can form the inner sheets.

Losses during extraction, transportation, logging and storage of timbers are known to be heavy. Logging and conversion losses are estimated at 40 per cent. Insect pests are responsible for heavy losses of stored timber; they also cause serious damage to standing trees and felled timber in forests. In addition, a large part of the wood extracted from the forests, estimated at 66 per cent, is burnt as fuel.

Many useful suggestions have been made at various conferences to relieve timber shortage. The preservation and nurturing of forest wealth is a primary responsibility of the present generation in the interests of posterity and forests should be tended also for reasons other than timber alone. Rational exploitation of forests without jeopardizing their productivity is, therefore, essential. The economic yield of tropical forests is small in comparison with the yield of temperate forests, and mechanization of forest operation is considered useful where the size and quantity of timber to be extracted within definite seasonal periods are beyond human capacity. Wood-based industries for utilizing inferior woods and waste wood should be established and damage due to insect pests should be minimized. The use of wood as fuel should be deprecated and alternative fuels for domestic use should be provided in rural areas. These suggestions and recommendations are by no means new or novel, but their reiteration is justified until they become part of the constructive thinking and action of individuals and organized groups. Technology has provided the means for optimizing wood use and preventing waste, but the availability of knowledge alone is not enough. In achieving full co-ordination of resources with utilization programmes lies the solution of the timber scarcity problem.

The Indian Programme for the International Geophysical Year: Part II — Survey of India's Contribution

S. K. S. MUDALIAR

Geodetic & Research Branch, Survey of India, Dehra Dun

THE Survey of India has been participating in the International Geophysical Year (IGY) programme in regard to five subjects: Latitudes and Longitudes, Gravimetry, Geomagnetism, Oceanography and Glaciology. The studies in these subjects have been carried out by the Geodetic and Research Branch of the Survey of India in addition to its normal activities. Also, Survey of India personnel surveyed Bara Shigri Glacier in Lahul during 1956 as a preliminary to this programme.

Latitudes and longitudes

The Astronomical Observatory at Dehra Dun is taking part in the latitudes and longitudes programme. This observatory also participated in the International Longitudes Projects of 1926 and 1933, and the present programme is thus the third operation of World Longitudes; in addition, simultaneous observations for latitudes have also been made. The duration of the observations cover a period of about 430 days which constitute the Chandler period. The object of this project is the precise determination of the astronomical co-ordinates of the participating observatories and the study of the variations of these co-ordinates. The results of these investigations will lead to a more precise knowledge of the instantaneous co-ordinates of the various observatories, by which the determination of time can be improved, a more precise determination of the irregularities of the earth's motion can be made and also the existing star catalogues can be improved.

Latitudes — For the determination of latitudes various methods are available; of these, Talcott's method with the zenith telescope and the equal altitudes method with the astrolabe are commonly in use. The former method is the one which has been used by the International Latitude Service for the past 58 years and is also what is being used for the present project in the Dehra Dun Observatory. If λ be the latitude of the place, δ_N and ζ_N be the declination and the zenith distance (corrected for refraction) respectively of the star transiting north of the zenith and δ_S and ζ_S the declination and corrected zenith distance of another star transiting south of the zenith, then

$$\lambda=\tfrac{1}{2}(\delta_N+\delta_S)+\tfrac{1}{2}(\zeta_S-\zeta_N)$$

The first term is computed from the star places given in the catalogue, while the second term is so adjusted by the proper selection of the pair of stars that it is measurable in terms of the instrument's micrometer screw only. The instrument is adjusted for level and setting of line of collimation in the meridian. The various instrumental constants are then determined.

For latitude observations this observatory possesses a zenith telescope and a Wild T4. Eight pairs of stars make one group, and two groups are observed each night, one before midnight and the other after midnight. Each group is observed for about two and a half hours and the programme includes six groups for the whole year. After about two months of observations the morning group becomes the evening group, and the old evening group is then dropped out and a new group is observed in the morning. The programme of pairs of stars is very carefully selected. After applying various corrections due to the axis tilt of the zenith telescope, dislevelment of the instrument, collimation of different wires and curvature of the star's path, etc., the instantaneous latitude of the place is computed. This value cannot be employed for plotting since it contains accidental errors of observations and declination errors of the catalogue. Therefore, after one year of observations the results of all the groups are reduced to a mean group and the mean value of the latitudes for about a fortnight is then plotted and from the graph a periodic latitude variation of the observatory is easily obtained. This is due to the earth's oscillation about its axis of rotation. The motion of the mean pole is represented by means of two co-ordinates X and Y on the surface of the earth, one along the Greenwich meridian and the other perpendicular to it. These values are supplied by the International Latitude Service (ILS) to correct the observed universal time UTO to UT 2 system.

Longitudes — The difference in astronomical longitude between two places is given by $L_1-L_2=(LST_1)-(LST_2)$, where L_1, L_2 are east longitudes and LST_1 and LST_2 are the local sidereal times at the two places at any one instant. Astronomical observations of the local time are thus needed at each place, and also the determination of a common simultaneous instant. The common instant is determined by wireless time signals, and the observation of local time is made by different types of instruments, such as transit instruments, zenithal photographic telescopes, or impersonal astrolabes. From time observations and the recorded local time of reception of a signal, the longitude is given by L=(LST of reception)−(reputed GST of emission)−(published correction)−(correction for speed of wireless signals). Also, the LST of reception=(local clock time of reception)−(e), where e is the LST error of the local clock, positive if fast, and negative if slow.

For time observations, this observatory possesses a shutter transit and two other transits fitted with impersonal micrometers, one driven by motor and the other (a Wild T4) by hand. These transits are instruments designed to record the clock times at which stars cross the local meridian. Subject to small corrections, the LST error of the clock is given by e=(clock time of transit)−(right ascension of stars). The instruments are adjusted for transit axis tilt, collimation and deviation from the meridian setting. Two series of observations are made, one before midnight and the other after midnight, on two different instruments each night. Each series consists of about 14 stars including two azimuth stars. The recorded times of transit of stars are duly corrected for transit axis tilt, deviation of the line of collimation from meridian and diurnal aberration of stars. The azimuthal error of the line of collimation of the telescope is obtained from the formula

$$a=\frac{\Sigma(\alpha_r-T)_N-\Sigma(\alpha_r-T)_S}{-\Sigma\tan\delta_N+\Sigma\tan\delta_S}\times\sec\lambda$$

where α_r is the right ascension of the star and T the recorded time of transit corrected for level error and diurnal aberration, δ is the declination of the star and λ is the latitude of the place of observation. Stars for this purpose are divided into two groups, the northern group and the southern group. The precision with which a is determined in this way is adequate for the purpose of time determination.

Rhythmic time signals, which consist of 61 dots in 60 mean time seconds, emitted by the principal wireless stations in U.K., U.S.S.R., Germany, France, Argentina, Brazil, China, Japan and Australia, are being received by the coincidence method. The clocks in use are pendulum sidereal clocks — Shortt and Riefler clocks. Chronographs, giving graphic records of the beats of the clock, records of star observations and reception of wireless signals, have been used. The errors of the local clock, e, are computed for each group of observations and are corrected for polar variations ($\Delta\lambda$) and for seasonal irregularity in the earth's rotation (ΔT_S) from the data supplied by the Bureau International Horaire (BIH), Paris. Clock corrections are plotted on a graph and a smooth curve is drawn, from which corrections to times of reception of the various signals are obtained. The reputed times of emission of the signals are corrected for 'definitive' corrections given by Bulletins Horaire. The most probable values of the radio propagation times over the relevant paths are also supplied by BIH and from these the instantaneous values of longitudes of the observatory are computed. Extracts of results of time observations have been sent to BIH, Paris, periodically.

Apart from other investigations, it will be possible to establish from the present programme a really reliable value for the longitude of Dehra Dun, which could be compared with a similar good value at some distant date and from which valuable data could be obtained for studies of continental drift. The values of longitude obtained on previous occasions are:

	hr	*min.*	*sec.*
1894-96	5	12	11·77
1926	5	12	11·75
1933	5	12	11·78

The 1894-96 value is the one that has hitherto been accepted, as the above values show no progressive change.

In order to improve the quality of time determination, Danjon's impersonal astrolabe and Belin's printing chronograph have been acquired and will be put into use as soon as the arrangements are completed.

Catalogue of stars — The catalogue of fundamental stars used in the reduction of astronomical observations is the FK3 (with its supplement).

Gravimetry

The IGY activities of the Survey of India concerning gravimetry consist of two parts, viz. observations for the study of earth tides and those for the determination of the gravimetric deflections of the plumb-line. Under the first part, half of the programme has been completed during the last winter and the remaining half has been planned for execution during the current season. Under the second part, the work is being taken up during the current field season.

Earth tide observations — The 'earth tide' is defined as the deformation or the 'yielding' of the solid mass

of the earth due to the tide-generating forces caused by the moon and the sun. Due to these forces a point on the surface of the earth continually increases and decreases in distance by a few feet from the centre of the earth, thereby causing a corresponding change in the value of gravity at that point. The variation of gravity due to this movement is studied by means of a sensitive gravimeter. The results provide valuable data for the investigation of the elasticity, as well as the constitution and structure of the earth; also they enable the precise reduction of gravimetric observations which form the basis for geophysical explorations. For the above studies, a series of eight stations spread over India and suitably located in relation to geological and geodetic considerations and at varying distances from the sea were selected. Of these eight stations, observations at the first four were executed during the last field season. The observations at each station consisted of half-hourly visual readings of a gravimeter both during day and night for a period of 31 consecutive days. Two sensitive gravimeters, viz. a geodetic Worden and a North American precision gravimeter, with a reading accuracy of a hundredth of a milligal, were used for the purpose. Simultaneous observations of temperature and pressure were also made and recorded. The sites for these observations were generally spacious rooms which were so selected as to be away from the traffic disturbances and free, as far as possible, from large variations in temperature. The half-hourly readings in respect of each instrument, duly corrected for the drift of the instrument used, provided two separate series of hourly values which could be subjected to harmonic analysis for the various tidal components. Analysis was accordingly carried out separately for each series for the primary tidal constituents (M_2, S_2, N_2, K_1 and O_1). The other tidal constituents were ignored, their effect being negligible. The mean of the results of the two series for each instrument was taken for the respective constituents. The results so far analysed reveal that the elasticity factor averages to about 1·4, which is in fair conformity with the value obtained by several other agencies.

Gravimetric deflections — The observations under this project are aimed at obtaining the deflections of the vertical by the gravimetric method, so that the results could be compared with the corresponding values derived by the astro-geodetic observations and used finally in determining the true orientation of the world spheroid (the figure of the earth) for geodesy and mapping. For this purpose, gravity observations are required to be carried out at suitably spaced stations around the geodetic origin of India, viz. Kalianpur H.S. in Central India and a few other geodetic stations in the neighbourhood. A minimum of 500 stations within a radius of 100 km. around each station would be required, the density of the gravity net gradually decreasing with the distance from the centre.

Geomagnetism

The Survey of India's magnetic survey work, embracing the whole of India including Burma and Ceylon, comprised mostly a general survey and secondly a detailed survey of several magnetically disturbed areas. The aim of the general survey had been to determine the three magnetic elements, viz. horizontal force, dip and declination, at various stations, called field stations, uniformly distributed at distances of about 30 to 40 miles apart over the whole of India, Burma and Ceylon and to obtain from them the true isomagnetic lines. Abnormal values of elements at several sites in the general survey indicated localities influenced by the presence of magnetic materials. In addition, observations were also taken from time to time at several well-chosen and evenly distributed repeat stations in order to determine, as satisfactorily as possible, the annual changes in the magnetic elements for reducing the results of the magnetic surveys to a common epoch.

During the IGY, magnetic survey work activities of the Survey of India were intensified, and during the field season 1957-58, two detachments were sent out for field observations. Absolute magnetic observations for the dip, horizontal force and declination were taken at 52 old repeat stations spread over the various States in India. Six new repeat stations were also established, five being on the geomagnetic equator on the east and west coasts of India and one at Cape Comorin. Observations were carried out twice a day (morning and evening) at each station. For the determination of true azimuth at these stations, observations were taken with reference to the sun or Polaris. Besides observations on horizontal force, declination and vertical force anomalies were taken at 270 field stations spread over the various States in India using such instruments as the dip circle, quartz horizontal force and kew pattern magnetometers, Wild T2 and vertical force variometers. These instruments were calibrated at Alibag Observatory against their respective standard instruments by simultaneous observations. Some of these were again checked against the standards at Kodaikanal Observatory.

Further magnetic field work on the above lines will be carried out during the field season 1958-59. In the meantime the compilation and preparation of the field data for further analysis have been taken up. The Survey of India is also scheduled, during the

IGY, to start magnetic observations for continuous recording of H, D and Z at Dehra Dun. As soon as the magnetic observatory at Sabawallah, about 21 miles from Dehra Dun, is built, this work will be started.

Oceanography

The Geodetic Branch is carrying out certain oceanographic observations and is also compiling and forwarding oceanographic data to World Data Centres during the IGY.

Survey of India tide gauges are functioning at Aden, Mundra, Kandla, Veraval, Bombay (Apollo Bandar), Ratnagiri, Mangalore, Madras, Visakhapatnam, Calcutta (Garden Reach) and Port Blair. Tide gauges owned by the ports are operating at Cochin, Saugor, Diamond Harbour and Rangoon. From these tidal records, hourly readings of tides are read off and monthly sea levels are computed. Systematic tidal observations for 31 days round the clock have been taken on tide poles at Pamban, Tuticorin, Trivandrum, Alleppy and Negapatam.

Surface water temperature and salinity observations are taken by the port authorities at a fixed time every day at Kandla, Mangalore, Cochin, Mandapam, Madras and Visakhapatnam (Palm Beach). Other meteorological observations, viz. direction and speed of wind, surface air temperature and pressure at a fixed hour every day, are also being taken by either the port authorities or the India Meteorological Department at Aden, Mandvi, Kandla, Veraval, Bombay (Colaba), Ratnagiri, Mangalore, Cochin, Madras, Visakhapatnam, Calcutta, Hooghly Point, Saugor and Port Blair.

The Survey of India has carried out short-period systematic tidal stream observations at over 30 sites in the Gulf of Cambay. The observations are being analysed. These are required for the preparation of an Atlas of Indian Waters depicting tidal streams at all conditions of the tide.

Data relating to observations on bathymetry, deep sea temperatures and salinity, etc., obtained from sea cruises at 34 sites by the Oceanography Department of the Andhra University, have also been collected.

Studies are being undertaken on steric rise in sea level, correlations between sea level and pressure distributions, as also between sea level and vertical gradients of salinity and regarding secular changes in the sea level and land, etc. Empirical relations have been established for the effects of variable freshets on the tides in the Hooghly river.

Glaciology

The Survey of India assisted the Geological Survey of India in the survey of Bara Shigri Glacier in Lahul in 1956. The glaciers of Lahul had been visited by the officers of the Geological Survey of India in September 1906 when observations were made on the Sonapani (λ 32°25′, L 77°23′) and on the Bara Shigri (λ 32°16′, L 77°37′). The survey maps of the glacier were then made by the magnetic compass method, corrected by ground photographs. These sketch surveys showed the position of the ice-caves with respect to neighbouring peaks and adjoining topography. Some marks were also left near the glacier snouts to enable the secular movements to be measured in course of time. However, none of the marks left by the past expedition could be identified in 1956. Therefore, rigorous plane-table surveys were made of 27 square miles on 1 in. to 1 mile scale and 1·2 sq. miles on 1: 10,000 scale. These maps show the snouts and surrounding topography, and have provided material which can throw light on the question whether or not these glaciers are retreating.

International Symposium on Macromolecules

THE INTERNATIONAL SYMPOSIUM ON MACROMOLECULES, sponsored by the International Union of Pure and Applied Chemistry, will be held during 12-16 October 1959 at Wiesbaden, Germany. There will be two groups of lectures, one plenary and the other main, convened simultaneously on each day. The main subjects to be dealt with are grouped under the following heads: (1) Physics of Macromolecular Substances; (2) Macromolecular Substances in Solution; (3) Elementary Processes and Kinetics of Polyreactions; (4), Chemistry of Organic and Inorganic Macromolecular Substances; and (5) Macromolecular Natural Substances and Models. All enquiries regarding the symposium should be addressed to: Dr W. Mauss, Wiesbaden-Biebrich, Rheingaustrasse 25 (Kalle & Co. Ag.), Germany.

A New Instrument for the Electrolytic Pre-treatment of Metals for Metallographic Examination

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A new type of electrolytic polishing instrument for application in the electrolytic pre-treatment of metals for metallographic examination is described, and its working and performance illustrated with brass and tin specimens. Worked in combination with a direct illumination microscope, the instrument permits continuous observation of the specimen during polishing and etching treatments.

In addition to mechanical polishing, electrolytic polishing is being applied to an increasing extent as a method of preparation in metal microscopy. Such an application of electrolytic polishing was described for the first time by Jaquet in 1932 for copper, and at the same time, attention was drawn to the possibility of a subsequent etching of the structure in one and the same working process. A number of subsequent publications on the subject have shown that this method is applicable to all metals of technical interest and to a great number of alloys.

Advantages of electrolytic polishing

Within the framework of its applications, electrolytic polishing has a number of advantages over the mechanical polishing of metal specimens. Thus, a metal section can be polished in a considerably shorter period than would be possible by mechanical polishing. With electrolytic polishing, unlike mechanical polishing, the structure of the metal does not become smeared with a shattered surface layer. Structure etching can be carried out on electrolytically polished specimens in the same working process as polishing and in a shorter time, as it is not necessary to remove the shattered surface layer prior to polishing.

These advantages stem from the fundamentally different levelling mechanism in electrolytic polishing. It is based on the principle that the surface of the metal section is dissolved by the action of an electric current in an electrolyte. This dissolution has to be effected, of course, in a certain manner. Usually, the speed of dissolution on dissolving a substance is greater on the surfaces of elevations than of depressions. On the other hand, various materials dissolve at different speeds under otherwise identical conditions. The same applies to the various crystal faces of a substance. In case of polycrystalline metal specimens all the various speeds of dissolution are superimposed with the result that the dissolving process does not result in any definite levelling nor any etched metal surfaces which would be suitable for microscopic investigations. When dissolving a metal in an electrolytic circuit it is, however, possible to render ineffective the various dissolving speeds conditioned by the structure or the profile of the surface by using a suitable electrolyte and selecting the appropriate electrical conditions. In this manner it is possible to produce either a polished surface or — in case of an already polished surface — an etched surface which can be used for microscopic investigations. Although the polishing and etching effects can be produced within a wide range of electrical conditions, the quality of the polished or etched surface depends, nevertheless, to a great extent on the applied terminal voltage and current density. The electrical conditions required for a particular quality of surface are in their turn determined by a number of factors. Such factors are, amongst others, the type and condition of the specimen to be treated and the composition of the electrolyte. Other factors are the resistances in the complete circuit, as well as the size, shape and position of the electrodes. Also, the movement of the electrolyte exercises a decisive effect in this respect. At times the influence of the various factors can only be comprehended with difficulty or not at all so that the prevailing conditions can hardly be made reproducible.

Special features of electrolytic polishing instruments

Even with simple instruments it is possible, after a thorough study of electrolytic polishing and etching, to obtain useful polished or etched metal specimens. Some instruments have, therefore, been developed with a view to keeping a number of the decisive factors constant by means of suitable control equipment, for instance, the size of the surface to be treated and of the cathode, as well as the shape and position of the electrodes. Certain measures have also been adopted with regard to the movement of the electrolyte. In this way, experienced laboratory assistants can usually prepare specimens which are suitable for routine investigation of the metal structure when the following conditions are defined: the electrical data for the instrument, the period of processing for the given specimen, the amount of preliminary grinding carried out and the electrolyte.

Recently, VEB Carl Zeiss, Jena, have developed an instrument combined with a direct illumination microscope in such a way that the surface of the specimen can be continuously observed, and even photographed, in the course of the treatment of the metal specimen. The advantages of such a design are obvious. By means of this instrument, the specimen can be judged by the metallographer in a single working process while polishing and etching is carried out, without having to subject the specimen to an intermediate treatment for the purpose of microscopic investigation. In the majority of series of investigations in material testing this may mean a great saving in time which should not be underestimated. By microscopic observation during the treatment of the specimen it is immediately possible to appreciate the influence of the given electrical data, the processing period, speed of flow of the electrolyte, etc., on the surface condition. Thus it is possible, to proceed with the treatment of the specimen and to interrupt it the moment the surface has attained the requisite finish. This is of importance, especially as the treatment instructions for the instruments hitherto known have not, and could not, always take into consideration all the factors affecting the quality of the surface. As all the instructions represent, therefore, only approximate values, it is left to chance to produce an optimum quality of surface even when all the instructions are strictly adhered to. If an optimum surface quality is aimed at, it would, with the working methods so far applied, be required to subject the specimen to several treatments until the required surface consistency is ascertained after inserting the microscopic specimen again and again. These specimens which have to be inserted time and again become very time-consuming when the treatment conditions have to be ascertained only by a test series, because they are not yet determined for the instrument in question and for the metal specimen to be investigated. If metal specimens are greatly damaged by the treatment of the specimen prior to polishing and if changes have occurred on the surface areas, it will be possible, quickly and certainly, by means of microscopic observation in the course of the treatment of the specimen to determine when the structure consistency does not change any longer, thus making it possible to observe the actual structure of the metal specimen.

Design and working of electrolytic polishing instruments

With the methods hitherto available many time-wasting microscopic tests had to be interspersed in such instances. The design of the electrolytic polishing instrument produced by VEB Carl Zeiss, Jena, and described in the paper is illustrated in Figs. 1 and 2.

The metal specimen is pressed from below against the non-conducting diaphragm with a circular aperture (6 mm. diam.). The specimen is observed from above through the electrolyte. The objective is projected by a cover serving at the same time as cathode, the lower opening of which is closed by a plane-parallel glass plate. The shape of the cathode in conjunction with the correspondingly shaped diaphragm ensures that a laminary flow of the electrolyte is produced over the metal specimen, as is required for any good polishing effect. This shaping also results in the treated specimen assuming, under the influence of the existing electric field, a condition which is as uniform as possible all over. The spare electrolyte is in a container at the back of the instrument. By means of a pump the electrolyte is made

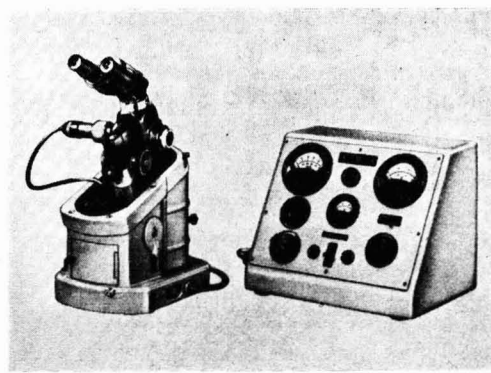

FIG. 1 — ELECTROLYTIC POLISHING INSTRUMENT

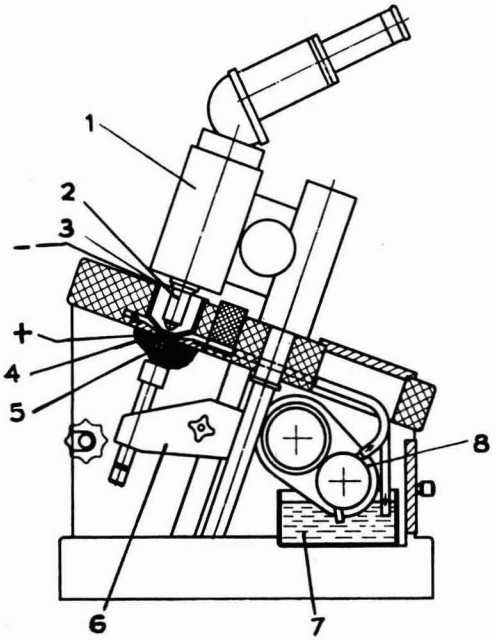

FIG. 2 — ELECTROLYTIC POLISHING INSTRUMENT — DIAGRAMMATIC [(1) Direct illumination microscope; (2) lens system; (3) cathode; (4) window of cathode; (5) metal specimen; (6) specimen mounting; (7) container with electrolyte; and (8) pump with motor]

to circulate with an adjustable speed of flow through the electrolytic cell. Observation of the metal surface can be carried out up to a magnification of 200 in a bright field and also by polarized light. This microscope, being the standard direct illumination microscope 'Epignost', can at any time be used together with a stand for other microscopic azimuthal observations. Microphotographs of the metal surface can be made during observation by connecting the attachment camera 'Miflex'.

A separate power pack (220 V. a.c.) supplies the instrument with current. This unit permits the regulation of direct current in the electrolyte cell continuously within the ranges 0-15 and 0-60 V. The transformer, rectifier and a device for smoothing the rectified current of the instrument are provided for up to 1 amp. which would make it possible to work with anodic current densities up to approx. 400 amp./sq. dm. The electrical data at any given moment can be read on a voltmeter set for the ranges 0-15 and 0-60 V., and on an ammeter with the ranges 0-0·1, 0-0·5 and 0-1 amp. The power pack also supplies the pump motor with the required d.c. The voltage applied to the motor can be adjusted as required from 0 to 24 V. It can be read on a voltmeter. The current density-voltage graph for the instrument is shown in Fig. 3. A number of other devices permit a safe and easy manipulation of the instrument. Thus the mounting for the specimens is designed in such a manner that any shape up to 100 mm. in diameter and 30 mm. high can be fixed. With smaller diameters of, say, 20 mm., specimens up to 100 mm. long can be attached. Regarding the shape of the specimen, it is only required to have at least one circular plane area of approx. 8 mm. diam. The head of the mounting is provided with springs which permit the removal of the specimen without loosening the setscrews, or if another part of the surface of the specimen is to be treated, to shift it accordingly. By closing the space occupied by the specimen with a two-winged door it is made impossible to touch the live anode, as the circuit is interrupted when the door is opened. The cathode, which is accessible, is earthed. In addition, a switch is provided at the foot of the instrument for the immediate interruption of the circuit of the electrolytic cell. A push-button switch in easy reach of the former switch makes it possible to switch on the current for a short time which may be very handy for obtaining a certain degree of etching at any set voltage at the terminals. Close to this switch is positioned the switch for the circuit of the pump motor. A tap in the cover plate of the instrument enables the draining speed of the electrolyte from the electrolytic cell to be adjusted. When placing the microscope in a high position the cathode can be removed for cleaning by loosening a setscrew above which the electrolytic circuit is closed. A stop prevents the window of the cathode from being destroyed by the microscope lens system. The door leading to the electrolyte container can only be opened when the pump has been tilted away from the electrolyte container by means of a lever. To obviate the danger of the plastic pump running dry, the electric circuit for the pump motor can only be closed when the pump is tilted into the electrolyte.

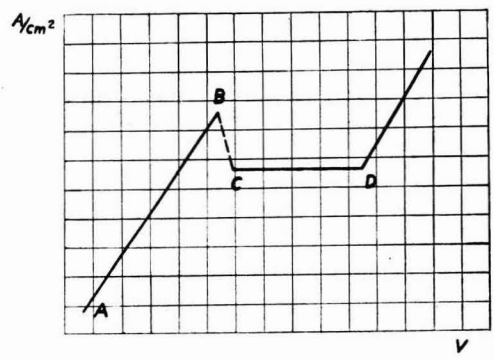

FIG. 3 — CURRENT DENSITY/VOLTAGE GRAPH — DIAGRAMMATIC [AB, etching range; CD, polishing range]

In all other respects the electrolytic polishing instrument in its largely corrosion-proof design meets the rigorous demands made of it.

Examples

The working of the instrument is illustrated by the following two examples. The photomicrographs, shown in Figs. 4 and 5, were taken during treatment, and always at the same spot on the specimen.

The first example shows the electrolytic polishing and etching of a brass specimen. The specimen has been rough-ground with abrasive paper of grain size 360. The initial state of the surface of the specimen is shown in Fig. 4A. After setting the speed of flow for the electrolyte, the terminal voltage is gradually increased. This results in a change of the surface of the specimen in the sequence illustrated in Fig. 4(A-D). The surface with its grinding grooves is gradually and quite evenly coated with a brown layer of increasing density. Finally, the layer becomes more transparent, breaking suddenly open and floating off in larger or smaller pieces. Underneath this layer a bright surface becomes visible which, however, still has some grinding grooves. With a further voltage increase the smoothing process commences, until after a short time the surface is polished. When the voltage is increased still further, gas bubbles form which cause the destruction of the polished surface. An increase in voltage up to this stage must be avoided. Should it occur, the voltage is reduced until no more gas is generated and the polishing action becomes once again effective. When the voltage is reduced still further, grain boundaries become apparent. A further slight reduction of the voltage results in a grain surface etching which soon leads to the entire surface being covered with the brown layer. By increasing the voltage this layer is again removed, as described above. Underneath the floated-off coating the profiling of the structure produced is clearly visible, this being removed only some time later by the effect of polishing.

To prevent an over-etched surface subsequent to polishing, the voltage is greatly reduced and then gradually increased until the exact degree of etching required is obtained. Also with a higher voltage the required degree of etching can be attained when, after switching off the electrolytic circuit, the push-button switch is depressed until the increasingly

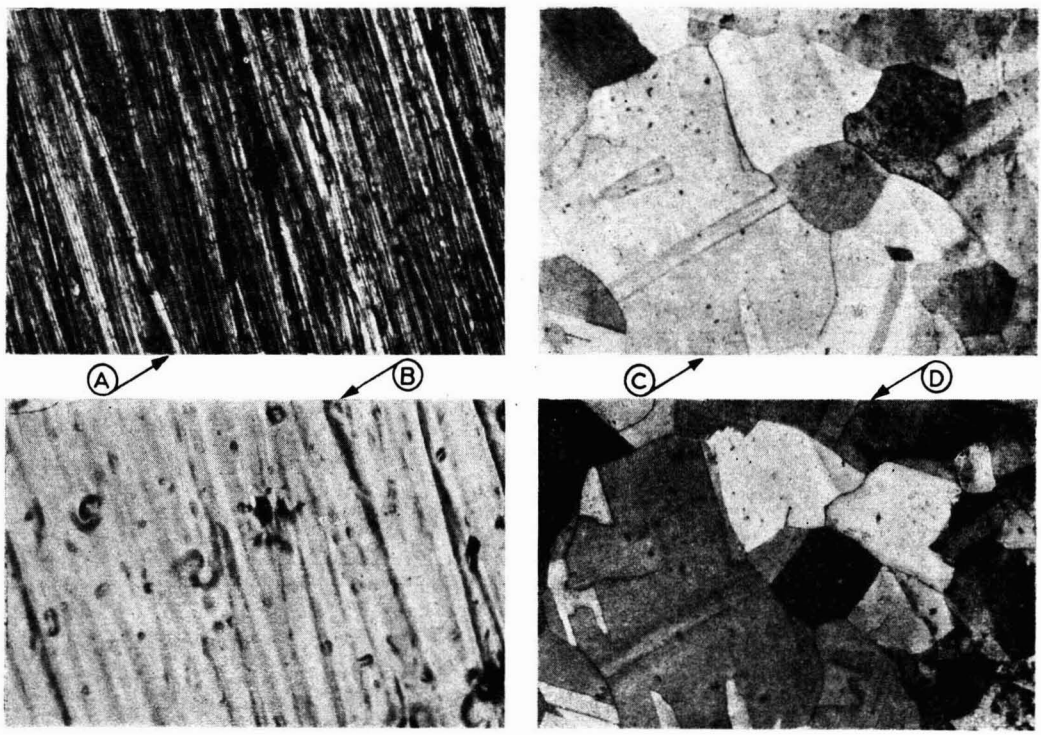

FIG. 4 — SURFACE OF A BRASS SPECIMEN AT DIFFERENT STAGES OF POLISHING AND ETCHING (× 400) [A, B, C and D are photomicrographs of the specimen taken at successive stages of polishing and etching treatments]

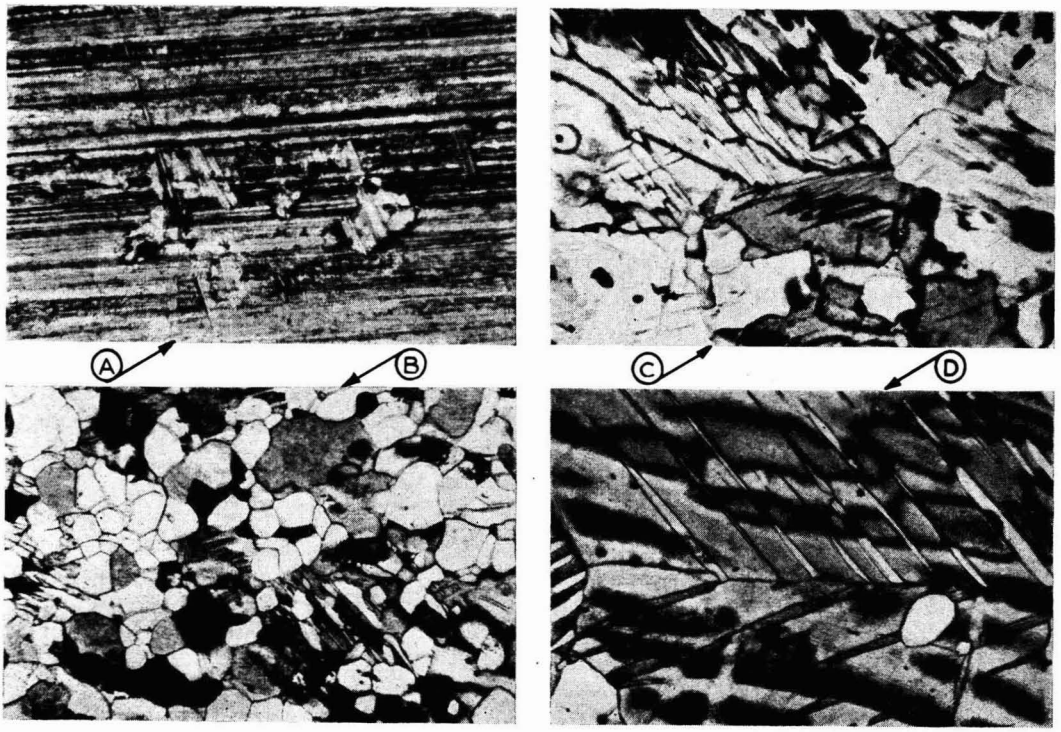

FIG. 5 — SURFACE OF A TIN SPECIMEN AT DIFFERENT STAGES OF POLISHING AND ETCHING (× 400) [A, B, C and D are photomicrographs of the specimen taken at successive stages of polishing and etching treatments]

strong etching corresponds to the required surface condition.

The second example shows the electrolytic polishing and etching of a tin specimen, the surface areas of which were transformed by a preceding grinding process. The initial state of the surface of the specimen can be seen in Fig. 5(A). In this instance also, after gradually increasing the terminal voltage, a dark top layer is formed covering the entire specimen. At somewhat higher voltages this top layer dissolves in pieces, revealing a bright surface still crossed by grinding grooves. At a higher voltage these grooves are rounded off and soon a polished metal surface is obtained. The structure of the metal surface layer becomes discernible within a second by reducing the voltage. It is the structure of a destroyed, recrystallized surface layer, as can easily be recognized by increasing the voltage and penetrating further into the metal specimen by electrolytic polishing, meanwhile rendering the structure visible by reducing the voltage for a short time. In this way the specimens shown in Fig. 5(B-D) were formed in turn. The individual photographs show how the shattered, recrystallized surface layer is removed to an increasing extent, until at last the coarse crystalline structure is revealed corresponding to the actual structure of the cast tin. From now on, further treatment no longer alters the structure of the metal.

The above examples show that in the field of electrolytic polishing and etching, the metallographer can carry out systematic work with the electrolytic polishing instrument described in this paper. The instrument affords every possibility of attaining an optimum surface by means of the electrolytes listed in the technical literature for the respective metals while permitting microscopic observation in the course of the treatment. The simultaneous microscopic observation reveals, within a short period, the true structure of the specimen under investigation, as it is not necessary, as when working blind, to continually intersperse a microscopic inspection. Further, the continuous observation of the metal surface in the course of the electrolytic processes enables the metallographer to investigate structures dynamically; for the scientist it opens up new prospects for the study of the various surface processes.

Precipitation Characteristics Based on Raindrop Size Measurements at Delhi & Khandala during South-west Monsoon

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A detailed analysis of drop size data relating to monsoon rain in India, based on observations at Delhi, a station situated well inland in the north, and Khandala, a high level station near the west coast and lying in the direct path of monsoon, has been made employing the filter paper technique for the measurement of drop size. A comparison has also been made of observed distributions at Khandala, where orography plays a part in the incidence of rainfall, with the drop size spectra obtained by Blanchard for orographic rain in Hawaii.

A comparison of actual size distribution curves corresponding to various intensities of rainfall at Delhi and Khandala with those given by the empirical relationship of Marshall and Palmer brings out clearly certain distinguishing features, the most important of these being the near horizontality, or even a tendency to slope upwards, of the distribution curve over a certain intermediate range of drop sizes. Some tentative explanations for this as well as peak and trough characteristics noticed in some of the curves have been suggested.

Based on drop size distribution, an attempt is made to correlate certain important parameters, such as rain water content in air and median volume diameter of drops with intensity of rainfall. While neither of these parameters is uniquely related to the rainfall intensity, a fairly close and useful relationship connecting all the three elements — rain water content, median volume diameter and intensity of rainfall — can be obtained. Relationships of a general nature have also been obtained between radar reflectivity and intensity of rainfall both for Delhi and Khandala. The applicability of these relationships, as in the case of similar relationships found by other investigators, is dependent upon the actual drop size distribution in a given case not differing materially from the mean.

A CERTAIN degree of inhomogeneity of cloud particle sizes is an essential criterion for initiation of rain in clouds. The factors which bring about this favourable initial condition and the details of the steps in which the growth process operates at various stages of precipitation development are as yet not understood fully. Due largely to difficulties of techniques and the cost involved in direct aircraft measurements in clouds, such basic data relating to various cloud elements, needed for evolving a satisfactory theory of the mechanism of rain formation, have so far been quite inadequate. This deficiency of available data has been sought to be met, so far as is possible, by collecting systematic information about raindrop size distributions at various phases of rainfall in different situations.

In recent years a fair amount of study has been made by investigators at various centres, the more important among the measurements made being due to Laws and Parsons[1], Best[2], Bowen and Davidson[3], Blanchard[4], and Mason and Ramanadham[5]. Except for some of the determinations made by Blanchard in orographic rain in Hawaii Islands, the bulk of the data collected relates to precipitation in temperate latitudes and to situations in which intensity of rainfall is mostly limited to below 20 mm./hr. Available data relating

to comparatively heavy showers in the tropics, where rain-initiating mechanisms are also considered to be substantially different from those in the temperate regions, are, however, scanty. A systematic chronological study of size distribution of drops in various rainfall situations in different areas and seasons in tropical countries, such as India, is, therefore, of value in the understanding of rain processes in these areas.

Centimetric radar in recent years has proved to be a valuable tool for probing into the structural details of cloud and precipitation cells, though much work has yet to be done to develop this technique, on a quantitative basis. Intensity of radar echo by precipitation elements being proportional to the sixth power of their sizes, a critical study of drop size distribution in rain of different types and intensity is one of the most important requirements for a satisfactory relationship being established between radar reflectivity and character of rainfall.

Keeping the above in view, attention has been paid to the careful determination of raindrop sizes in different types of rainfall situations in India during various seasons. The present paper summarizes the data relating to monsoon rain at Delhi in northern India, and also at Khandala on the Western Ghats. Measurements at the latter station, besides providing data representing conditions in rainfall influenced by orography, are of interest, inasmuch as the observations being recorded inside the cloud or slightly below cloud base, uncertainties in the size distribution picture, as may be caused by not easily ascertainable modifications in drop sizes by collision and coalescence between drops of different size groups and also loss by evaporation during fall from cloud base to ground, are eliminated.

Character of monsoon rainfall and drop size measurements

Delhi (lat. 28°35'N, long. 77°12'E; height above sea level, 714 ft), situated in north-west India about 120 miles to the south of the Western Himalayan range, lies on the border zone between the rich rain-washed Gangetic plains of north India and the semi-arid tracts of Rajasthan, where the monsoon usually extends feebly and intermittently and often in a shallow layer limited to no more than 2 km. above ground. The inter-tropical convergence zone between the tropical continental air from western and central Asia and the equatorial maritime air dominating over the greater part of the Indian subcontinent during the south-west monsoon season runs very close to Delhi, and the relative position of the station with reference to this zone on individual days determines the nature of the air mass over the area and the weather which occurs there. Even in situations of normal monsoon activity, the overlying air mass at 3 km. and above over the region is often dry continental air from west to north-west in which the lapse rate of temperature is rather high. The resulting thermodynamical structure of the atmosphere is thus conducive to development of latent instability and, under favourable synoptic situations helping convergence in the lower maritime air mass, the clouds formed and the associated weather are predominantly of the convective type. Rainfall at Delhi during the three principal monsoon months, July to September, totals 485 mm., the mean number of rainy days being 22·6. Rain is frequently in the nature of instability showers occurring in short spells, and, except on a few occasions when proximity of an eastern depression originating from the head Bay of Bengal causes precipitation of a more continuous character, the bulk of the rain occurring on a day is usually restricted to an hour to two, particularly towards the afternoon or evening. In many cases, rain is accompanied with a thunderstorm which at times is quite severe, especially during the first onset of monsoon over the area. Rain-giving clouds are mainly large cumulus or cumulonimbus, the clouds at other times being chiefly stratocumulus or small cumulus. Moderate to heavy showers of a sustained nature are associated frequently with cumulonimbus clouds whose tops extend well into the sub-freezing layers, but light rain or temporary showers seem to occur at times from purely 'warm' clouds also. Height of cloud base during rain is generally about 3000 ft or more above ground, though in a few instances of heavy, continuous rain, fractonimbus clouds may descend to as low a height as 1000 ft. High temperature and consequent low relative humidity, especially during afternoons, in the layer intervening between cloud base and ground provide factors causing depletion or shrinkage by evaporation of small-sized droplets before reaching the ground.

Due to very different geographical situation and orography of the place, the general character of monsoon rains at Khandala (lat. 18°15'N; long. 73°42'E; height above sea level, 1900 ft) differs materially from that at Delhi. Situated about 40 miles east south-east of Bombay, Khandala on the Western Ghats lies in an area of abundant rainfall occurring almost daily during the greater part of the monsoon season. As Khandala lies on the windward side of a continuous chain of hills rising rather abruptly to a height of 2000 ft or more over a distance of a few miles from the coast and running in a line almost normal to the direct path of the Arabian Sea monsoon current, orography plays an important role in causing cloud development, and possibly also

in initiating rain processes at the station and its neighbourhood. Total rainfall of the season at Khandala is of the order of 4500 mm., and it rains almost every day during the period, from early June to end of August. Despite rather high daily average rainfall, intensity of precipitation is rarely very high except in certain special meteorological situations. In contrast with the conditions at Delhi, there is no marked diurnal variation in rainfall at Khandala, the frequency of rainfall being nearly uniform at all hours of the day. Clouds, as seen from ground, are mostly of a stratiform nature, drifting steadily eastwards from the Arabian Sea. Height of cloud base, about 2000 ft above sea level, is usually only a 100 or 200 ft above station but may often touch the ground or even descend to further lower levels. Observations made from aircraft show that in many of the rain situations, low cloud tops are well below freezing level, without any significant medium or high clouds above, suggesting that precipitation in such cases is entirely of the 'warm' type. There are, however, occasions when, above the general layer of stratiform type clouds, cumulus towers develop at various points, the tops of which may reach the 0°C. isotherm or be even higher.

Measurement of drop size

At both the places, the technique used for the measurement of raindrop sizes was the same, namely the well-known method of exposing standard Whatman filter paper No. 1 treated with a powdered mixture of sodium carbonate and phenolphthalein. Raindrop falling on the filter paper leaves a permanent and nearly circular impression, the diameter of which is dependent on the size of the drop. To avoid difficulties of general pigmentation of the filter paper under conditions of high humidity — this presented a problem during Khandala measurements — necessary precautions were taken to keep the filter papers dry both before and after treatment with the powdered mixture. The filter paper disc was held between two bakelite rings and exposed to rain for periods of one second or more depending upon the rate of rainfall. In our measurements, filter paper discs of diameter 12·5 cm. were used, and drop sizes were determined with reference to a previously prepared calibration curve (Fig. 1) covering a size range of 0·2 mm. to over 5·0 mm. diameter. For production of droplets of very small sizes in the range of 0·2 to 1·5 mm. diameter, the method adopted was the vibrating reed technique used by Dimmock[6]. Drops of very large sizes of diameter 3 mm. and more were produced by allowing water to run through glass tubes of different diameters held slantingly at different angles.

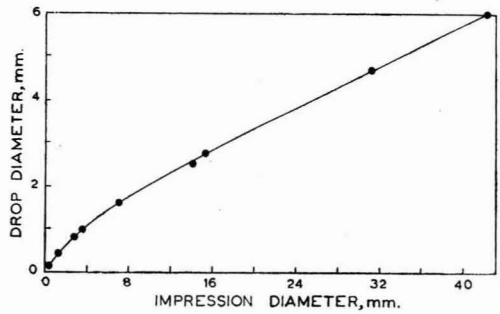

FIG. 1 — CALIBRATION CURVE OF WHATMAN FILTER PAPER NO. 1 FOR THE DETERMINATION OF DROP SIZES

Basic data collected and derived parameters based on drop size characteristics

Over one thousand samples of drop size distribution in rain were collected at Delhi and Khandala during the monsoon season of 1956. Of these, fully analysed data relating to about five hundred samples have been used for the present study. To save space, data for only 229 samples have been included in this paper. Tables 1 and 2 (given at the end of the paper), giving the drop size data for Delhi and Khandala respectively, include also associated information relating to observations made, such as date, time, period of exposure of filter paper in various rainfall situations. Drop sizes are grouped at intervals of 0·2 mm. diameter and their mean sizes are indicated in Tables 1 and 2. Absence of any figure less than 0·5 mm. mean diameter does not mean that no drops smaller than 0·4 mm. were associated with any of the rain situations studied. The reason why such droplets have not been taken into account is that splashing of drops, especially during rain accompanied with gusty winds, often prevented accurate determination of the number of genuine raindrops of such sizes. Also, owing to uncertainties caused by factors such as the presence of a few relatively large granules in the dusting powder and their getting pigmented to some extent under prevailing high humidity, it was rather difficult to say, unequivocally, if coloured impressions of minute sizes were due to some of these extraneous factors or represented genuine rain droplets. In any case, omission of small droplets of sizes less than 0·4 mm. diameter, in the present study, does not make any material difference either in the basic nature of the size distribution curves, or in the values of some of the precipitation parameters derived from observed drop size data. Drop size figures included in the tables refer to an inner sampling area of 10 cm. diameter on a filter paper of diameter of 12·5 cm., drops in the outer ring

having been excluded from the study to eliminate possible sources of error or uncertainties due to edge effect.

Derived parameters based on drop size characteristics

Columns 2, 3 and 4 in Tables 1 and 2 give computed values of some of the important precipitation elements, namely R (intensity of rainfall), W (rain water content per cubic metre of air), and D_o (median volume diameter of drops) relating to various samples. A comparison of mean rainfall intensity, calculated on the basis of drop sizes in some of the samples taken during periods of moderate to heavy rain, with that given by a self-recording rain gauge has, in general, shown a fair agreement, indicating that the size determinations made are reasonably correct. For measurements relating to Khandala, this comparison was further facilitated by the use of an intensity rain gauge (giving the intensity of rain during each minute interval), which was installed temporarily at the observation site with the kind co-operation of the India Meteorological Department. In some of the rainfall situations, during which a large number of samples were taken in the course of a few minutes, the computed mean intensity and that given by the intensity gauge agreed mostly within about ± 10 per cent.

The study of drop size distribution in space in a rainfall situation entails computation of $N_D \Delta D$ (number of drops per cubic metre of air with diameters lying between D and $D + \Delta D$), by taking into account the terminal fall speed of drops of various mean sizes. To facilitate getting these values from the basic figures of drop sizes included in Tables 1 and 2, $N_D \Delta D$ values corresponding to a single raindrop of a given size falling over a sampling area of $(\pi.5^2)$ sq. cm. in one second have been added at the end of each table. Values of terminal velocities as given by Gunn and Kinzer[7] have been used for these calculations.

An important aspect of the study of drop size distribution in rain is the attempt to establish a plausible relationship between the observed distribution features, or some of the derived parameters based thereon, and the different rates of precipitation. While such investigations by various workers have led to certain useful generalized relations connecting intensity of rainfall and drop size distribution, it is quite a common experience to find that fundamental differences in the character of drop size distributions often occur in rainfall of the same intensity, not only in different rainfall situations but also at different phases of one and the same occasion of rainfall. As illustrations, we may refer to samples 1, 10 and 16 of series II in Table 1, for Delhi, and to samples 8 and 2 of series VI and XII respectively in Table 2, for Khandala, showing quite a marked difference in drop size distributions associated with rainfall of very nearly the same intensity, namely *c.* 30 mm./hr. That the size distributions for a particular intensity occurring at different phases of one and the same rainfall situation can differ materially at times will be apparent from even a general examination of some of the data included in the tables. It is of interest to compare the size distributions as in samples 1 and 14 of series IV under Delhi in Table 1. For the same intensity of rainfall at 26 mm./hr, while sample No. 1 shows a very narrow spectrum limited only to three size groups in the range 2·1 to 2·5 mm., sample No. 14 is associated with quite a wide spectrum ranging from 0·5 to 2·5 mm. diameter. Similarly, samples 5 and 11 of the same series corresponding to a rainfall intensity of 5 mm./hr show a marked difference in their drop size distribution characteristics. For a satisfactory comparative study of size distribution of drops in rain of different types and intensities, it is thus important that due consideration is given to the stage of precipitation to which the samples relate, and that such a study is based chiefly on samples taken during some intermediate or relatively steady phase of rainfall. This has been kept in view in relation to studies and discussions in this paper.

A careful study of drop size distribution at the very start of a precipitation process and of its progressive changes with time helps to throw some useful light on the distinguishing characteristics of rain in different instances. From general observations it is seen that, while in continuous type rain, associated often with front or discontinuity, the drop size spectrum is limited at first to small size groups and then widens gradually to include drops of larger and larger sizes, a shower from an overhead convective cloud often starts with a relatively narrow spectrum containing drops of some intermediate sizes, later broadening both ways to include larger as well as smaller drops. Series IV in Table 2 is an example of the former kind, while series IV in Table 1 illustrates features of the latter type.

Size distribution of raindrops

Distribution, in space, of drop sizes associated with rainfall of different intensities may be studied readily with reference to curves obtained by plotting log $N_D \Delta D$ against D. As already pointed out, data provided by an individual sample may not always be truly representative of the rainfall situation in a given case. Hence, for a generalized study of this kind, it was considered necessary to plot such curves based on the averages of a number of samples showing more

or less the same rainfall rate and belonging to some intermediate or steady stage of precipitation. For purposes of such grouping, limits have been chosen suitably, so that the intensity range may not be unduly large relative to the mean rate considered. Thus, for mean intensities of rainfall of 2·5, 10, 25 and 50 mm./hr, the limits are 2-3, 8·5-11·5, 22·5-27·5 and 45-55 mm./hr respectively.

Comparison of size distributions in Delhi and Khandala — Fig. 2 gives $N_D\Delta D$-D curves, plotted on semi-logarithmic scale separately for Delhi and Khandala, for mean rainfall rates of 10, 25 and 50 mm./hr. A common feature of the curves for both the stations is a much smaller slope or relative horizontality over certain intermediate drop size range compared to that over portions of curves at the two ends, as against the same uniform slope throughout according to the exponential relationship of Marshall and Palmer[8]. A critical examination of the details of the curves for the two stations, however, reveals certain distinguishing features which, though not very marked in all cases, appear nevertheless to be consistent. One important feature noticed is that, while for a given intensity of rainfall Khandala has a smaller number of drops of very small sizes and also of drops above a certain size, the number of medium-sized drops are appreciably more in rain at this station than at Delhi. This difference in the number of drops belonging to the intermediate size range is more prominently shown by curves corresponding to a rainfall intensity of 25 mm./hr.

In comparing the relative features of size distribution curves for Delhi and Khandala, it is of interest to refer to the findings of Blanchard[4] of some of the distinguishing characteristics of drop size distribution in orographic and non-orographic rain in Hawaii. From an examination of curves 7 and 9 in Fig. 12 of his paper (reproduced in the inset in Fig. 2), representing conditions in these two types of rain of nearly the same intensity (about 20 mm./hr), it is seen that the differences between Khandala and Delhi are, broadly speaking, similar to those between orographic and non-orographic rain in Hawaii. Examining more closely the two curves of Blanchard referred to above, and comparing these with 25 mm./hr curves for Khandala and Delhi it is, however, seen that, whereas the diameter range with higher $N_D\Delta D$

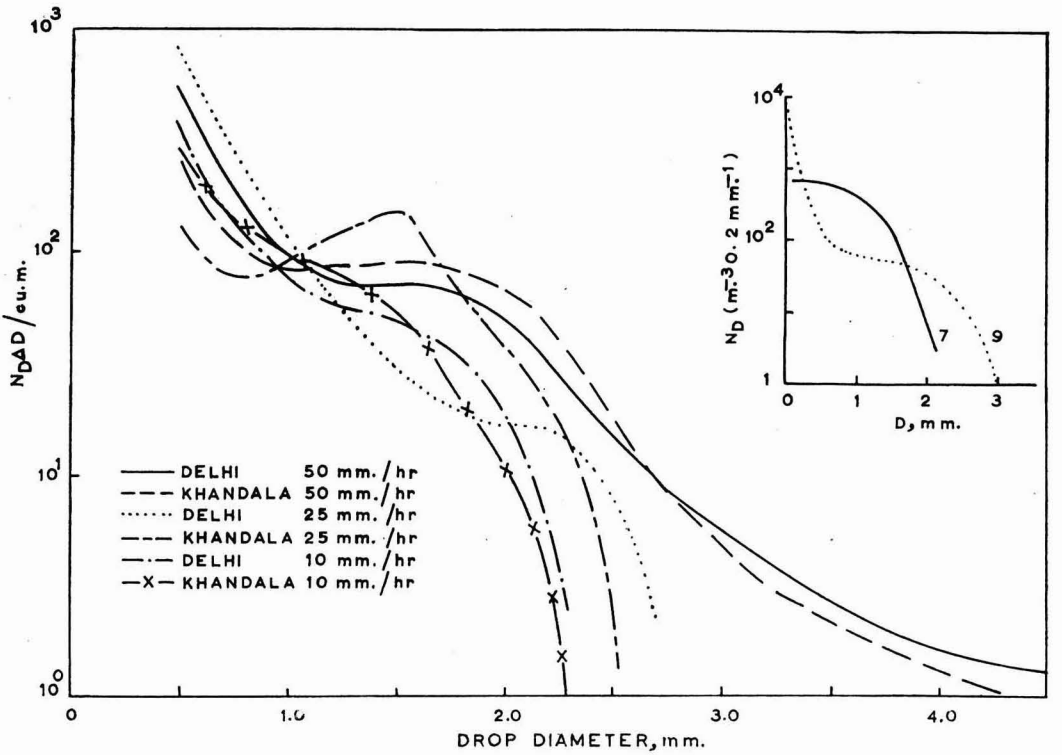

FIG. 2 — DROP SIZE DISTRIBUTION CURVES OF MONSOON RAIN AT DELHI AND KHANDALA [Inset: Blanchard's curves for orographic and non-orographic rain]

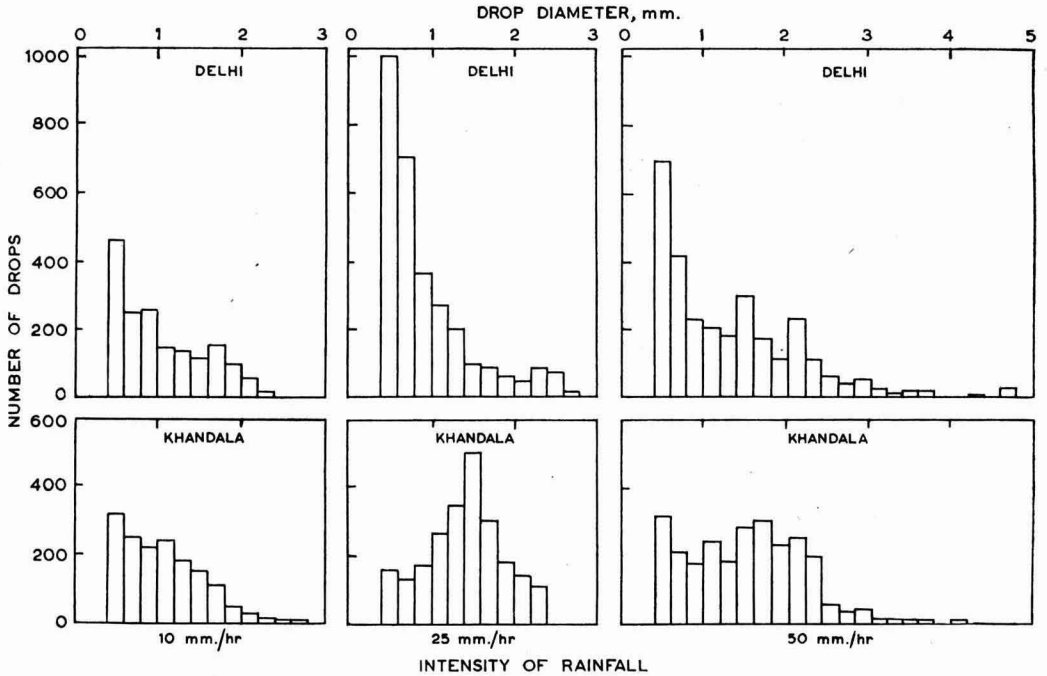

FIG. 3 — HISTOGRAMS SHOWING NUMBER OF DROPS OF DIFFERENT SIZES FALLING ON AN AREA OF 100 SQ. CM. IN 1 MIN.

values for orographic than for non-orographic rain in Hawaii lies between 0·3 and 1·7 mm., the corresponding range for Khandala and Delhi is 1·1 to 2·4 mm. Further, comparing the ratios of $N_D\Delta D$ values corresponding to drop diameter at which separation between the two curves is maximum, we find that this is about 7 at a diameter of 1·0 mm. in case of Hawaii, and is about 5 at a diameter of 1·5 mm. in the case of Khandala and Delhi curves. While some of the similarities as above in the comparative features of rain of the two types and in the two areas mentioned are of interest, we may not be justified in stretching the comparison too far and in concluding that all Khandala rain in the monsoon season is purely orographic in character.

In Fig. 3 are presented histograms showing the number of drops of different sizes falling over an area of 100 sq. cm. during a time interval of 1 min., corresponding to rainfall intensities 10, 25 and 50 mm./hr at Delhi and Khandala. Besides giving a relative picture of the size distribution of drops reaching a certain level at a given time, these diagrams help to bring out somewhat more clearly the characteristic differences in drop size distribution for the same rate of rainfall at the two stations. While the curves for Delhi show, in general, a progressive decrease in the number of drops with increase of size, there is, in the case of Khandala, a noticeable tendency for the number of drops to increase with diameter over a certain range of drop size. This is more strikingly brought out by the curve for 25 mm./hr for Khandala, which shows a well-defined peak with maximum number of drops at diameter 1·5 mm. This aspect, and also the feature of near horizontality of curves showing spatial distribution of raindrop sizes at Khandala and Delhi, are discussed further below.

$N_D\Delta D$-D curves for Delhi and Khandala combined— In Fig. 4 are given the mean distribution curves (log $N_D\Delta D$-D) for intensity ranges 2-3, 4-6, 8·5-11·5, 22·5-27·5, 45-55, 65-80 and 110-140 mm./hr, based on samples obtained both at Delhi and Khandala, and also Marshall-Palmer curves for the corresponding mean intensities. The main objects of the study of these curves are, firstly, to compare the drop size distributions in monsoon rain generally in India with those suggested by the exponential relationship of Marshall and Palmer and, secondly, to examine how the features of the curves change with increasing intensity of rainfall. Drop size samples of both Delhi and Khandala have been grouped together in preparing these curves. The following are among the more important features which are

brought out by the curves for the various intensity ranges:

(i) For very low intensity, namely 2·5 mm./hr, the curve is in general agreement with that given by the Marshall-Palmer relationship.

(ii) As the rainfall rate increases, definite departure from this simple exponential relationship is noticed. The curve obtained, instead of being a straight line, consists actually of three distinct parts showing different rates of change of log $N_D\Delta D$ with D.

(iii) With increasing intensity, the intermediate section of the curve showing near constancy of $N_D\Delta D$ values tends to extend over a wider range of diameter.

(iv) The number of drops belonging to small size groups is, in general, less than that given by the empirical relationship of Marshall and Palmer, while the drops in the intermediate size range are more in number. When we consider the distribution at the large size end, it is seen that, for intensities of 50 mm./hr and less, $N_D\Delta D$ values are lower than those suggested by the above empirical relation, while the opposite is the trend for intensities greater than 50 mm./hr.

In a rainfall situation in which Bergeron mechanism predominates, if the size distribution of water droplets originating from melting snow flakes is taken to be exponential, the resulting distribution, in space, of finally formed raindrops will also be broadly the same. In studying this, Mason and Ramanadham[9] have considered modifying influences of factors, such as accretion of raindroplets with cloud particles, coalescence of raindrops of various sizes, and evaporation loss during fall below cloud base, and have come to the conclusion that, while these may cause a small shift of the spectrum towards larger size and also explain depletion of drops of very small sizes, the general character of drop size distribution will remain exponential. Thus, in rain formed by ice mechanism, one common feature of drop size spectrum will be the progressive decrease in the number of drops with increasing size. On the other hand, in the case of pure warm rain determined by growth of giant cloud droplets colliding and coalescing with average cloud particles, the trend will be just the opposite. This is because, while the number of giant cloud droplets believed to form largely on hygroscopic nuclei decreases as the size increases — this is an observed fact, and is also to be expected from observations by Woodcock[10] and Twomey[11] of concentration of sea-salt nuclei decreasing exponentially with size — one finds, following Bowen's[12] model of raindrop growth in warm cloud, that a raindrop formed on a cloud droplet of relatively large size is smaller than the one grown on a droplet which is smaller initially. From

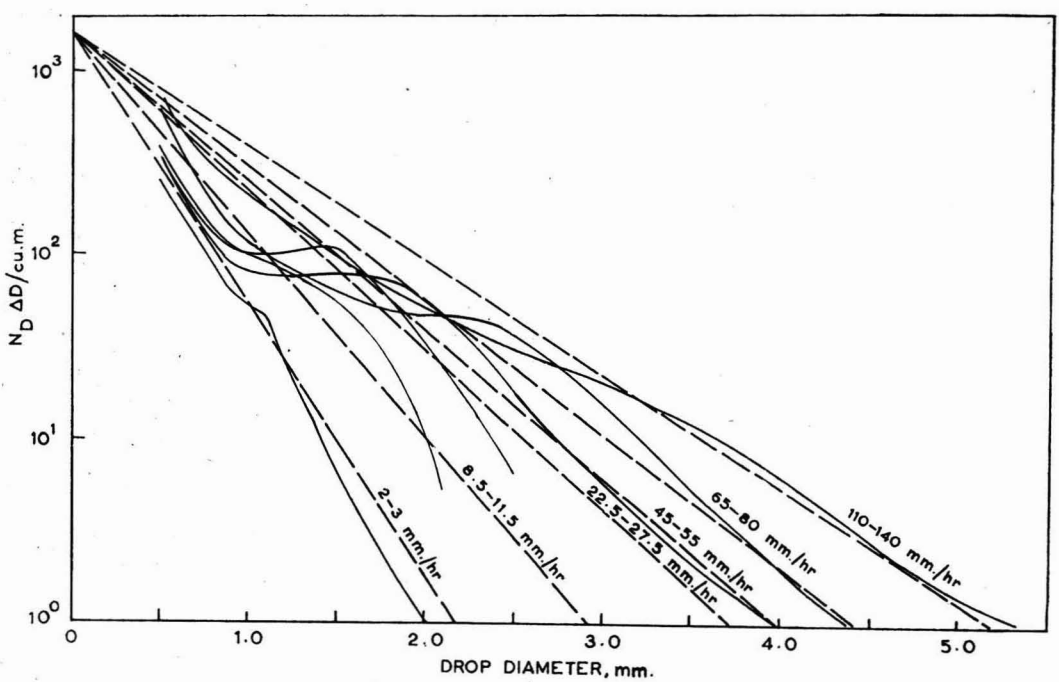

FIG. 4 — MEAN DROP SIZE DISTRIBUTION CURVES CORRESPONDING TO DIFFERENT INTENSITIES OF RAINFALL [Continuous line curves represent data for Delhi and Khandala grouped together; and broken line curves represent distribution curves based on Marshall-Palmer relations]

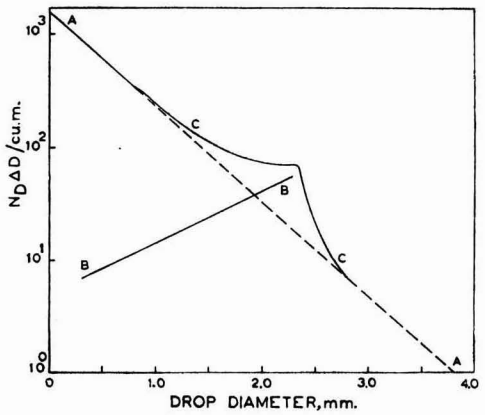

FIG. 5 — DROP SIZE DISTRIBUTION IN A SITUATION WHERE RAIN FROM A CLOUD IS GOVERNED PARTLY BY ICE PROCESS AND PARTLY BY COLLISION-COALESCENCE PROCESS [Curve AA, Marshall-Palmer distribution; curve BB, probable distribution in the hypothetical case of rain resulting from coalescence growth of giant droplets; and curve CC, theoretically derived distribution, assuming equal contribution by the 'cold' and 'warm' rain processes]

these considerations one also sees that the diameter of the smallest raindrop in a given situation will be determined by the size of the largest amongst giant cloud droplets present at or near cloud base and by the intensity of vertical currents in lower layers of the cloud. At the other end of the spectrum, the limit to the maximum size of a raindrop will be set by the intensity of updraft and depth of cloud. In considering the features as above, we have not taken into account the possible effects of coalescence growth by discrete accretion process, as postulated by Telford[13], nor the particular sea-salt nuclei hypothesis of Woodcock and Blanchard[14], suggesting one-to-one correspondence between number and size of salt nuclei and of raindrops.

If a situation is considered in which rain from a cloud is governed partly by ice process and partly by collision-coalescence mechanism, the resulting drop size spectrum may show the combined size distribution characteristics of both the processes, one important feature of which will be near horizontality of the distribution curve over a certain intermediate size range. This is illustrated in Fig. 5, in which curve AA gives the exponential Marshall-Palmer distribution corresponding to rain intensity of 36 mm./hr by cold process alone, and curve BB represents a hypothetical drop size distribution in rain of the same intensity by warm process, assuming a probable exponential distribution of giant hygroscopic nuclei and a certain constant value for updraft and liquid water in cloud. If, in a particular situation, there is rain at 72 mm./hr contributed equally by the 'cold' and 'warm' rain mechanisms, the combined effect on size distribution may be expected to be as indicated by curve CC. The actual distribution in any one case will, however, depend naturally upon relative contribution to rain by the two mechanisms. Besides, we have also to give consideration to factors, such as breaking of raindrops, variations in time and space of updraft in cloud, which will obviously have considerable effects on the resulting size distribution at various epochs of rainfall.

Judging from the nature of curves relating to monsoon rain at Delhi and Khandala and their broad similarity of features with those shown in curve CC, it appears that moderate to heavy rain in India in this season is governed frequently by both the precipitation mechanisms discussed above. This view is supported by our recent radar observations of monsoon clouds in Delhi.

Observed irregularities in drop size distribution curve: *Peaks and troughs* — In the previous discussion of raindrop size, consideration has been given mainly to distribution curves, based on averages of a number of samples belonging to the same intensity group. This process of grouping, by causing to smooth out the peculiarities of distribution in individual instances, may not always give an exact picture of the size distribution characteristics associated with rainfall on a particular occasion. One such feature is the fairly frequent occurrence of peaks and troughs on the distribution curve, showing otherwise broadly regular distribution of raindrops with size. While these peaks and troughs are usually more prominent on curves for individual samples — one reason for this may be inadequacy of sampling area or time — such features are also shown on many of the mean curves obtained by grouping of samples. This is illustrated in Fig. 6, in which curve 1 shows distribution as in an individual sample of rain at 50 mm./hr, while curve 2 represents averages of four consecutive samples

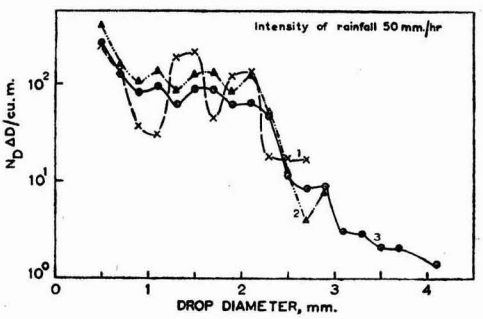

FIG. 6 — PEAK AND TROUGH CHARACTERISTICS SHOWN BY THE DROP SIZE DISTRIBUTION CURVES [×——×, sample 9, series VI, Table 2; △—△, mean of samples 18-21, series IV, Table 2; and ⊙—⊙, mean curve for Khandala data]

taken during a phase of nearly steady rain at the same rate in the same shower situation. Curve 3 gives the mean of 21 samples of rainfall in the intensity range 45-55 mm./hr. Features shown on the mean curves, and also those on curves obtained by Mason and Ramanadham[5], based on their analysis of data collected for a period of a few minutes, using a continuous drop size recorder, appear to suggest that these are genuine and inherent in the actual distribution of raindrops in a given situation. It is interesting to see in the recent theoretical study by Roy and Srivastava[15] of drop sizes in rain from 'warm' convective cloud under certain prescribed conditions of updraft and distribution of giant cloud droplets, that the overall distribution curve also shows well-marked ups and downs suggestive of peaks and troughs.

It is not easy to find a simple and satisfactory explanation for the features discussed above, unless it is assumed that similar irregularities exist in size distribution of original precipitation elements — products of melting snow flakes in case of 'cold' rain, or of giant cloud particles in 'warm' rain situations. Besides irregularities of concentration of original precipitation elements, there may be one other important factor to account for a distinctly larger number of drops of a certain size compared with drops of sizes next below or above; this is the marked discontinuity in updraft rate, with maximum occurring at a certain level at a given time. A level such as this, by acting as a sort of barrier to falling raindroplets below a certain size, will cause a maximum concentration of raindrops belonging to a particular size group. This factor would be more important in relation to raindrop growth by 'warm' process. Effect of wind shear below cloud base may also be a factor introducing irregularities in size distribution observed in certain cases.

Rain water content in air and intensity of rainfall

From available drop size data, an estimate can be made of the rain water content (W) in the column of air through which rain is falling, and see how this is related to rainfall intensity (R). As W is dependent upon and is derived from basic data of drop sizes, it may be expected to serve, in a general way, as a convenient single-term representation of the drop size distribution characteristics associated with rain of a given intensity in various situations. Thus, for the same rate of rainfall in two instances, a lower value of W denotes, in general, a size spectrum covering a relatively wide range of drop diameters, while a higher value of W means a relatively narrow spectrum with more numerous drops of smaller sizes. It is seen that, notwithstanding appreciable differences in the details of drop size distribution, W values for the same rate of rainfall are often substantially the same, suggesting some kind of a broad relationship between these two parameters of rainfall. To find what this general relationship is for monsoon rainfall at Delhi and Khandala, values of W and R for a number of rainfall situations have been plotted in Fig. 7, separately for the two stations, and mean curves drawn through the points obtained. In preparing the diagram, W and R values of all the analysed samples, irrespective of the precipitation phase at which these were obtained, have been taken into consideration. While the general features of curves for the two stations appear to be broadly similar, a closer examination shows that W values for Khandala for the same rate of rainfall are somewhat higher than those for Delhi, the differences being about 30, 20, 6 and 1 per cent for rainfall intensities of 0·5, 2, 10 and 20 mm./hr respectively. The higher W values of Khandala are explained by the relatively narrow drop size spectrum for this station, compared to that for Delhi. The effect of this, however, is partly compensated by the comparatively large number of drops in the medium size range, as has been discussed already under the section on 'Size distribution of raindrops'.

The mean W-R curves for Khandala and Delhi may be represented approximately by the following empirical relations:

$$W = 76R^{0\cdot840} \quad \text{(Khandala)}$$
$$W = 62R^{0\cdot895} \quad \text{(Delhi)}$$

The corresponding relations suggested by Blanchard for orographic and non-orographic rain in Hawaii are $W = 150R^{0\cdot7}$ and $W = 61R^{0\cdot89}$ respectively. It is seen that there is a fairly close agreement between the equations representing monsoon rain at Delhi and non-orographic rain at Hawaii. However, the W-R relation for Khandala is materially different from that representing orographic rain in Hawaii. This, as well as the general features of size distribution curves for Khandala (Fig. 2), show that, though orography no doubt plays a part in triggering the processes of cloud and rain development over the area, monsoon rain at the station in general, and heavy showers in particular, cannot be treated as purely orographic in character. Convergence of a general nature determined by prevailing synoptic situations and convective instability of the monsoon air mass apparently are important factors which influence rainfall over this area also.

From Fig. 7 it is observed that individual plots of W values for the same rate of rainfall do not show any large scatter, and that most of these lie fairly close

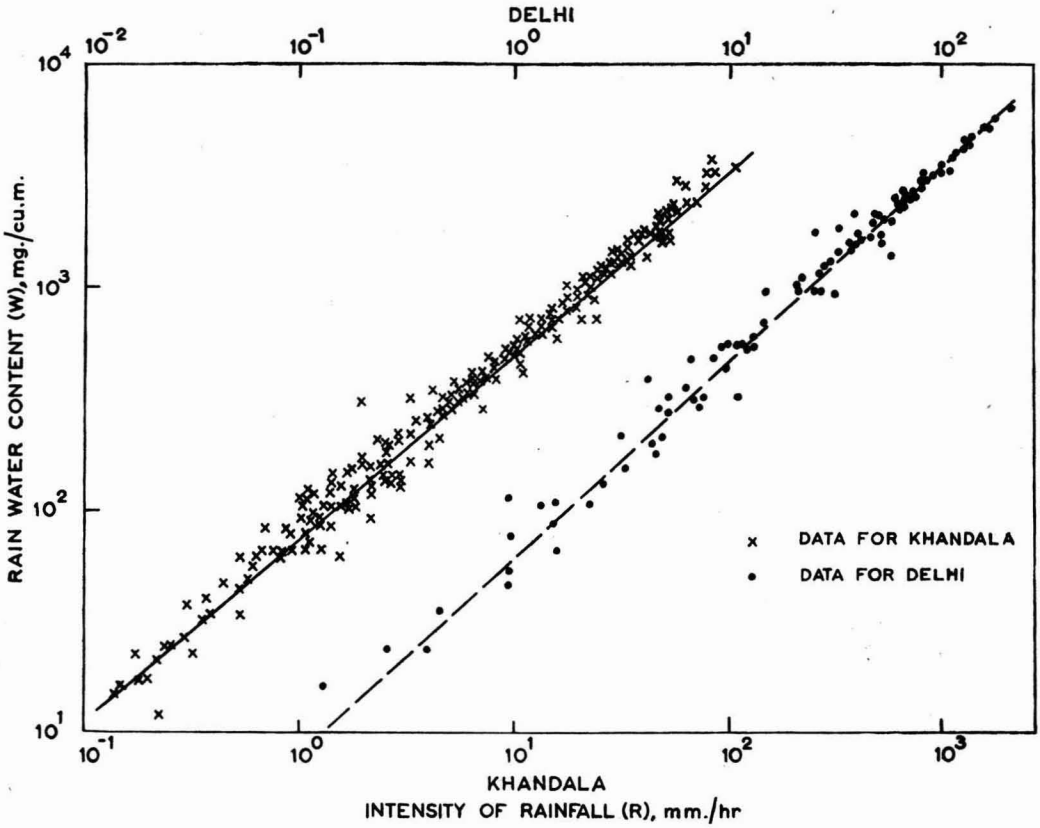

FIG. 7 — RAIN WATER CONTENT VERSUS INTENSITY OF RAINFALL FOR A NUMBER OF RAINFALL SITUATIONS AT DELHI AND KHANDALA

to the mean curve drawn. Marked departures are, however, noticed in a few instances, and are attributable to extreme peculiarities of drop size distribution, such as those found to be associated at times with samples taken during transient type of rain, or at the very start or end of a convective shower process. One important aspect of drop size distribution influencing the value of W for a given rainfall intensity is the central tendency of the distribution, which may be representable in a general way by the median volume diameter of drops discussed in the next section.

Median volume diameter

Median volume diameter (D_0), defined as that value of drop diameter above and below which the cumulative value, for a given distribution of drop sizes, of liquid water content is the same, is considered to be yet another useful single-term parameter representing size spectrum of raindrops. Values of D_0 corresponding to a large number of samples taken in various rainfall situations at both Delhi and Khandala have been plotted against corresponding rainfall intensity (R) separately for the two stations (Fig. 8). For comparison, D_0-R curves based on data used by Laws and Parsons[1], Best[16], Anderson[17] and Blanchard[4] for a similar study have also been included in the diagram. A general examination of the points plotted shows considerable scatter of D_0 values for the same rate of rainfall, particularly when this is low, and it is difficult to derive any plausible relationship or draw a smooth curve representing average distribution of D_0 and R. Comparing the general features of distribution at Delhi and Khandala, it can be seen that these are broadly similar, except that the scatter of D_0 values for low intensity rainfall at Delhi is somewhat greater than at Khandala. The plotted points for both the stations lie generally below the curves suggested by other workers referred to above, except for the one relating to orographic rain in Hawaii given by Blanchard, in which case D_0 values have been found to be considerably lower than in rains studied elsewhere.

In Fig. 9 have been plotted the various observed values of D_0, corresponding to certain specified

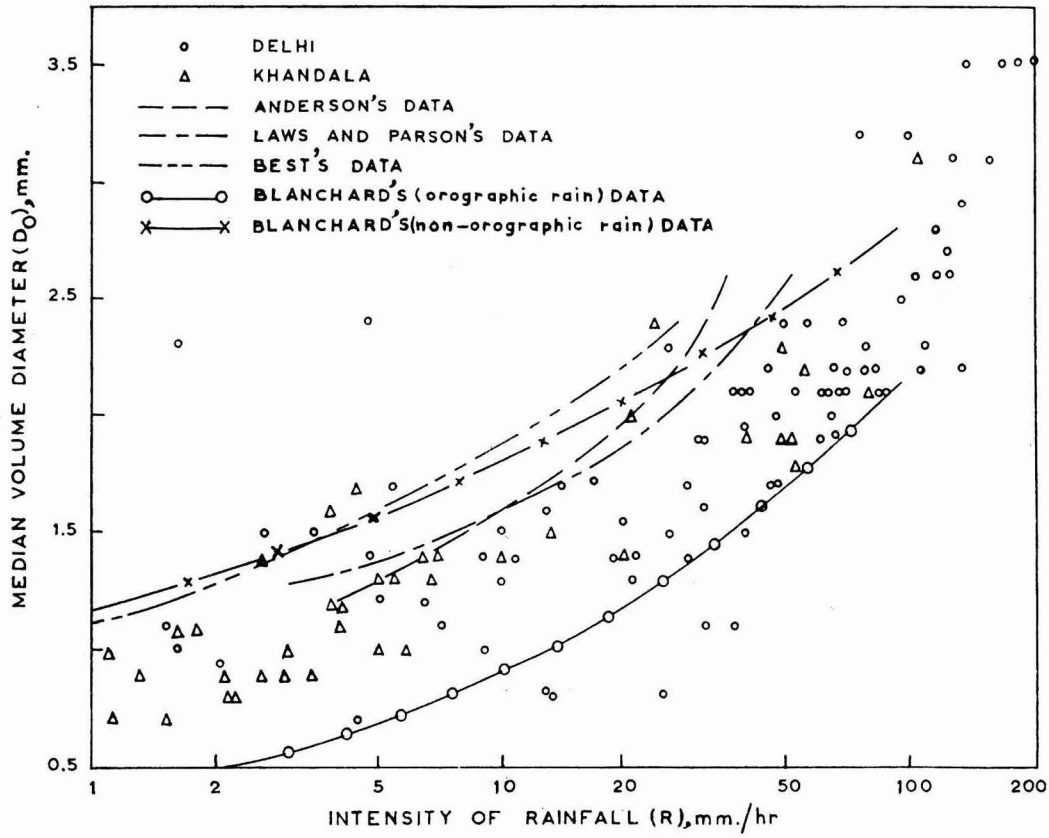

FIG. 8 — COMPARISON OF MEDIAN VOLUME DIAMETER VERSUS INTENSITY OF RAINFALL DATA OBTAINED BY DIFFERENT WORKERS

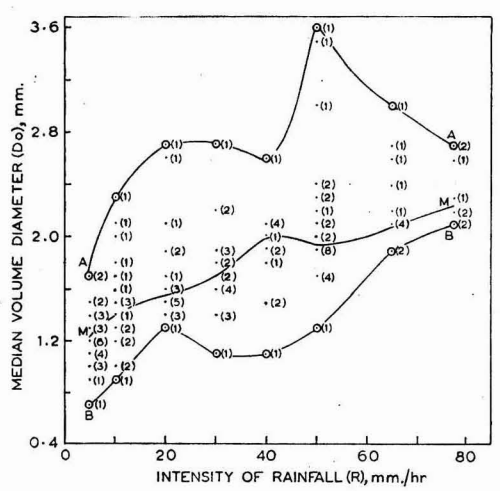

FIG. 9 — VARIATION OF D_0 FOR THE SAME INTENSITY OF RAINFALL [Number within parenthesis indicates frequency of occurrence of plotted points. Curve MM passes through median frequency values of D_0 corresponding to different rainfall intensities. Curves AA and BB give upper and lower limits respectively of D_0]

intensities of rainfall, indicating also the number of cases in which the particular value of D_0 occurred. Curves AA and BB have been drawn through points of maximum and minimum values of D_0 respectively, while the curve MM passes through points giving D_0 values corresponding to their median frequency. The diagram shows more clearly the considerable degree of scatter of D_0 values for the same intensity of rainfall, and also that it tends to decrease when the intensity exceeds a certain value. The values of D_0, as given by the median frequency curve MM, are lower than those given by the curves of Anderson, Laws and Parsons, Best and Blanchard (for non-orographic rain), the difference tending to increase with increasing intensity of rainfall. This lower value of D_0 in rainfall situations in India may largely be accounted for by the preponderance of drops belonging to medium size groups, compared to what one would expect from the exponential distribution suggested mainly on the basis of drop size measurements in temperate latitudes.

The study of both W and D_0 in relation to rainfall intensity has shown that neither of these parameters

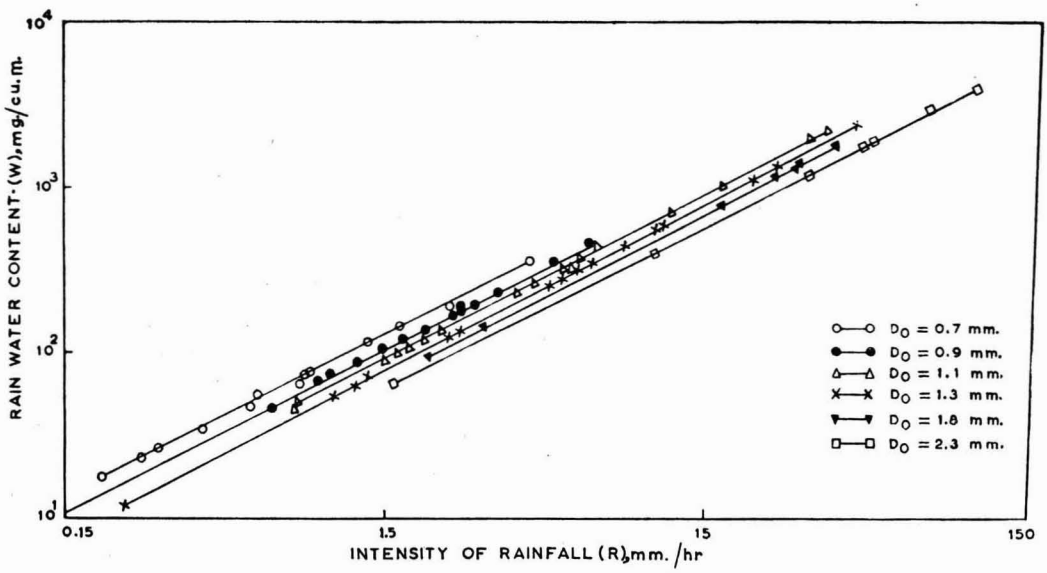

FIG. 10 — RAIN WATER CONTENT-INTENSITY OF RAINFALL CURVES CORRESPONDING TO DIFFERENT VALUES OF MEDIAN VOLUME DIAMETER

represents uniquely the drop size distribution in rain in different situations and, as such, the rate of rainfall. Consideration to both these factors — one giving a general idea of the spread of the size distribution curve, and the other its central tendency—has to be given in order that we may establish a satisfactory relationship connecting these three precipitation elements. In Fig. 10 have been drawn W-R curves corresponding to various values of D_o, the curve in each case extending over the intensity range in which the particular D_o value has been found to occur. It is seen that, for the same value of D_o, W and R are uniquely related, and that the curves corresponding to different D_o values show an identical trend, which can be represented by a single relationship

$$R=\frac{1}{67}WD_o^{0\cdot6}$$

It will be seen that little or no smoothing is necessary for drawing the curves and that the individual plots follow the curves quite closely. The applicability of the above relationship has also been examined with reference to drop size data of rain in Hawaii as obtained by Blanchard. Comparing the calculated values of D_o on the basis of the above equation with those computed directly from drop size data and included in Blanchard's tables, it is seen that these are in agreement generally within ± 15 per cent.

Radar reflectivity and intensity of rainfall

For portraying quantitatively, with the help of a microwave radar, the characteristic features of rainfall associated with a rain-storm at a distance, the most important aspect of study to be made is how the echo intensity or radar reflectivity factor (Z) is related to the intensity of rain generally, and also how, for the same rate of rainfall, this factor varies in different situations depending upon the actual distribution of raindrop sizes.

If P_o is the power transmitted by the radar antenna, A_e the effective antenna aperture for extended targets, h the pulse length, r the range, and $\Sigma\sigma$ the sum of back scatter cross-sections of the scattering particles in a unit volume, the value of P_{ro}, the average power received back from the precipitation elements, would, in the absence of any attenuation, be given by

$$P_{ro}=\frac{P_o h A_e \Sigma\sigma}{8\pi r^2}$$

The quantity $\Sigma\sigma$ in the above equation is proportional to what is known as radar reflectivity factor which, in the case of precipitation elements composed of spherical droplets, is taken to be equal to $\Sigma N_D \Delta D.D^6$. Since both rainfall intensity and radar echo power are thus dependent upon drop size distribution, an exact determination of the rate of precipitation from observed radar echo intensity would be possible if, for a given rainfall intensity, distribution of drop sizes was the same or nearly so in all cases. Observations based on individual samples on different occasions and at various phases of rainfall, however, show that actual distribution of drop sizes often differs materially, and this introduces a certain degree

of uncertainty in the estimate of rainfall on the basis of radar echo intensity alone. Owing to the sixth power characteristic of drop diameters involved in the expression for Z, even a relatively small variation in the distribution features, particularly at the large size end, may make a considerable difference in the value of Z, although the intensity of rainfall (R) may not be affected appreciably. It is thus seen that an empirical relation, however carefully derived, connecting Z and R may not satisfy the actual condition in all instances and may often be wrong by as much as ± 30 per cent or more. Indeed, Twomey's[18] observations in Australia showing marked variations in drop size distributions for the same rate of rainfall showed that this error factor can be as high as 4 in some cases.

Nevertheless, as has been attempted by various other workers, the data collected have been examined to see if some approximate relationship can be found between radar reflectivity and intensity of monsoon rain at Delhi and Khandala. For this purpose values of Z, equal to $\Sigma N_D \Delta D.D^6$, relating to quite a large number of samples have been calculated, and plotted against corresponding values of R, separately for the two stations (Fig. 11). It is seen that while the mean curves DD and KK give, on the average, a fairly good representation of the variation of Z with R, there are instances in which intensity values as given by the curves differ substantially from those obtained directly from drop size measurements.

A relationship connecting Z and R may be deduced, using the equation

$$Z = \frac{6}{\pi} G(n) D_o^3 W$$

where D_o and W have their usual meaning and $G(n)$ is a constant which may differ slightly from one region of rainfall to another, and also from one type of precipitation to another. Plotting the values of $D_o^3 W$ against calculated values of Z, the mean value of $G(n)$ has been computed for Delhi and Khandala and is found to be 1·4 in both cases, the standard deviations being 25 and 29 per cent respectively for Delhi and Khandala. With this value of $G(n)$, and making use of the relation $R = \frac{1}{67} W D_o^{0.6}$ suggested in the previous section and also substituting for W in terms of R from the relations given in the section on ' Rain water content in air and intensity of

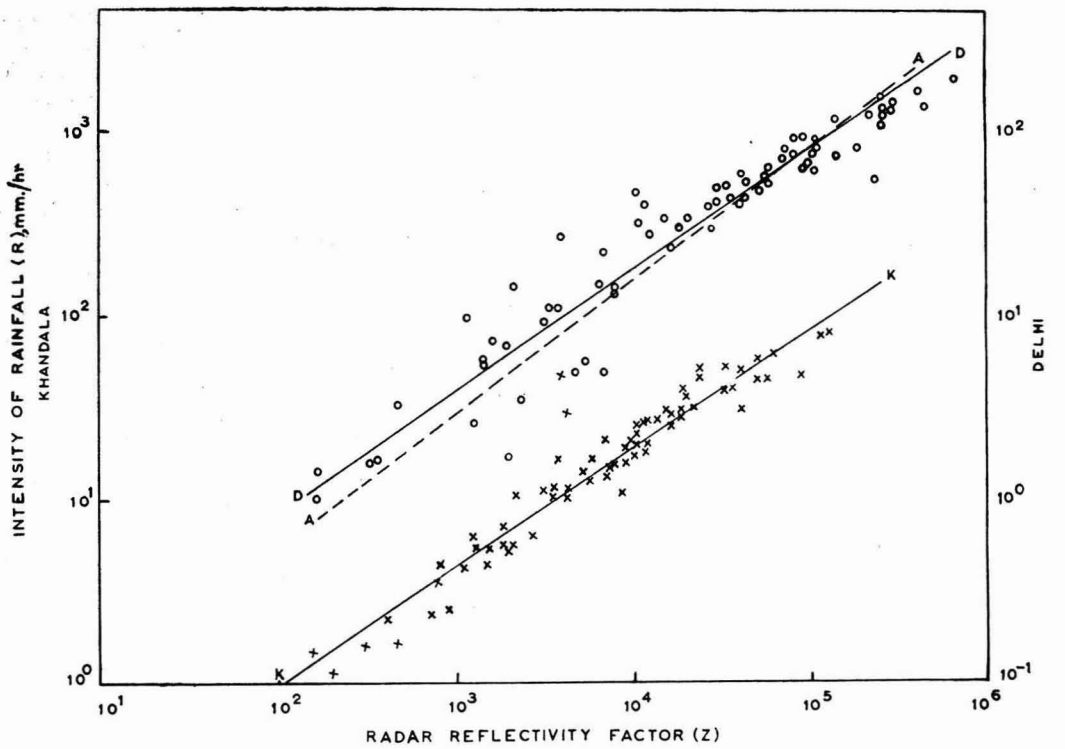

FIG. 11 — RADAR REFLECTIVITY FACTOR VERSUS INTENSITY OF RAINFALL [DD and KK are mean curves for Delhi and Khandala respectively, drawn through plotted points. AA represents the deduced curve based on $Z = 242R^{1.42}$ for Delhi. Deduced curve for Khandala based on $Z = 109R^{1.64}$ coincides with the mean curve KK]

rainfall ', we obtain the following empirical relations between Z and R for Khandala and Delhi:

$$Z = 109R^{1.64} \text{ for Khandala}$$
$$Z = 242R^{1.42} \text{ for Delhi}$$

Plotting curves corresponding to the above equations in Fig. 11, it is seen that the one relating to Khandala agrees almost entirely with the mean curve for that station, while in the case of Delhi the two curves show some differences, particularly in the range of medium to low intensity rainfall. The general agreement between the plotted curves and those given by the above equations provides further confirmation of the dependability of the suggested relationship, connecting D_o, R and W.

Conclusion

Despite differences in geographical situation and topography of Delhi and Khandala, drop size distributions in monsoon showers at Delhi are found to be broadly similar to those observed in orographically influenced rain of a more continuous type at Khandala during the same season. A few distinguishing features are, however, noticed, but, compared with the differences found by Blanchard between orographic and non-orographic rain in Hawaii, these are not quite so marked. It appears that, although orography plays a part in helping steady development of clouds and more or less continuous rain in Khandala area, precipitation at the station cannot be treated as typically orographic in character.

The most important feature brought out by spatial distribution of drops in monsoon rain at Delhi and Khandala is the observed tendency towards horizontality of the distribution curves over certain intermediate range of drop diameters. Combined effect of the two mechanisms of rain formation, namely ice crystal process and also pure coalescence growth of drops as in ' warm ' rain, is suggested as a possible explanation for the features observed.

Although mean distribution curves obtained by averaging a large number of samples of the same intensity group show fairly smooth variation of the number of drops with size, curves relating to individual samples or based on average of a few taken successively during a certain steady stage of precipitation reveal well-marked irregularities in the nature of peaks and troughs. Besides possible irregularities in the distribution of original precipitation elements, discontinuities in rate of updraft within the cloud may be a factor causing occurrence of peaks and troughs on the distribution curves.

On the whole, the two elements, liquid water content (W) and rainfall intensity (R), are fairly well correlated. W-R relationship found for monsoon rain at Delhi is seen to be in good agreement with that obtained by Blanchard for non-orographic rain in Hawaii. However, similar relationship obtained for Khandala is very different from that for Hawaiian orographic rain.

Median volume diameter (D_o) values for the same intensity of rainfall show a much greater scatter than in the case of W. The D_o values for monsoon rain in India are found to be generally lower than those found by investigators in other areas. Relative preponderance of drops belonging to the medium size group, as against smooth decrease exponentially of number of drops with size as in temperate latitude rain, apparently accounts for somewhat lower values of D_o in tropical rain.

While neither W nor D_o individually is related uniquely with the intensity of rainfall (R), it is seen that a relationship connecting all the three elements and given by the equation, $R = \frac{1}{67}WD_o^{0.6}$, gives a satisfactory representation of the actual condition in most cases.

It is difficult to obtain a satisfactory generalized relation connecting radar reflectivity (Z) and intensity of rainfall (R). However, based on drop size distributions of a large number of samples, an approximate relationship has been worked out for monsoon rain at Delhi and Khandala.

Acknowledgement

The authors wish to express their grateful thanks to Shri A. K. Roy for his valuable help and guidance at various stages of the investigation. They would also like to record their thanks to Shri R. C. Srivastava for help in calibration work, and to Shri Raj Kumar Kapoor for considerable assistance in the computation of data included in the paper.

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TABLE 1 — RAINDROP SIZE DISTRIBUTION AND ASSOCIATED RAINFALL PARAMETERS AT DELHI

Sample No.	R mm./hr	W mg./cu. m.	D_0 mm.	Period of exposure sec.	No. of drops as recorded on the filter paper within 0·20 mm. size interval centred around indicated diam. (mm.)																					
					0·5	0·7	0·9	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9
Series No. I; date: 11 July 1956; time: 13.30 to 14.45 hrs IST																										
1	51·0	1648	4·2	3	10	5	8	1	2	3	2	—	—	—	—	—	—	2	—	2	1	—	—	1	—	3	—
2*	137·0	4700	3·5	1	6	6	13	6	3	3	2	—	2	1	1	—	—	2	1	1	—	—	—	—	—	—	—
3	39·7	1855	1·5	1	19	24	16	9	4	4	1	1	—	1	—	1	1	—	1	—	—	—	—	—	—	—	—
4†	202·0	—	—	1	10	11	7	6	5	6	1	—	—	—	1	3	1	1	—	—	—	—	—	1	—	—	1
5	135·0	4734	2·9	1	4	5	5	7	5	4	3	2	1	6	—	2	—	3	1	2	1	1	—	—	—	—	—
6‡	206·0	6972	3·5	1	—	2	1	2	—	1	1	1	4	1	3	5	—	2	2	1	4	2	—	—	—	—	—
7	105·0	4114	2·6	1	4	9	7	7	6	4	1	5	3	4	1	2	1	—	2	—	—	1	1	—	—	—	—
8	98·0	4192	2·5	1	4	7	8	14	9	3	2	1	1	3	5	3	1	—	1	1	—	—	—	—	1	—	—
9	108·0	3562	2·2	1	3	5	6	7	5	9	5	3	4	2	1	2	1	1	1	—	—	1	—	—	—	—	—
10	97·0	3750	2·5	1	4	5	8	6	4	5	5	4	2	3	1	2	1	3	1	1	—	—	—	—	—	—	—
11	118·0	4404	2·8	1	1	2	4	3	4	2	5	1	4	2	2	1	5	3	—	1	—	—	1	—	—	—	—
12	78·0	3007	2·7	1	4	5	2	3	1	4	—	1	4	3	—	2	—	—	1	—	—	—	1	—	1	—	—
13	26·0	1206	2·3	1	4	2	—	1	—	1	3	2	1	1	3	1	—	—	—	—	—	—	—	—	—	—	—
14	39·0	1661	1·9	1	1	2	2	4	4	6	3	1	5	1	1	—	1	—	—	—	—	—	—	—	—	—	—
15	70·0	2679	2·4	1	3	5	—	6	4	3	5	2	2	2	1	1	—	2	1	1	—	—	—	—	—	—	—
16	31·0	1326	1·9	1	4	3	4	1	1	1	3	4	4	—	1	1	—	—	—	—	—	—	—	—	—	—	—
17	41·8	1741	2·1	1	9	6	3	5	6	2	1	2	2	1	—	1	—	1	—	1	—	—	—	—	—	—	—
18	21·2	1008	1·9	1	8	8	5	3	2	2	1	—	2	2	—	1	—	—	—	—	—	—	—	—	—	—	—
19	21·3	1142	1·3	1	6	9	7	7	8	3	3	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	8·9	519	1·4	1	12	8	4	2	1	1	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21	0·4	23·7	1·2	15	9	7	1	2	2	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	0·95	45·4	1·7	15	4	7	2	—	—	4	1	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Series No. II; date: 26 July 1956; time: 12.30 to 14.15 hrs IST																										
1	31·5	1527	1·6	1	—	6	4	6	1	6	9	3	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—
2	20·7	1084	1·4	1	1	1	4	5	5	9	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	68·5	2841	2·1	1	6	6	8	5	4	5	1	3	6	4	1	1	2	1	—	—	—	—	—	—	—	—	—
4	31·3	1341	1·9	1	9	6	5	5	4	4	—	—	2	—	2	1	1	—	—	—	—	—	—	—	—	—	—
5	53·5	2176	2·1	1	4	2	4	5	4	2	—	1	7	1	—	2	3	—	—	—	—	—	—	—	—	—	—
6	37·0	1660	2·1	1	14	5	5	7	1	1	—	1	10	1	—	1	—	—	—	—	—	—	—	—	—	—	—
7	136·1	5018	2·2	1	37	13	8	5	4	1	1	4	3	4	—	—	2	1	2	1	1	3	—	—	—	—	—
8§	182·5	6232	3·5	1	17	11	6	—	1	1	1	1	2	4	1	2	4	1	1	1	1	1	1	—	1	—	1
9	125·6	5121	2·7	1	23	22	16	9	7	7	5	2	4	2	1	4	1	2	—	—	1	1	—	1	—	—	—
10	32·0	1992	1·1	1	52	39	23	7	3	—	4	3	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—
11	13·6	1018	0·8	1	46	26	13	8	5	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	47·6	2096	1·9	1	11	7	2	2	3	5	5	5	5	2	1	1	—	—	—	—	—	—	—	—	—	—	—
13	119·0	4424	2·6	1	13	9	3	2	9	4	5	4	3	1	4	1	2	1	—	—	1	—	1	1	—	—	—
14	78·8	3476	2·2	1	6	6	2	6	1	5	7	5	3	3	2	1	2	1	2	—	—	—	—	—	—	—	—
15	73·0	2776	2·6	1	10	6	5	3	3	1	1	1	3	1	2	4	2	1	—	1	—	—	—	—	—	—	—
16	28·7	1376	1·9	1	2	5	6	7	3	11	—	—	2	—	—	1	1	—	—	—	—	—	—	—	—	—	—
17	71·1	2935	2·1	1	4	7	5	2	3	4	5	6	4	4	1	2	1	—	1	—	—	—	—	—	—	—	—

*One drop of 5·1 mm. and one drop of 5·9 mm. diameter were also recorded.
†One drop of 5·7 mm. and one drop of 6·5 mm. diameter were also recorded.
‡One drop of 5·3 mm. diameter was also recorded.
§One drop of 5·1 mm. diameter was also recorded.

TABLE 1 — RAINDROP SIZE DISTRIBUTION AND ASSOCIATED RAINFALL PARAMETERS AT DELHI — *contd*

Sample No.	R mm./hr	W mg./cu. m.	D_o mm.	Period of exposure sec.	No. of drops as recorded on the filter paper within 0·20 mm. size interval centred around indicated diam. (mm.)																					
					0·5	0·7	0·9	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9
Series No. II; date: 26 July 1956; time: 12.30 to 14.15 hrs IST — *contd*																										
18	10·9	576	1·4	1	3	1	2	—	5	6	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	60·6	2589	1·9	1	6	3	3	7	7	5	4	4	6	—	2	2	—	—	1	—	—	—	—	—	—	—
Series No. III; date: 18 August 1956; time: 18.30 to 19.15 hrs IST																										
1	2·6	132	1·5	2·5	2	1	2	1	2	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—
2	0·5	35	0·8	5·0	4	7	4	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	1·6	65	2·3	10·5	16	2	—	—	—	—	—	—	1	—	—	3	—	—	—	—	—	—	—	—	—	—
4	12·1	542	1·9	2·5	9	1	1	—	—	—	5	6	5	1	—	—	—	—	—	—	—	—	—	—	—	—
5	4·6	185	2·4	2·5	6	1	—	2	1	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—
6	48·8	2300	1·7	1·0	33	19	9	6	5	4	6	3	6	1	1	1	—	—	—	—	—	—	—	—	—	—
7	71·2	2943	2·2	1·5	18	12	16	5	6	9	6	2	4	7	3	1	3	—	2	—	—	—	—	—	—	—
8	127·0	4450	3·1	1·0	6	5	4	8	3	1	2	—	4	3	1	2	—	2	1	—	—	—	1	1	—	—	1
9	77·9	3175	2·3	1·0	23	15	8	5	3	3	6	—	2	4	2	2	1	2	1	—	—	—	—	—	—	—
10	1·0	75	0·9	2·5	8	5	1	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	13·0	626	1·6	2·5	29	11	2	4	6	6	4	2	1	1	2	—	—	—	—	—	—	—	—	—	—	—
12	0·3	23	0·7	5·0	12	1	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. IV; date: 4 October 1956; time: 13.49 to 14.28 hrs IST																										
1	26·6	1004	—	1	—	—	—	—	—	—	—	—	2	5	2	—	—	—	—	—	—	—	—	—	—	—
2	7·3	300	—	1	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—
3	7·8	332	—	1	—	—	—	—	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—
4	7·8	332	—	1	1	—	—	—	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—
5	5·0	220	—	1	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	11·1	336	—	1	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—
7	9·5	448	—	1	—	—	—	—	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	2·4	112	—	1	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	11·8	560	—	1	—	—	—	—	—	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	7·1	316	—	1	—	—	—	—	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	5·0	297	1·2	1	8	3	3	1	—	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	13·2	563	1·6	1	5	1	1	—	—	4	2	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
13	45·3	1776	2·2	1	7	6	1	2	—	2	3	2	3	1	3	—	1	—	1	—	—	—	—	—	—	—
14	25·9	1016	1·5	1	5	2	2	3	5	5	4	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—
15	37·8	1550	2·1	1	7	4	—	2	2	1	2	2	3	2	—	2	—	1	—	—	—	—	—	—	—	—
16	41·3	1786	2·0	1	17	7	3	4	5	—	1	2	5	2	1	1	1	—	—	—	—	—	—	—	—	—
17	1·6	112	1·0	1	5	2	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	6·4	371	1·2	1	4	1	2	3	4	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	3·2	221	—	1	1	4	4	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	1·4	107	—	1	2	4	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Values of $N_D \Delta D$ corresponding to a single raindrop falling over a sampling area of ($\pi .5^2$) sq. cm. in 1 sec.					62	44	35	29	26	23·5	22	20	19	18	17	16·5	16·0	15·5	15·2	15	14·7	14·5	14·3	14·2	14·1	14·0	14·0

TABLE 2 — RAINDROP SIZE DISTRIBUTION AND ASSOCIATED RAINFALL PARAMETERS AT KHANDALA

Sample No.	R mm./hr	W mg./cu. m.	D_0 mm.	Period of exposure sec.	No. of drops as recorded on the filter paper within 0·20 mm. size interval centred around indicated diam. (mm.)																				
					0·5	0·7	0·9	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9
Series No. I; date: 16 August 1956; time: 14.00 to 14.05 hrs IST																									
1	2·2	159·8	0·8	3	10	11	12	5	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	4·5	258·1	1·4	3	10	8	5	4	2	8	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—
3	5·0	276·3	1·3	3	17	9	3	3	5	3	—	3	1	—	—	—	—	—	—	—	—	—	—	—	—
Series No. II; date: 16 August 1956; time: 14.10 to 14.30 hrs IST																									
1	23·6	884·5	2·4	2	—	—	—	1	—	—	1	2	2	1	3	2	—	2	—	—	—	—	—	—	—
2	1·7	109·2	1·1	3	6	6	4	2	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	4·0	329·9	1·2	3	8	6	5	5	4	1	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	13·4	612·6	1·5	3	3	3	8	7	3	3	6	5	3	1	—	—	—	1	—	—	—	—	—	—	—
5	5·5	316·7	1·3	3	7	5	4	10	6	8	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	3·4	240·5	0·9	3	7	18	10	14	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	1·5	130·6	0·7	3	15	21	7	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	1·0	115·0	0·8	3	10	13	9	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. III; date: 16 August 1956; time: 18.10 to 18.20 hrs IST																									
1	45·7	1906·2	2·2	1	4	1	—	3	1	3	4	5	1	4	2	—	—	1	—	—	—	—	—	—	—
2	19·5	994·2	1·4	1	18	5	2	5	6	3	2	1	1	—	—	1	—	—	—	—	—	—	—	—	—
3	40·0	1873·8	1·9	1	7	—	8	5	2	5	6	4	8	—	—	—	—	—	—	—	—	—	—	—	—
4	3·9	242·2	1·1	3	8	11	5	9	4	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	0·9	61·3	1·0	5	7	3	6	3	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	0·9	33·7	1·0	5	1	4	—	3	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. IV; date: 16 August 1956; time: 23.20 to 00.10 hrs IST																									
1	2·3	198·5	0·8	4	10	30	19	7	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	2·5	192·8	0·7	5	36	45	20	5	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
3	1·1	124·7	0·4	5	88	30	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	1·9	168·3	0·6	5	95	18	2	4	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	8·0	438·7	1·4	3	11	7	7	8	7	6	5	3	—	—	—	—	—	—	—	—	—	—	—	—	—
6	9·2	535·4	1·2	3	20	12	16	13	10	5	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—
7	10·9	582·2	1·5	3	25	5	12	9	2	7	12	2	1	—	—	—	—	—	—	—	—	—	—	—	—
8	10·3	577·4	1·4	3	16	14	12	7	9	12	7	—	1	—	—	—	—	—	—	—	—	—	—	—	—
9	13·2	729·4	1·9	3	5	9	15	23	24	3	5	1	—	2	—	—	—	—	—	—	—	—	—	—	—
10	2·5	172·5	0·9	5	1	17	14	19	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	8·2	459·2	1·2	3	2	2	9	15	14	6	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—
12	8·5	480·9	1·2	3	3	6	13	17	13	7	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	16·9	864·5	1·4	3	1	—	10	23	16	10	6	4	5	—	—	—	—	—	—	—	—	—	—	—	—
14	21·9	1001·9	1·7	3	2	1	2	4	7	15	9	9	4	3	—	1	—	—	—	—	—	—	—	—	—
15	28·4	1403·5	1·5	2	12	10	4	10	19	15	10	2	—	2	1	1	—	—	—	—	—	—	—	—	—
16	29·2	1402·5	1·6	2	5	7	6	13	11	5	12	9	3	1	1	—	—	—	—	—	—	—	—	—	—
17	33·0	1554·3	1·7	1	5	3	6	5	7	6	2	3	2	2	1	—	—	—	—	—	—	—	—	—	—
18	47·1	2147·2	1·7	1	4	3	8	10	7	4	7	—	3	4	1	1	—	—	—	—	—	—	—	—	—
19	54·5	2409·2	1·9	1	8	7	—	—	1	8	5	4	10	4	—	—	—	—	—	—	—	—	—	—	—
20	54·6	2263·3	2·0	1	9	3	2	2	1	2	3	6	7	1	2	—	2	—	—	—	—	—	—	—	—
21	46·7	2159·5	1·7	1	4	1	2	6	4	7	8	6	5	2	—	—	—	—	—	—	—	—	—	—	—
22	5·6	298·7	1·4	5	21	17	5	3	8	11	3	—	—	1	—	1	—	—	—	—	—	—	—	—	—

TABLE 2 — RAINDROP SIZE DISTRIBUTION AND ASSOCIATED RAINFALL PARAMETERS AT KHANDALA — *contd*

Sample No.	R mm./hr	W mg./cu. m.	D_o mm.	Period of exposure sec.	No. of drops as recorded on the filter paper within 0·20 mm. size interval centred around indicated diam. (mm.)																				
					0·5	0·7	0·9	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9
Series No. IV; date: 16 August 1956; time: 23.20 to 00.10 hrs IST — *contd*																									
23	0·6	60·8	0·5	5	32	10	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	6·4	394·3	1·1	3	12	14	7	15	12	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	2·1	158·4	0·8	3	10	14	12	6	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26	2·5	196·2	0·8	3	15	19	13	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27	2·5	193·6	0·9	3	17	21	6	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28	2·8	212·3	0·8	3	14	12	15	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29	9·2	470·0	1·4	3	29	16	3	7	6	3	2	1	4	—	1	—	—	—	—	—	—	—	—	—	—
30	33·9	1440·4	2·0	3	11	8	6	10	10	9	6	7	5	3	2	—	—	—	—	—	1	—	—	—	—
31	19·7	817·2	2·1	3	9	11	4	4	5	2	4	1	5	3	1	—	1	1	1	—	—	—	—	—	—
32	7·2	385·5	1·4	3	15	11	5	6	1	7	2	4	1	—	—	—	—	—	—	—	—	—	—	—	—
33	1·8	124·9	0·9	5	15	15	9	8	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
34	0·4	40·4	0·4	5	29	8	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35	1·3	107·0	0·8	5	15	21	17	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
36	0·4	47·1	0·5	5	24	14	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
37	2·7	142·2	1·4	5	5	2	—	4	4	6	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
38	6·0	325·3	1·3	3	—	1	2	6	11	10	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
39	0·08	10·6	0·5	5	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. V; date: 18 August 1956; time: 12.30 to 12.48 hrs IST																									
1	54·2	2392	1·9	1	13	7	6	5	4	2	4	5	6	3	—	—	2	—	—	—	—	—	—	—	—
2	43·2	1799	2·1	1	17	1	1	3	2	4	3	2	2	2	2	—	1	1	—	—	—	—	—	—	—
3	81·7	3314	2·1	1	1	3	9	3	5	4	6	3	6	4	—	1	2	1	—	—	1	—	—	—	—
4	100·6	3558	3·1	1	10	4	1	2	3	5	2	1	2	3	1	1	—	—	—	2	—	—	—	1	1
5	50·8	2153	1·9	1	7	1	—	2	2	3	3	9	3	4	1	—	1	—	—	—	—	—	—	—	—
6	1·5	62	1·5	5	—	—	—	—	2	2	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
7	34·2	1277	2·8	1	10	7	—	—	1	1	—	—	1	—	1	—	2	2	—	—	—	—	—	—	—
8	67·0	2427	2·6	1	2	3	—	—	2	—	—	—	—	3	—	6	1	2	1	—	—	—	—	—	—
9	67·1	2424	2·7	1	6	1	1	1	2	—	3	1	—	4	1	1	—	—	2	1	1	—	—	—	—
10	3·2	156	1·8	3	8	7	—	—	—	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	—
11	0·8	63	0·8	3	5	3	7	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	0·2	16	0·5	3	4	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. VI; date: 19 August 1956; time: 09.10 to 09.25 hrs IST																									
1	38·9	1607	2·0	1	1	3	2	—	2	4	4	3	2	1	2	2	—	—	—	—	—	—	—	—	—
2	50·5	2303	1·6	1	7	6	8	6	3	12	7	3	2	—	—	—	3	—	—	—	—	—	—	—	—
3	26·9	1313	1·6	1	—	—	1	4	4	9	7	2	2	—	—	—	—	—	—	—	—	—	—	—	—
4	46·2	1900	2·0	1	—	3	—	5	3	1	6	3	3	2	—	—	—	1	—	1	—	—	—	—	—
5	44·5	1883	1·9	1	5	4	2	4	3	3	6	2	4	1	—	—	1	—	—	1	—	—	—	—	—
6	26·6	1203	1·9	1	3	2	3	1	1	4	3	3	2	3	—	—	—	—	—	—	—	—	—	—	—
7	36·3	1676	1·6	1	1	2	2	6	3	7	7	3	3	1	1	—	—	—	—	—	—	—	—	—	—
8	30·4	1502	1·6	1	8	4	3	3	9	6	2	3	4	1	—	—	—	—	—	—	—	—	—	—	—
9	51·1	2269	1·9	1	4	3	1	1	7	9	2	6	7	1	1	1	—	—	—	—	—	—	—	—	—
10	19·5	918	1·4	1	3	2	—	1	4	4	3	—	2	2	—	—	—	—	—	—	—	—	—	—	—
11	45·7	1791	2·1	1	2	2	1	2	2	3	3	1	4	2	—	1	—	—	—	—	—	—	1	—	—

TABLE 2 — RAINDROP SIZE DISTRIBUTION AND ASSOCIATED RAINFALL PARAMETERS AT KHANDALA — *contd*

Sample No.	R *mm./hr*	W *mg./cu. m.*	D_0 *mm.*	Period of exposure *sec.*	No. of drops as recorded on the filter paper within 0·20 mm. size interval centred around indicated diam. (*mm.*)																						
					0·5	0·7	0·9	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9
Series No. VI; date: 19 August 1956; time 09.10 to 09.25 hrs IST — *contd*																											
12	37·6	1754	1·6	1	1	5	6	5	4	5	13	1	3	—	—	1	—	—	—	—	—	—	—	—	—	—	—
13	6·3	413	1·0	1	3	10	5	4	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	11·9	705	1·1	1	2	7	5	11	6	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	0·9	79	0·7	5	6	25	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	1·5	107	0·9	5	21	8	7	8	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	0·4	35	0·6	5	9	10	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	0·08	8	0·5	5	4	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. VII; date: 19 August 1956; time: 18.10 to 18.20 hrs IST																											
1	5·6	292	1·4	3	4	4	2	3	4	6	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	5·8	324	1·1	3	9	3	4	11	9	3	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	58·6	2386	2·2	1	5	3	—	—	3	2	2	2	4	8	2	2	—	—	—	—	—	—	—	—	—	—	—
4	10·5	700	1·0	1	13	10	13	8	4	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	15·3	718	1·6	2	5	1	3	—	1	5	10	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	46·9	2298	1·3	1	3	3	7	13	9	9	9	4	1	2	1	—	—	—	—	—	—	—	—	—	—	—	—
7	38·7	1836	1·5	1	6	3	2	1	4	8	11	6	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—
8	29·4	1347	1·8	1	1	1	2	4	2	—	5	8	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—
9	79·9	2892	2·7	1	13	—	1	—	—	—	1	2	2	1	—	5	2	3	—	1	—	—	—	—	—	—	—
10	25·6	1157	1·8	1	4	—	—	—	1	7	4	2	2	—	3	1	—	—	—	—	—	—	—	—	—	—	—
11	12·5	615	1·7	1	4	1	3	1	—	3	2	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	9·6	498	1·4	2	—	2	2	3	8	9	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	9·6	514	1·4	1	—	2	6	3	1	3	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	10·0	492	1·6	2	—	2	1	2	3	6	6	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	0·7	68	0·6	5	30	19	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. VIII; date: 20 August 1956; time: 08.10 to 08.18 hrs IST																											
1	1·4	134	0·5	2	36	6	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1·1	113	0·5	3	40	12	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	2·9	189	0·7	3	35	16	7	8	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	2·9	189	0·7	2	28	6	7	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	33·8	1646	1·4	1	3	5	—	5	10	13	4	3	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—
6	26·0	1106	1·9	2	6	5	1	3	2	4	8	—	7	4	1	1	—	—	—	—	—	—	—	—	—	—	—
7	34·7	1648	1·6	1	4	1	—	1	4	8	12	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	25·4	1284	1·3	1	1	1	1	7	14	10	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	0·9	84	0·6	4	36	16	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	0·8	66	0·6	4	18	12	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	1·8	155	0·6	3	35	22	8	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. IX; date: 23 August 1956; time: 09.17 to 09.21 hrs IST																											
1	4·4	200	1·7	3	—	—	—	4	—	1	—	4	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	3·8	185	1·6	3	—	—	2	2	3	2	1	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	2·6	131	1·4	3	1	3	3	2	1	2	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
4	1·8	108	1·1	4	2	2	3	6	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	1·1	73	1·0	5	1	2	7	11	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	0·2	18	0·7	5	4	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	0·1	6	0·9	5	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 2 — RAINDROP SIZE DISTRIBUTION AND ASSOCIATED RAINFALL PARAMETERS AT KHANDALA — *contd*

Sample No.	R mm./hr	W mg./cu. m.	D_0 mm.	Period of exposure sec.	No. of drops as recorded on the filter paper within 0·20 mm. size interval centred around indicated diam. (mm.)																					
					0·5	0·7	0·9	1·1	1·3	1·5	1·7	1·9	2·1	2·3	2·5	2·7	2·9	3·1	3·3	3·5	3·7	3·9	4·1	4·3	4·5	4·7	4·9
Series No. X; date: 23 August 1956; time: 19.30 to 19.40 hrs IST																										
1	1·3	66	1·3	3	—	—	2	—	2	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	10·9	411	2·3	3	1	—	—	1	—	1	—	1	3	1	1	2	—	1	—	—	—	—	—	—	—	—	—
3	8·4	392	2·0	3	1	—	—	—	—	3	5	1	5	2	—	—	—	—	—	—	—	—	—	—	—	—	—
4	51·6	1803	3·5	1	4	—	—	—	2	—	—	1	—	2	1	1	—	—	—	1	2	—	—	—	—	—	—
5	48·8	1656	2·9	1	—	—	—	—	—	—	1	—	—	1	1	1	2	—	—	1	—	1	—	—	—	—	—
6	49·8	1779	3·0	1	1	1	1	2	—	1	—	—	—	2	1	1	—	—	2	—	—	—	1	—	—	—	—
7	11·5	577	1·4	1	—	—	—	1	—	8	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	51·8	1669	3·6	1	—	—	—	—	—	—	—	1	—	1	1	—	—	—	1	—	1	—	—	—	1	—	—
9	20·6	719	2·6	2	—	—	—	—	—	1	—	1	2	—	3	1	1	—	—	—	1	—	—	—	—	—	—
10	16·9	587	2·9	2	—	1	—	—	—	—	2	—	—	—	—	1	—	2	—	—	1	—	—	—	—	—	—
11	3·9	154	2·2	3	—	—	—	—	1	—	1	—	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—
Series No. XI; date: 23 August 1956; time: 19.42 to 19.47 hrs IST																										
1	2·9	198	0·9	3	4	2	4	20	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	4·0	232	1·2	3	3	6	6	5	5	6	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	6·9	379	1·4	2	2	3	5	5	1	10	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	2·1	139	0·9	3	8	12	5	5	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	0·4	35	0·7	10	15	15	8	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	0·6	49	0·7	5	11	12	4	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	0·3	23	1·0	10	2	6	3	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	1·3	85	0·9	4	12	10	3	2	2	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Series No. XII; date: 24 August 1956; time: 09.15 to 09.21 hrs IST																										
1	6·4	313	1·5	2	—	2	7	6	1	1	—	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—
2	29·8	1210	2·2	1	—	2	3	—	3	4	2	1	1	1	—	1	—	—	—	1	—	—	—	—	—	—	—
3	27·6	1361	1·7	1	3	1	3	13	5	4	1	4	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	29·2	1487	1·8	1	3	2	1	6	5	4	3	2	5	2	—	—	—	—	—	—	—	—	—	—	—	—	—
5	21·3	1057	1·6	1	2	3	2	3	8	3	3	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	11·3	599	1·3	1	1	3	1	8	3	2	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	17·3	797	1·8	1	—	5	2	—	1	3	1	3	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—
8	14·7	771	1·6	1	—	1	4	4	—	2	4	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
9	17·1	914	1·4	1	6	3	7	2	2	9	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	3·2	206	1·0	3	18	12	8	3	1	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	5·6	340	1·1	2	8	5	7	8	2	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	5·3	307	1·2	3	7	9	4	6	8	8	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	4·6	301	1·0	2	5	9	5	10	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	4·6	252	1·4	2	7	5	—	2	2	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	4·4	266	1·1	3	10	4	4	15	7	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	1·2	90	0·9	3	8	9	3	2	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	2·6	145	1·3	3	3	1	6	1	2	3	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	1·6	109	1·0	3	6	4	5	5	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Values of $N_D \Delta D$ corresponding to a single raindrop falling over a sampling area of ($\pi.5^2$) sq. cm. in 1 sec.					62	44	35	29	26	23·5	22	20	19	18	17	16·5	16	15·5	15·2	15	14·7	14·5	14·3	14·2	14·1	14·0	14·0

Criteria for Design of Windmills for Low to Moderate Wind Velocities

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The criteria for the design of windmills for low to moderate wind velocities have been examined and two designs of windmills for pumping water are described. The elementary theories of windmills — the momentum theory and the blade element theory — general requirements and optimum values of design variables are discussed. Different designs of rotors for blades have been studied and the theoretical values of torque and power developed have been determined. From an analysis of the performance characteristics, the specifications for two types of windmills, which would be most suitable for conditions in India, have been drawn up.

THE art of making windmills is an ancient one and for a long time it has been based on empirical methods transmitted from generation to generation of millwrights. This state of affairs continued till about the twenties of the present century when the spread of aviation and the study of problems of aircraft propulsion gave a clearer insight into the principles of design of windmill rotors. Pioneer investigations in the field were made by A. Betz of the Aerodynamic Institute, Gottingen, and the scientific theory of windmills began to take shape in the late twenties.

Although the design of high speed propellers meant for absorbing large horsepowers would require exact theoretical analysis, the same would not apply to the design of small low speed windmill rotors which are expected at the most to absorb up to 5 h.p. Moreover, considering the nature of the installation and the fact that the primary use of such windmills is for pumping water using piston type pumps, it is sufficiently accurate to use elementary theories for practical design purposes. It will be appreciated that most of the conventional multibladed type windmill rotors are aerodynamically inefficient and there has been no need to apply advanced aerofoil theories in their design. While in the case of conventional multibladed rotors not much attention need be paid to the shape of the blades, the application of basic aerofoil principles in the design of two or four-bladed rotors having aerofoil shapes would be of considerable significance.

The object of the present paper is to determine the optimum design conditions for windmill rotors primarily intended for moderate to low wind velocities. Usually, windmills of foreign make give optimum performance only at wind velocities of the order of 15 m.p.h. In India, the wind velocities are only of the order of 6 to 10 m.p.h. on the average. Hence, in the present case, the elementary theory has been used and estimates of performance made for a rotor of 14 ft diam. assuming specific values for design wind velocity, design r.p.m. and number of blades. Although the aim has been to determine the mutual influence of the design variables, the ultimate object is the choice of an optimum size of windmill which will be the most suitable for the wind conditions prevailing in India.

Elementary theory of windmills

The aerodynamics of airscrews has been explained by several theories. The momentum theory and the blade element theory are dealt with in text-books[1] and only a passing reference is made to these theories here. The energy in the wind at any instant is proportional to the product of the mass of air moving through any cross-section and the square of its velocity. To capture this energy or a part of it (since it is not practicable to extract the whole) a mechanical device such as a rotor is placed in the path of the wind. The mass of air undergoes a loss of speed in passing through the rotor from a value V, which it possessed

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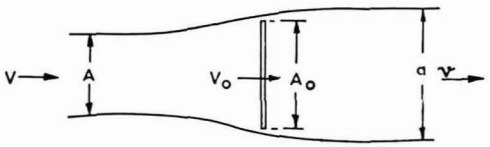

FIG. 1 — VARIATION OF WIND VELOCITY BEFORE AND AFTER WIND WHEEL

before encountering the rotor to a value v after its passage to leeward. Betz[2] has shown, with certain simplifying assumptions, that the speed of the wind at the rotor wheel is the arithmetical mean of the two speeds V and v and that the maximum extraction is obtained when $v/V = \frac{1}{3}$, i.e. when the residual speed is one-third of the initial speed of wind. It is also assumed that the changes in the pressure of the wind in passing through the wind wheel are negligible. It follows from the equation of continuity that

$$AV = A_oV_o = av \quad \ldots\ldots\ldots\ldots \quad (1)$$

In order to conform to the relationship $v/V = \frac{1}{3}$, which corresponds to the maximum power output, the three sectional areas A, A_o and a will be in the ratio of 1 : 1·5 : 3 (Fig. 1).

From the foregoing the maximum energy that can be extracted by the windmill can be calculated.

The mass of air passing through the wind wheel per sec.

$$= \tfrac{2}{3}\rho A_oV \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

where ρ is the density of air.

Loss of kinetic energy per unit mass during passage through the wind wheel

$$= \tfrac{1}{2}\left(V^2 - \frac{V^2}{9}\right) = \tfrac{4}{9}V^2 \quad \ldots\ldots\ldots \quad (3)$$

Hence power absorbed by the wind wheel

$$= \tfrac{2}{3}\rho A_oV \times \tfrac{4}{9}V^2 = \tfrac{8}{27}\rho A_oV^3 \quad \ldots\ldots \quad (4)$$

This energy is $\frac{16}{27}$ of the total energy of the wind, namely $\frac{1}{2}\rho A_oV^3$ passing through the swept area A_o with the speed V at the entrance side.

The momentum theory of windmills, as outlined above, is based on the consideration of a mean axial velocity in the slipstream and determines the drag and torque of a windmill from the rate of decrease of momentum of the wind. The theory determines an upper limit to the power produced but it gives no indication of the configuration of the windmill rotor to achieve this result. This is made possible by applying what is called the blade element theory in which the rotor is considered as consisting of a number of blades of aerofoil shapes.

In the most elementary case, the air flow is treated as two-dimensional, neglecting interference effects between the blades, tip correction and radial flow due to slipstream expansion.

Consider an element dr (Fig. 2) located at a distance r from the centre of rotation. If the r.p.m. of the blade is n, its rotational velocity $2\pi rn$, when combined with wind velocity V, will subject the blade to a resultant velocity V_R at an angle of incidence α (Fig. 3).

The lift acting on the element is given by

$$\Delta l = \tfrac{1}{2}C_l\rho V_R^2 dA = \tfrac{1}{2}C_l\rho V_R^2 b\,dr \quad \ldots\ldots \quad (5)$$

The profile drag acting on the element is given by

$$\Delta d = \tfrac{1}{2}C_d\rho V_R^2 b\,dr \quad \ldots\ldots\ldots \quad (6)$$

where C_l is the lift coefficient of the blade section; C_d, the drag coefficient of the blade section; ρ, the air density; V_R, the resultant wind velocity; and b, the blade width.

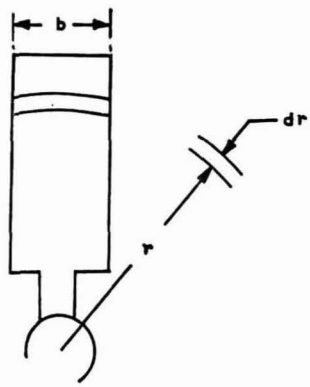

FIG. 2 — POSITION OF ELEMENT dr WITH RESPECT TO CENTRE OF ROTATION OF THE BLADE

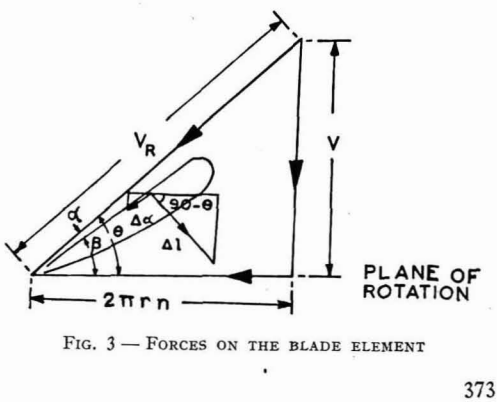

FIG. 3 — FORCES ON THE BLADE ELEMENT

The lift and drag components Δl and Δd can be resolved into components in the plane of the windmill rotor blade (Fig. 3). The resultant torque due to the element is given by

$$\frac{dQ}{dr} = \tfrac{1}{2}(C_l \sin\theta - C_d \cos\theta)\rho V_R^2 br \quad \ldots\ (7)$$

The above expression gives the torque load for the radial element under consideration. By choosing a suitable number of radial elements and determining the torque developed by these elements, the total torque of the blade can be found out by plotting values of dQ/dr against radius. The points obtained are joined by a smooth curve. The total area under the curve for the radial elements under consideration will give the total torque per blade. Once the total torque Q per blade is determined, the b.h.p. developed by the windmill can be obtained by the formula

$$P = QN\omega \quad \ldots\ (8)$$

where Q is the total torque per blade; N, the num- of blades in the rotor; and ω, the angular velocity of the rotor.

The components of Δl and Δd perpendicular to the plane of the windmill rotor act as air resistance loads on the rotor and the tower and are important for the design of the tower.

General requirements and optimum values of design variables

The simple blade element theory has been used in the present analysis. The type of the windmill chosen for any locality in India would depend on the prevailing wind conditions. It is necessary to standardize a minimum number of types as otherwise their production will become expensive. The main objectives aimed at in any design should be simplicity and cheapness in order that it could be used by the average Indian farmer and also easily repaired by the village carpenter or smith.

A reasonable diameter for windmills will have to be chosen. Since the wind velocities in India are not high, too small a diameter will not be effective. On the other hand, too large a diameter would increase the capital cost. In the present study a diameter of 14 ft for the rotor has been tentatively chosen. To keep the cost of the windmill low, it is also necessary to limit the number of blades. The chord length for the section should, however, be made sufficiently large to ensure that sufficient starting torque is available even at low wind velocities.

Design wind velocity

The wind velocities in India are rather low compared to those obtaining in other countries like U.S.A., Australia and northern Europe. It is, therefore, desirable that the windmill should have a reasonable output even at a 6 m.p.h. wind (nearly 10 ft/sec.). If the windmill rotor is designed to give optimum performance at a wind velocity of, say, 10 m.p.h., it would meet most of the requirements.

Selection of blade section

The main considerations for the choice of the blade shape to be used for windmill rotor are: (1) ease of fabrication, (2) adequate thickness/chord ratio, to give a reasonable spar depth, (3) minimum c.p. movement with angle of incidence to avoid undesirable torsional effects and (4) gradual stall characteristics. This assists in giving better performance over a wide range of wind velocities and r.p.m.

An aerofoil section which more or less satisfies the above considerations has been chosen and is designated as WP-X1[3]. The characteristics of this section, such as centre of pressure location (C.P.), C_L and C_D as functions of the angle of incidence (α), are given in Fig. 4.

Although the optimum blade is one that has constant incidence, two other types, namely one with constant blade setting and another with constant incidence at the root and tip, with blade settings varying linearly in between, have been considered in the design study; the latter types will be easier to construct.

Type A: *Linear pitch variation* — The angle of incidence at both the root of the blade (2·5 ft radius) and tip (7 ft radius) is assumed to be 0°, 4°, 6° and 8°

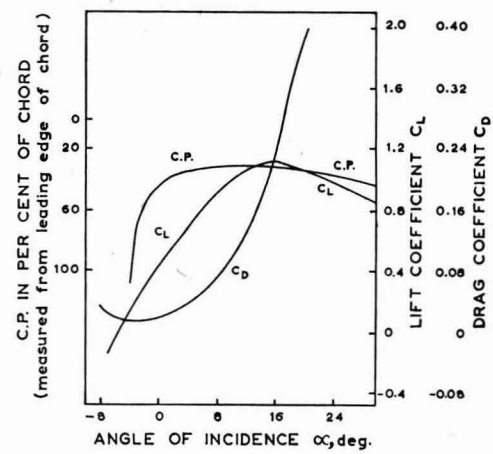

FIG. 4 — CHARACTERISTICS OF AEROFOIL WP-X1 SECTION

TABLE 1 — CHARACTERISTICS OF 14 FT DIAM. EXPERIMENTAL ROTORS

Particulars	Type A PT-3	Type B PT-4	Type C PT-5
Windmill diameter, ft	14	14	14
Design wind velocity, ft/sec.	15	—	15
Design r.p.m.	60	—	60
No. of blades	4	4	4
Aerofoil section	WP-X1	WP-X1	WP-X1
Root chord distance from axis, ft	2·5	2·5	2·5
Blade angle variation	Linear, giving same incidence at root and tip under design conditions	Constant setting of blade angle	Variable to give 4° constant incidence under design conditions
Spar dimensions (in.) at			
Hub joint	$2\frac{1}{4}\times4\frac{3}{4}$	$2\frac{1}{4}\times4\frac{3}{4}$	$2\frac{1}{4}\times4\frac{3}{4}$
Root rib (width)	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$
Tip rib (width)	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
Spar location in % chord	35	30	35

respectively. The blade settings at tip and root are determined by assuming a design r.p.m. of 60 and a design wind velocity of 15 ft/sec. The blade setting of the intermediate sections of the blade is made to vary linearly.

Type B: *Constant blade setting* — A constant spanwise value of the blade setting angle (β) is assumed. The performances at blade settings of 10°, 15°, 20°, 25° and 30° at wind velocities of 10, 15 and 25 ft/sec. have been estimated respectively.

Type C: *Constant incidence* — Constant spanwise values of the angle of incidence of 0°, 4°, 6° and 8° are assumed. Blade setting (β) at each station is obtained assuming a design wind velocity of 15 ft/sec. and a design r.p.m. of 60. The rotor blades will have continuous varying blade settings along the radius.

A summary of the basic characteristics of the three types is given in Table 1.

Results and discussion

The variations of the torque and power coefficients with the speed ratio $\Omega = \omega R/V$ are shown in Figs. 5 and 6 respectively[4]. The blade setting at station $r = 5$ ft is also indicated for each type in the figure.

It may be noted in Fig. 6 that for lower values of $\omega R/V$, say, less than 2·5, there appears to be no significant advantage, from the standpoint of power output, in strictly adhering to an aerodynamic design. It would save considerable cost in using blades which work mainly on the reaction principle.

As regards starting torque it will be noted that the greatest advantage is obtained for low values of speed ratio $\omega R/V$ when the blade setting angle is high. In fact, the maxima of the curves progressively shift in the same direction as the speed ratio. Hence a slow speed windmill should have high blade setting angle. However, in order to get a high value of the torque for the whole rotor we have to increase the number of blades. The low design speed of the rotor also dictates the necessity for a direct action type and since the starting torque for a direct action type has to be high, a multibladed design which increases the solidity of the rotor is obviously the proper choice.

When the speed ratio is high, a propeller type rotor is the best choice and the aerodynamics of such a design has to be worked out carefully. But such rotors have the disadvantage of low starting torque. They will be unsuitable for low wind velocity regions. To overcome the effects of lower starting torque to some extent, a reduction gear has to be employed. The reduction gear should be adjusted to the speed of

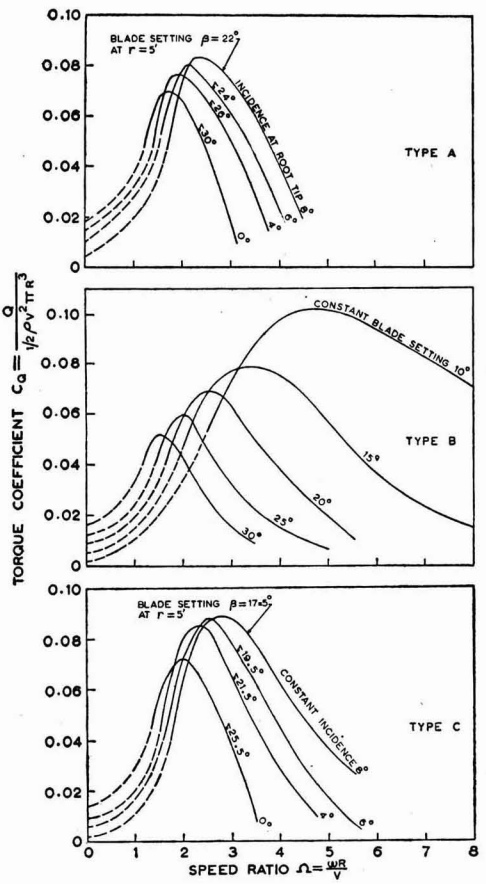

FIG. 5 — VARIATION OF TORQUE COEFFICIENT WITH SPEED RATIO AT DIFFERENT BLADE SETTINGS

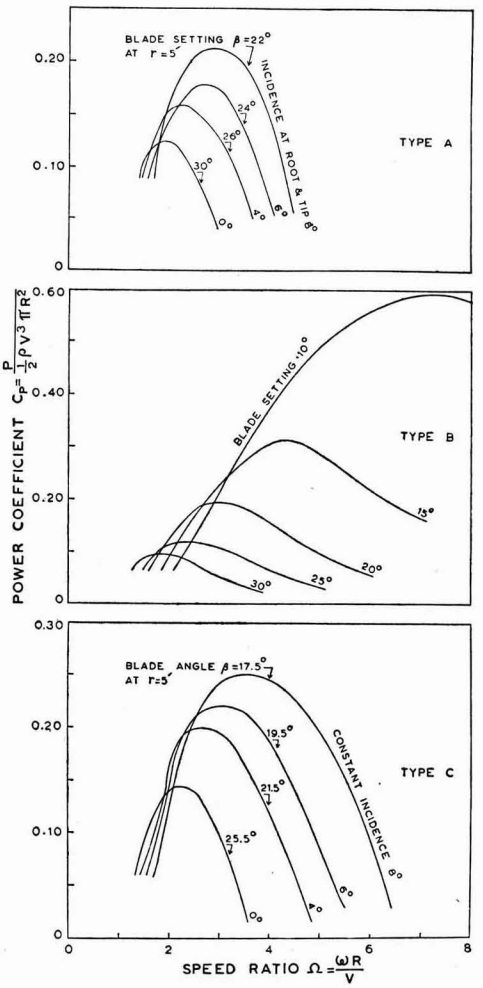

FIG. 6 — VARIATION OF POWER COEFFICIENT WITH SPEED RATIO AT DIFFERENT BLADE SETTINGS

reciprocating type pump and also to the design of the rotor.

Conclusion

An analysis of the above curves has led to the conclusion that two basic types of windmills are needed in India for pumping water, using reciprocating type cylinder pumps — one for low wind and the other for moderate wind regions. As a result of these studies and also the results of actual tests carried out with prototype windmills, the following design features for the two types are considered optimum:

Design A (for moderate winds of 8 to 16 m.p.h.) — Diam., 18 ft; type of blade, aerofoil section WP-X1 in view of high r.p.m.; number of blades, 4; solidity, 0·255; design r.p.m., 120; geared head mechanism; and gear ratio, 3: 1.

Design B (for low winds of 5 to 10 m.p.h.) — Diam., 18 ft; type of blade, simple vane type; aerofoil shape, WP-X2; solidity, 0·53; and direct action head mechanism.

The detailed characteristics of these two designs will be described in later publications.

A significant result of these studies is that for all practical purposes, it is sufficient to keep the same incidence for the root and tip in the blade design and vary the blade setting linearly from root to tip. This would facilitate mass production as jigging and tooling will not be difficult.

Acknowledgement

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Effect of Vitamin A on the Baudouin Test Reading of Vanaspati

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The effect of vitamin A fortification (700 I.U./oz.) of vanaspati (edible hydrogenated vegetable oil) on its Baudouin test reading, on storage at different temperatures, has been studied in detail. The results show that there is no difference in the characteristics of vitaminized and unvitaminized samples of vanaspati on storage in so far as the Baudouin test reading is concerned. Also, vitamin A does not influence the Baudouin test reading of vanaspati. The temperatures at which the samples of vanaspati are maintained, viz. 15°C., room temperature (25-40°C.) and 40°C., do not affect the Baudouin test reading. The above results are contrary to the earlier findings that added vitamin A is responsible for the failure of vanaspati to answer the Baudouin test satisfactorily.

IN accordance with the provisions of the Vegetable Oil Products Control Order 1947[1], vanaspati (edible hydrogenated vegetable oil) is required to contain a minimum of 700 I.U. of synthetic vitamin A per ounce and sufficient sesame oil, subject to a minimum of 5 per cent, as may be required for the product to give a Baudouin test reading of at least 2·0 red units in a 1 cm. cell on the Lovibond scale under the prescribed conditions. Prior to May 1955, the level of fortification of vanaspati with vitamin A was 300 I.U. per ounce, but since that date, the level of 700 I.U. per ounce has been in force.

Working with vanaspati samples fortified at the original level 300 I.U. of vitamin A per ounce, Mathur *et al.*[2] reported that when the samples were stored at 40°C. the Baudouin test reading of the samples rapidly fell off and within nine months, none of the samples responded to the test any more, while in a few cases this occurred even within three months. On the other hand, the Baudouin test reading of vanaspati, which was not fortified with vitamin, was found to remain unchanged throughout the experimental storage period. These authors were, therefore, led to believe that the added vitamin A was responsible for the vitaminized samples of vanaspati not answering the Baudouin test and concluded that vitamin A and sesamolin cannot exist together.

Fortification of vanaspati with vitamin A is being carried on in the country for over a decade now, initially on a voluntary basis by the industry, and since 1953 it has been made compulsory by the Government of India. In the process, a large number of samples of vitaminized vanaspati have been examined for conformity to specifications including Baudouin test reading after varying periods of storage, both by the factories as well as by the Directorate of Sugar and Vanaspati of the Ministry of Food and Agriculture, New Delhi. The findings of Mathur *et al.*[2] are contrary to the accumulated experience in this

*Present address: Regional Research Laboratory, Hyderabad.

regard not only of the Directorate but also of the industry as a whole.

Considering the implications of these findings on the tenability of the relevant provisions of the V.O.P. Control Order 1947, it was thought desirable to repeat the experiments of Mathur *et al.* in a systematic manner and under carefully controlled conditions, the test samples being stored both at 40°C. (as was done by Mathur *et al.*), as well as at room temperature (R.T.) which would more closely approximate the normal conditions of storage of vanaspati containers. The work was initially carried out in the laboratories of the Directorate of Sugar and Vanaspati, the samples being stored at room temperature alone. Subsequently the Central Food Technological Research Institute, Mysore, and the National Chemical Laboratory, Poona, were requested to take up parallel investigations independently, storing the samples both at room temperature as well as at 40°C. Investigations at a storage temperature of 15°C. were also carried out. Meanwhile, Messrs Hindustan Lever Ltd, Bombay, also initiated similar experiments on their own. As the work carried out at all the four laboratories was essentially of an identical nature, it was considered appropriate to collate the results obtained at the different places and present them in the form of a joint report.

Materials and methods

The experimental samples of vanaspati used in all the laboratories conformed to the specifications for vanaspati prescribed under the V.O.P. Control Order 1947, viz. melting point, 33-7°; free fatty acids (as oleic), 0·25 per cent (max.); moisture, 0·25 per cent (max.); butyrorefractometer value, 48 (min.); unsaponifiable matter, 1·25 per cent (max.); vitamin A (in the vitaminized samples), 700 I.U./oz. (initial level); and sesame oil, 5 per cent by weight (min.). The samples were uncoloured and unflavoured (except where specifically indicated). In addition, Messrs Hindustan Lever Ltd carried out one set of experiments with a higher initial vitamin level of 1000 I.U./oz. In all cases synthetic vitamin A acetate (Roche) was employed to fortify the samples.

The procedure for carrying out the Baudouin test on the vanaspati samples followed in all the laboratories was that officially prescribed under the V.O.P. Control Order 1947. The sample under test was diluted with refined groundnut oil (1: 4) and 5 ml. of the mixture shaken vigorously with 5 ml. of concentrated hydrochloric acid (sp. gr. 1·19/15·5°C.) and 0·4 ml. of a 2 per cent alcoholic solution of freshly distilled furfural in a 25 ml. measuring cylinder for 2 min. After standing for 2 min., the contents of the cylinder were filtered and the red colour of the filtrate determined immediately in a Lovibond tintometer using a 1 cm. cell. The blank obtained with the diluent alone was subtracted before the reading was recorded.

Experiments carried out at the Central Food Technological Research Institute, Mysore — Six sets of vanaspati samples from different batches, fortified with vitamin A at a level of 700 I.U./oz. and without fortification, were obtained from Messrs Indian Vegetable Products Ltd, Bombay. They were separately distributed into smaller containers and sealed. One set of samples were stored for ten months at room temperature and their duplicates at 40°C. Baudouin test was carried out on individual samples, first at the end of every month for the first six months and later at two-month intervals. The initial Baudouin test reading values for the different sets of vitaminized samples varied from 3·8 to 4·9 red units (Lovibond) and the final value after ten months of storage from 3·7 to 4·9, the variation in the initial and final values of the readings being nil to 0·2 units.

Experiments carried out at the National Chemical Laboratory, Poona — Two sets of vanaspati samples, fortified with vitamin A at a level of 700 I.U./oz. and without fortification, were obtained, one from Messrs Hindustan Lever Ltd, Bombay, and the other from Messrs Indian Vegetable Products Ltd, Bombay. A third set was prepared in the laboratory starting with vanaspati containing neither vitamin A nor sesame oil (obtained from Messrs Hindustan Lever Ltd, Bombay) and adding to it the requisite quantity of sesame oil and vitamin A (the latter was omitted in the case of unfortified sample). Each of the three sets of samples (six in all) were distributed in 1 lb. tins with loose fitting lids. One set was stored for a period of twelve months at room temperature (24·5-31°C.), the second at 40°C. and the third set at 15°C. Baudouin test was carried out on different samples at the end of every month during the first four months and later at two-month intervals.

Experiments carried out by Messrs Hindustan Lever Ltd, Bombay — A set of two samples of vanaspati, one unvitaminized and the other vitaminized at a level of 700 I.U./oz., was obtained from a single batch of vanaspati and each duplicated into another two samples, one unflavoured and the other flavoured in accordance with A.S.C. specification (No. 139) for 'Oil Hydrogenated'. The four samples were further duplicated and one set stored at room temperature (25-35°C.) for six months and the other at 40°C. Another sample of vanaspati, fortified at a higher level of 1000 I.U./oz., was also prepared and stored both at room temperature (25-35°C.) as well as at

TABLE 1 — BAUDOUIN TEST READING OF VANASPATI SAMPLES STORED FOR VARYING PERIODS AND AT DIFFERENT TEMPERATURES

Source of sample	Vitamin A content *I.U./oz.*	Storage temp. °C.	Baudouin test reading (*red units*)									
			Initial	After storage for								
				1 month	2 months	3 months	4 months	5 months	6 months	8 months	10 months	12 months
Messrs Indian Vegetable Products Ltd, Bombay*	nil	R.T.	4·4	4·3	4·2	4·3	4·2	4·2	4·1	4·1	4·0	—
		40	4·4	4·2	4·2	4·1	4·3	4·5	4·3	4·1	4·1	—
	700	R.T.	4·5	4·3	4·3	4·3	4·3	4·4	4·3	4·2	4·2	—
		40	4·5	4·4	4·2	4·3	4·3	4·1	4·2	4·1	4·1	—
Messrs Hindustan Lever Ltd, Bombay†	nil	15	4·4	4·4	4·4	4·4	4·3	—	4·3	4·3	4·3	4·3
		R.T.	4·4	4·4	4·3	4·3	4·2	—	4·0	4·0	4·0	4·0
		40	4·4	4·4	4·2	4·2	4·2	—	4·0	4·0	4·0	3·9
	700	15	4·9	4·9	4·9	4·9	4·8	—	4·4	4·4	4·4	4·4
		R.T.	4·9	4·9	4·8	4·8	4·7	—	4·4	4·4	4·4	4·4
		40	4·9	4·9	4·7	4·7	4·7	—	4·4	4·4	4·3	4·3
Messrs Indian Vegetable Products Ltd, Bombay†	nil	15	5·9	5·9	5·9	5·9	5·8	—	5·6	5·6	5·6	5·6
		R.T.	5·9	5·9	5·7	5·7	5·7	—	5·5	5·5	5·5	5·4
		40	5·9	5·9	5·7	5·7	5·7	—	5·7	5·7	5·6	5·6
	700	15	5·9	5·9	5·8	5·8	5·7	—	5·7	5·7	5·7	5·7
		R.T.	5·9	5·9	5·8	5·8	5·8	—	5·6	5·6	5·5	5·5
		40	5·9	5·9	5·8	5·8	5·8	—	5·8	5·8	5·8	5·7
Prepared at N.C.L. from unvitaminized and sesame oil-free product obtained from Messrs Hindustan Lever Ltd, Bombay†	nil	15	6·0	6·0	6·0	6·0	6·0	—	6·0	6·0	6·0	6·0
		R.T.	6·0	6·0	5·8	5·8	5·8	—	5·8	5·8	5·8	5·8
		40	6·0	6·0	5·8	5·8	5·8	—	5·8	5·8	5·8	5·8
	700	15	6·0	6·0	6·0	6·0	6·0	—	6·0	6·0	6·0	6·0
		R.T.	6·0	6·0	5·9	5·9	5·9	—	5·9	5·9	5·9	5·9
		40	6·0	6·0	5·8	5·8	5·8	—	5·8	5·8	5·7	5·7
Messrs Hindustan Lever Ltd, Bombay‡	nil	R.T.	5·7	—	5·2	—	5·7	—	5·3	—	—	—
		40	5·7	—	5·7	—	5·2	—	4·9	—	—	—
	700	R.T.	5·7	—	5·3	—	5·1	—	5·2	—	—	—
		40	5·7	—	5·7	—	5·0	—	5·1	—	—	—
	nil§	R.T.	5·7	—	5·0	—	5·4	—	5·4	—	—	—
		40	5·7	—	5·0	—	5·7	—	5·2	—	—	—
	700§	R.T.	5·7	—	5·5	—	5·2	—	5·5	—	—	—
		40	5·7	—	5·5	—	5·4	—	5·1	—	—	—
	1000	R.T.	6·7	6·8	—	6·7	—	—	6·2	—	—	—
		40	6·7	6·8	—	6·6	—	—	6·4	—	—	—
Messrs D.C.M. Chemical Works, Delhi¶	700	R.T.	13·3	13·1	13·2	13·1	13·0	12·9	12·8	—	—	—
	700	R.T.	5·5	5·6	5·5	5·2	5·3	5·2	5·2	—	—	—
Messrs Hindustan Lever Ltd, Ghaziabad¶	700	R.T.	7·3	7·4	7·3	7·2	7·3	7·1	7·3	—		—
Messrs Modi Vanaspati Mfg Co. Ltd, Modinagar¶	700	R.T.	2·9	2·9	3·0	3·0	2·7	2·8	2·8	—		—

*Sample analysed at the Central Food Technological Research Institute, Mysore.
†Sample analysed at the National Chemical Laboratory, Poona.
‡Sample analysed at the laboratory of Messrs Hindustan Lever Ltd, Bombay.
§These samples were flavoured as per A.S.C. specification No. 139 for 'Oil Hydrogenated'.
¶Sample analysed at the laboratory of the Directorate of Sugar and Vanaspati, New Delhi.

40°C. for six months. In either case the Baudouin test was carried out on each of the samples at two-month intervals.

Experiments carried out at the laboratories of the Directorate of Sugar and Vanaspati — Ten samples of vanaspati, fortified with vitamin A at a level of 700 I.U./oz., were drawn from different factories. Each sample was divided at source into seven 4-oz. portions which were packed in sealed containers. The samples were stored at room temperature (25-40°C.) over a period of six months. One sample from each set was examined at monthly intervals for Baudouin test.

The results obtained in the different laboratories are summarized in Table 1.

Conclusion

The results obtained at every one of the four laboratories clearly show that there is no difference in the characteristics of vitaminized and unvitaminized samples of vanaspati on storage in so far as the Baudouin test reading is concerned. Further, vitamin A does not have any adverse influence on the Baudouin test reading of vanaspati. This holds good irrespective of the temperature of storage, whether the samples are stored at 15°C., room temperature or 40°C., and also regardless of whether the product is stored in sealed tins or in containers with loosely fitting lids.

Considering that the level of fortification adopted in the experiments reported by Mathur *et al.* was 300 I.U./oz. of vitamin A, the results of the present experiments, which were carried out at much higher levels of fortification (700 and 1000 I.U./oz.), are significant. If the contention of Mathur *et al.* were correct, then the response of the samples employed in the present series of experiments to Baudouin test should have been poorer in view of the higher concentration of vitamin A in the samples. The present investigations, carried out independently at four separate laboratories, have conclusively established that, contrary to the findings of Mathur *et al.*, vitamin A has no adverse effect on the Baudouin test reading of vanaspati on storage.

References

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2. MATHUR, L. B., TILARA, K. S. & SAHA, R., *J. Indian chem. Soc., Industr. & News Ed.*, **18** (1955), 123.

Dr P. Nilakantan Appointed Director, National Aeronautical Research Laboratory, Bangalore

DR P. NILAKANTAN, formerly Director of Technical Development & Production (Air), Ministry of Defence, has been appointed Director, National Aeronautical Research Laboratory, Bangalore, with effect from 1 June 1959.

Dr Nilakantan was born on 19 April 1910 at Nagercoil (Kerala). He had a distinguished academic record at the Banaras Hindu University and obtained the Master's degree in Physics in 1935, standing first in the University for which he was awarded the Chancellor's Gold Medal. Later, he joined the Physics Department of the Indian Institute of Science, Bangalore, to work with Dr C. V. Raman and was awarded the D.Sc. degree of the Madras University for his thesis on 'Crystal magnetism'. He proceeded to U.S.A. in 1941 and joined the California Institute of Technology (1941-43) to specialize in aeronautical engineering under Dr Theodore von Karman. He was awarded the M.S. degree in Aeronautical Engineering in 1942. He served as Chief of Vibration and Flutter Analysis at Hughes Aircraft Co., California, during 1943-44. On his return to India, he joined the Civil Aviation Department of the Government of India and organized the Research & Development Directorate. He was responsible for setting up the Technical Research Centre in this Directorate and initiated work on the

DR P. NILAKANTAN

design and construction of gliders from indigenous materials.

Since 1948, Dr Nilakantan has been intimately associated with practically all aircraft design and development activities of the Hindustan Aircraft Ltd, Bangalore. During the past few years, he had been organizing the Directorate of Technical Development & Production (Air), Ministry of Defence, and completed successfully a number of important Air Force development and production projects.

As convener of the Wind Power Project, Council of Scientific & Industrial Research, Dr Nilakantan has also directed his attention to research on windmills, as a result of which windmills suitable for use under Indian conditions have been designed and constructed from indigenous materials.

Dr Nilakantan is the author of a number of research papers and monographs on magnetism, X-rays, aerodynamics, flutter and vibration, and aviation. He is a Fellow of the Indian Academy of Sciences and the Institute of Physics, London, Associate Fellow of the Institute of Aeronautical Sciences, U.S.A., and Fellow and Founder-Secretary of the Aeronautical Society of India.

Lady Tata Memorial Trust Awards, 1959-60

THE TRUSTEES OF THE LADY TATA MEMORIAL TRUST have announced the award of the following scholarships for the year 1959-60.

International Scholarships (totalling £ 5065) for research in the diseases of blood with special reference to leucaemias have been awarded to: Dr M. Simonsen, Patologisk-Anatomiske Institute, Copenhagen, Denmark: *Treatment of mouse leucaemia by irradiation and grafting of normal cells*; Dr M. Bessis, Centre National de Transfusion Sanguine, Paris, France: *Electron microscopic studies on ultra structure of normal and leucaemic cells*; Dr G. Klein, Karolinska Institute, Stockholm, Sweden: *The nature of development of drug resistance by malignant growths*; P. A. Pillai, Centre de Microscopic Electronique, Lausanne, Switzerland: *The electron-cytological effects of radiations*; Dr J. Ponten, Patologiske Institute, Uppsala, Sweden: *Study of the virus-host relationship in fowl leucaemias*; Dr (Miss) B. M. Braganca, Indian Cancer Research Centre, Bombay: *Enzymes involved in folic acid metabolism in normal tissue and their role in disease*; Dr J. Hastrup, Institute of General Pathology, Aarhus, Denmark: *Experimental and clinical studies on the effect of cysteamine and antineoplastic chemotherapeutic agents on leucaemia*; Dr E. Kelemen, Postgraduate School of Medicine, Budapest, Hungary: *Genetic factors in experimental transmission of murine leucaemia*; and Dr A. E. Stuart, Department of Pathology, University of Edinburgh, Scotland: *Study of the leucocyte antigens in relation to disturbed immunology in acute leucaemia and in malignant reticulosis.*

Indian Scholarships of Rs 250 per month each for one year for investigations having a bearing on the alleviation of human suffering from disease have been awarded to the following: (Miss) M. H. Gandhi, St Xavier's College, Bombay: *Epidemiological studies in diphtheria*; P. Suryanarayana Murthy, Indian Institute of Science, Bangalore: *Carbohydrate metabolism of susceptible and INH-resistant strains of Mycobacterium tuberculosis* $H_{37}R_v$; N. L. Tikotkar, Department of Chemical Technology, University of Bombay, Bombay: *Synthesis of heterocyclic steroids and polycyclic compounds*; Dr (Miss) M. R. Bakhtiary, Nowrosjee Wadia Maternity Hospital, Parel, Bombay: *Pathological investigation into the cause of obstetric deaths in the foetus*; (Miss) M. D. Menon, Government College, Chittur, Cochin (Kerala): *Studies of the inhibition of mitosis by adrenal-cortical steroids on embryonic cells of vertebrates*; Dr R. K. Panja, Institute of Postgraduate Medical Education and Research, Calcutta: *An immunological approach to cutaneous collagen diseases — An experimental study*; and G. N. Parvate, Indian Cancer Research Centre, Bombay: *Effect of β-rays from yttrium*^{90} *on different tissue cells by using interference microscopy.*

REVIEWS

PROCESSED PLANT PROTEIN FOODSTUFFS, edited by Aaron M. Altschul (Academic Press Inc., New York; *Distributors in India*: Asia Publishing House, Bombay), 1958. Pp. xv + 955. Price $ 26.00

The book consists of two parts: Part I — General Properties of Plant Proteins and Their Utilization and Part II — Processed Plant Proteins. Part I has 12 chapters: Proteins; Plant proteins; Processing of oilseeds; Effect of heat on plant proteins; Effect of other processing factors on vegetable protein meals; Evaluation of protein quality; Use of processed plant proteins in mixed feeds; Use of processed plant proteins as human food; Vegetable protein isolates; Potential uses of isolated oilseed protein in foodstuffs; Chemical sources of nitrogen as supplements to protein feeds; and Supplementation of plant proteins with amino acids. Considering the scope of the book, this part could have been given in a more condensed form. Part II deals with: Soyabean oil meal; Edible isolated soyabean protein; Groundnuts (peanuts) and groundnut meal; Cottonseed meal; Sesame meal; Sunflower seed oil meal; Rapeseed; Mustard seed; Poppy seed meal; Linseed meal; Minor oilseed and tree nut meals; Coconut oil meal; Palm kernel meal; Alfalfa and other leaf meals; Peas and beans; Fermentation feedstuffs; Milling feeds; Microbial proteins; The algae; Inedible oilseed meals; Plant residues and pomaces; and Amino acid composition of foodstuffs. There is a certain amount of uniformity in the treatment of the subject in each of these chapters as represented by the following sub-heads: Introduction; Production and trade; Structure and composition of the seed; Methods of processing; Composition of the oil meal, its use for feed; and Future trends in meal utilization. Occasionally, as with soyabean, a second chapter has been devoted to giving greater details regarding the protein isolated from a particular material. The chapter on Minor oilseeds includes: Introduction; Safflower meal; Almonds; Walnut; Babassu; Hempseed; Pecans; Illipe nut; and References. A useful table listing the contents of essential amino acids of proteins of selected products and expressed uniformly in terms of 16 g. nitrogen is a thoughtful inclusion in the last chapter. Besides, there is a chapter on general introduction to start with. The matter treated under Appendix on ' National Average Food Supplies ' also deserves the status of a chapter because of much new information provided therein by means of tables and diagrams. There is a copious citation of the literature references at the end of each chapter.

As has been stated in the Preface, " The general aim of this work is to present information needed alike by growers, producers and users, and to bridge the gaps between different kinds of knowledge and interest ". Thus, the book has the very ambitious intention of taking in its sweep readers of varied interests and calibre. Naturally, any attempt to cater to such an assortment of tastes can only end up in information encyclopaedic in nature and in a presentation which craves excuse for being discursive. And because it is a collaborative effort with individual preferences and no limit set on the type or the quantity of information, there is a considerable amount of overlapping, to which the editor has drawn attention in the preface, in extenuation. In spite of this overlapping and roominess of the book, there is no mention of ' little-known foods ' like *Quinoa, Chenopodium quinoa*, and seeds of *Sesbania grandiflora*. A particularly glaring omission is that of cashewnut, which is a well-known edible nut.

This is a collaborative volume providing a wide range of information in 33 chapters by 38 authors. The book commends itself as satisfying for purposes of reference on the subject, and so a worth while effort.

M. SRINIVASAN

CERENKOV RADIATION AND ITS APPLICATIONS by J. V. Jelley (Pergamon Press Ltd, London), 1958. Pp. vii + 304. Price 65*s*. net

With the growing importance of high energy particle detection necessitated both in the field of cosmic rays and high energy machine physics, Cerenkov counters are playing a useful role and Dr J. V. Jelley's monograph is timely and should prove useful to the experimentalist as well as the general reader. The many aspects of the literature on Cerenkov radiation and its applications are scattered over many periodicals and in different languages. This monograph is the only one which attempts to collect all the relevant information and presents it within the covers of a single book.

Though the book is primarily intended for the experimentalist, the theoretical background necessary for an understanding of the subject is presented briefly. Also the various results of theoretical study are summarized, enabling the reader to acquaint himself with the many fields on which the effect

impinges, viz. nuclear physics, cosmic rays, optics, high frequency radio-techniques, astrophysics, etc.

The author begins with a historical introduction about the early experiments of Mallet and Cerenkov which led to the discovery of the effect. The simple but powerful experiments of Cerenkov are described with necessary details. In Chapter 2, the classical theory of Tamm and Frank is developed and the modifications introduced by quantum theory are discussed. Chapter 3 contains the later extensions to theory and also the many interesting features such as radiation in ferrites, optically active media, plasma, etc. The effects of finite track length, dispersion, diffraction, etc., are discussed and the chapter has a very good summary of the recent Russian theoretical work accessible so far only in Russian language. Chapter 4 lists the later experimental work whose pace was very much quickened by the development of the photomultiplier. Chapter 5 contains an extremely useful and critical discussion on the properties of the photomultiplier in relation to its application in Cerenkov detectors. A very useful feature of this chapter is a collection of all the properties of commercially available photomultipliers and the list is fairly exhaustive. In Chapters 6 and 7, the various experimental considerations to be taken into account in the design of Cerenkov counters are discussed. Optical considerations, which are quite important, are given necessary emphasis. The optical properties of various media suitable as Cerenkov radiators are given. Chapter 8 is a very interesting one where some of the classic experiments in which Cerenkov counter has played an important role are described. The discovery of the anti-proton by Segre, Chamberlain *et al.*, the cosmic ray albedo estimation by Winckler *et al.*, the determination of the charge spectrum of primary cosmic radiation by the Minnesota group experiments where the Cerenkov counter has played the most effective role in clinching controversial issues are described with clarity and precision. In Chapter 9, the author discusses the role of Cerenkov radiators in the atmosphere — a field in which Dr Jelley's personal contribution has been quite significant. Recently these ideas have been usefully applied by Russian workers in their study of extensive air showers, and this should stimulate interest in this particular application of Cerenkov radiation. Chapter 10 describes the feasibility of gas Cerenkov counters which are bound to play a very important role in high energy physics. Work in this exceedingly interesting field is starting just now and the reviewer is happy to notice the emphasis that Dr Jelley places on the developmental work in this field. Chapter 11 lists miscellaneous ideas and applications of Cerenkov effect in various allied fields.

The book is copiously illustrated and contains a lot of useful experimental data in appendices and tables. The excellence of the bibliography at the end of the book cannot be over-praised. Typographical errors are very few and the book is got up attractively.

The book should prove extremely useful to experimental workers in the field of high energy physics.

A. S. RAO

COMPOSITE CONSTRUCTION IN STEEL AND CONCRETE FOR BRIDGES AND BUILDINGS by I. M. Viest, R. S. Fountain & R. C. Singleton (McGraw-Hill Book Co. Inc., New York, Toronto, London), 1958. Pp. xv + 176. Price $ 7.50

The book has been divided into six chapters with two appendices. As the authors state, it is a logical development of the basic concepts in the composite design of structures, particularly combinations of steel sections with R.C.C. slabs, both in bridges and buildings.

The formulae dealing with the design of composite structures in steel and concrete have been logically developed on the well-known straight line theory of distribution of stresses. Formulae have been also developed for composite construction with rolled steel sections and cement concrete slabs; rolled steel sections with additional cover plates; plate girders with concrete flange in simple spans as well as continuous spans.

The most important aspect which ensures a homogeneous action between steel section and cement concrete slab is the shear connector. Formulae for the design of three types of shear connectors, viz. stud, channels and spirals, and design formulae for their strength and their spacing have been developed. Construction details of shear connectors are described.

Chapter 4 deals with worked examples of different types of bridges with rolled beams without shoring; rolled beams with cover plates but without shoring; simple-span bridge with welded plate girder without shoring; simple-span bridge with rolled beam and cover plates with shoring; three-span continuous bridge with rolled beams and cover plates without shoring; and four-span continuous bridge with welded plate girder without shoring, have been worked out in detail. These examples are worked out according to the American Association of State Heavy Official Standards.

Chapter 5 deals with design aids in the form of tables and curves for different combinations of steel sections and slabs and also includes ready reckoner tables for the design of studs, channels and spirals as

shear connectors. The addition of curves for different types of combinations given in pages 135 to 142 are useful for the quick designing of these types of structures.

Chapter 6 gives a useful list of literature references from which a student can obtain further information on composite structures.

Appendix I deals with the application of composite construction in steel and concrete for buildings. In the examples cited both in this chapter and in Chapter 4, account has been taken of the effect of creep and shrinkage in concrete on the design of such structures.

Appendix II gives a brief idea of how to get the ultimate moment of resistance of composite T beams.

The book is a very useful aid for those engaged in the design and construction of composite structures in steel and concrete.

N. R. SESHADRI

PHOTOMICROGRAPHY by R. M. Allen (D. Van Nostrand Co. Inc., Toronto, New York, London), Second Edition, 1959. Pp. xiii + 441. Price 67*s*. 6*d*.

Photomicrography covers a field of wide applicability, being extensively utilized in medicine, metallurgy, crystallography and mineralogy, and in industry. Photomicrography is, however, both an art and science. To be able to produce successful photomicrographs requires considerable practical experience and at the same time sufficient acquaintance with the basic principles of microscopy and photography. A book entitled photomicrography has, therefore, to deal with principles of microscopy and photography, apart from special techniques of photomicrography. The book under review opens with a chapter on ' Fundamental principles of photomicrography ', describing the construction and optical system of a compound microscope, theoretical concepts of resolution and methods of illumination which have considerable bearing on taking good photomicrographs.

The second chapter, covering 50 pages, describes modern photomicrographic equipment in which there is a great diversity. The commercial designs, which have been described, many with photographs, have been classified into (1) Miniature cameras; (2) Universal vertical cameras; (3) Horizontal-vertical outfits; (4) Self-contained universal models, and (5) Specialized photomicrographic outfits. To supplement the commercial equipment, hints are given in the chapter on ' Home-made equipment '. The fourth chapter, consisting of 105 pages, discusses the many practical factors on which successful photomicrography depends such as exposures, use of filters and illumination, etc.

The next three chapters cover specialized fields such as metallography, photography in polarized light, ultraviolet and infrared lights, motion picture and colour photomicrography. Then the optical principles and practice of phase contrast and interference microscopy are discussed. About eleven pages are devoted to electron microscopy.

Chapter 9 describes, in about 50 pages, the photographic principles and practice. The last chapter gives a selection of fifty-four photomicrographs with the exposure data for each, illustrating fields in which photomicrography is useful.

The first edition of the book came out in 1941; in the second edition published in September 1958, which is the volume under review, many of the advances in microscopy and the technique of photomicrography have been included. The attempt, however, is only partly successful. A good deal of commonplace subject matter is allowed to remain. For example: (i) Chapter 2 is only a collection of a large number of photographs of commercially available equipment; (ii) when modern techniques have become so complicated, it is doubtful if a separate chapter on ' Home-made equipment ' is at all necessary; (iii) in the chapter on ' The technique of photomicrography ' too much attention has been devoted to less important topics — 13 pages devoted to filters as compared with 3 pages for polarized light, 2 pages for fluorescence microscopy and 3 pages for motion picture photography (all in Chapter 5). As a matter of fact, the subject matter of the book from page 41 to 221 can be severely curtailed, thus releasing space for the more important topics dealt with briefly in Chapters 5, 6 and 7 (pages 222-312); 45 pages seem too much for describing photographic processes.

The book covers many topics in photomicrography; the emphasis is, however, uneven. Too much attention has been given to ordinary subjects while recent advances are inadequately dealt with.

W. M. VAIDYA

NUCLEAR REACTOR EXPERIMENTS by the Staff of the Argonne National Laboratory, edited by J. Barton Hoag (D. Van Nostrand Co. Inc., Toronto, New York, London), 1958. Pp. xv + 480. Price $ 6.75 or 51*s*.

The book, *Nuclear Reactor Experiments*, is written by the members of the staff of Argonne National Laboratory and serves the purpose it is intended for. Any member of a nuclear reactor team, whether he be an engineer, physicist or chemist, and has specialized in his own subject, must have a knowledge of the whole reactor field before his services can be utilized effectively. With this end in view, the editor has incorporated a wide diversity of experiments to bring out

particular ideas or broad concepts of nuclear reactor physics.

The first two chapters are devoted to the elementary concepts of radioactivity, its detection and measurement with simple laboratory experiments. The next few chapters give the details of the measurement of physical constants and parameters which are essential for the design of nuclear reactors, starting progressively from moderator assemblies to critical ones. The experiments, incorporated in the two chapters on operating reactors, give a good insight of the static and kinetic behaviour of the reactor. Heat transfer loops, which are used for the removal of heat from a nuclear reactor, are dealt with in the next chapter. The last few chapters are devoted to the metallurgical and radiochemical aspects of nuclear reactors in as much as the fabrication of the fuel elements, the corrosion and radiation damages, often encountered in reactors, and separation of plutonium formed in burnt up fuel, are intimately connected with them.

The book, besides being helpful to experimental scientists and engineers, should prove useful to teaching staff and students connected with nuclear science and engineering courses conducted by various atomic energy establishments throughout the world.

M. P. NAVALKAR

ADVANCES IN CHEMICAL PHYSICS, Vol. 1, edited by I. Prigogine (Interscience Publishers Inc., New York), 1958. Pp. xi + 414. Price $ 11.50

Though the scope of chemical physics is none too well defined, the whole spectrum of activity ranging from purely physical processes such as transport properties of matter to purely chemical processes such as reaction kinetics treated as a stochastic process, is conventionally made to belong to the subject and in this book one finds articles on eleven such topics by different authors. The reviewer has never been able to appreciate the appearance of such volumes, a mere conglomerate of papers, articles and reviews by renowned authors, as the existing review journals are felt adequate for the purpose. Such volumes merely tax the slender library budget of educational institutes and tend to leak away valuable articles which would have otherwise appeared in standard easily accessible journals. The criticism is more pertinent as many of the articles contained in this volume are not reviews but original papers which should have appeared in standard scientific journals. The reviewer feels that if the present series were modelled after the ' Annual Review of Biochemistry ' or ' Recent Advances in Physical Chemistry ' it would have served as a more potent stimulus towards advancement of the science of chemical physics.

The articles are (1) Statistical-Mechanical Theory of Transport Processes: The Heat of Transport in Binary Liquid Solutions by Richard J. Bearman, John G. Kirkwood and Marshall Fixman; (2) Theoretical and Experimental Aspects of Isotope Effects in Chemical Kinetics by Jacob Bigeleisen and Max Wolfsberg; (3) Dielectric Properties of Dilute Polymer Solutions by L. de Brouckere and M. Mandel; (4) Some Physical Aspects of Gaseous Chemical Kinetics by G. Careri; (5) Transport Processes in Liquids by Frank C. Collins and Helen Raffel; (6) The Relation between Structure and Chemical Reactivity of Aromatic Hydrocarbons with particular reference to Carcinogenic Properties by R. Daudel; (7) Molecular Theory of Surface Tension by A. Harasima; (8) Recent Developments in Molecular Orbital Theory by H. C. Longuet-Higgins; (9) Intermolecular Forces and Equation of State of Gases by Taro Kihara; (10) On Statistical Mechanics and Electromagnetic Properties of Matter by P. Mazur; and (11) The Application of the Theory of Stochastic Processes to Chemical Kinetics by Elliott W. Montroll and Kurt E. Shuler.

The article on isotope effect is a readable summary of the theoretical position as also its experimental verification with regard to the differential chemical kinetic behaviour of isotopes. Though Melander's important discovery that there is no isotope effect in electrophilic substitution in benzenoid compound has been mentioned through a reference to only one of his papers, the later extension of the work by other workers in the last few years sometimes even yielding results at variance with that of Melander has received no mention. This might mean that the article was prepared quite a few years ago. In the fourth article the author has critically re-examined the kinetics of reaction of the type $H + D_2 = HD + D$ as also of atomic recombination reactions and draws the optimistic conclusion that " we can now use with more confidence the familiar expressions of the rate process " which to many would have the ring of robust optimism of a traveller in complete darkness in a blind alley. The article on structure and carcinogenic properties hardly merits a place in this book though it raises high hopes, which have been repeatedly rudely shocked and smashed in the past that at least in one field a successful correlation of physiological effect with molecular data has been possible. The article on molecular orbital theory, besides giving briefly the usual LCAO theory, discusses the possibility of its application to spectra of aromatic compounds with a passing reference to the free-electron molecular orbital theory. The article on electromagnetic properties of matter is a well-written introduction to the subject and the last article deals

with the adjustment of energy distribution in molecular assembly which is undergoing chemical change.

One cannot but be struck by even a casual perusal of the present volume with the tremendous amount of labour that is being currently spent to devise models of molecular assemblies, which would simulate nature to an increasingly higher degree of accuracy and how baffling have been all such attempts. It is certainly too much to expect that much of the current coins would remain in circulation say after fifty years, but let us at least bury them in familiar accessible places.

S. R. PALIT

STATISTICAL PHYSICS — Vol. V of the Course of Theoretical Physics, by L. D. Landau & E. M. Lifshitz (Pergamon Press Ltd, London), 1958. Pp. x + 484. Price 80s. net

This is the authorized English edition of the volume on Statistical Physics which forms a part of the authors' "Course of Theoretical Physics", which is proposed to be published in full by the Pergamon Press in nine volumes. The first edition of this volume, published in 1938, contained only an exposition of classical statistics. This edition is a completely revised one and includes both classical and quantum statistics, presented in a unified manner.

The scope of the book may be gauged from the following list of chapter headings: (i) Basic principles; (ii) Thermodynamic quantities; (iii) Gibbs distribution; (iv) Perfect gas; (v) Fermi and Bose distributions; (vi) Condensed bodies; (vii) Real gases; (viii) Phase equilibrium; (ix) Solutions; (x) Chemical reactions; (xi) Matter at very high temperatures and densities; (xii) Fluctuations; (xiii) Symmetry of macroscopic bodies; (xiv) Second order phase transitions; and (xv) Surfaces. As is to be expected, the mathematical aspects of the theory are presented with admirable clarity. However, as is common with most other books on mathematical physics, no indications are given in this book as to how far the theories agree with facts nor even references are given to help the reader. The choice of topics is in some parts limited to the authors' special interests and in some cases, as with the superfluid state, alternative lines of approach are not presented at all. This, of course, is true of other treatises as well, but it is mentioned here so that if this book is prescribed as a text for a postgraduate course on the subject, the need for supplementing it will have to be kept in view.

The translation is excellent and reads very well. The book can be recommended to all students of mathematical physics.

G.N.R.

TRANSPORT PROCESS IN STATISTICAL MECHANICS — Proceedings of the International Symposium held in Brussels during 27-31 August 1956, edited by I. Prigogine (Interscience Publishers Inc., New York), 1958. Pp. x + 436. Price $ 10.00

It is generally known that the theory of bulk matter based on the recognition of its molecular structure has two aspects: one dealing with equilibrium or time-independent properties which is usually known as statistical mechanics and the other known as kinetic theory, which deals with non-equilibrium time-dependent behaviour of matter, in particular the so-called transport problems. It is the latter that is the subject of this symposium in which have participated eminent investigators from many countries. Nearly 50 papers dealing with the subject matter, as also related topics, have been contributed. They have been arranged into fourteen different sets; at the end of each set is given the discussion pertaining to it. This helps the examination of each topic from the point of view of the others engaged in the study.

While in the case of equilibrium processes the basic theory is known and the difficulties are of a mathematical character, it is quite otherwise in the field of irreversible processes such as the transport problems. Universally agreed basic concepts are not yet in evidence; nor have the basic methods of attack been agreed upon. The field thus provides scope for what may be termed as useful speculation at present.

Attempts at placing the kinetic theory and the Boltzmann equation in a general framework, which includes equilibrium and irreversible processes have been described. Use is made of the situation that the distribution function in the kinetic theory which deals with 'actual' molecules propagates itself in the same way as the distribution function in the case of the 'fictitious' ensemble of the statistical mechanics. Concepts pertaining to the phase space, the Liouville equation, encounter between molecules, deterministic mechanics to which the molecules are subject, statistical assumptions and probability methods have all to be interwoven, from a unified point of view, to obtain the general theory in agreement with experiment. Evidently many starting points with concomitant differences on the emphasis of each one of the aspects to be considered are to be expected and they are given. Attempts which have a quantum-mechanical background from the outset are given. The perturbation method is employed and the Chandrasekhar equation, a generalization of the Fokker-Planck equation for phase space, has been obtained using distribution functions coarse grained in time and the formalism of the phase space transformation functions. Applications to solids, moderately condensed systems, gases and globular clusters are

indicated. Attempts have been made to extend the definitions of temperature and chemical potential to cover non-equilibrium but steady assemblies. The concept of 'equilibrium' is sought to be replaced by the more general one of 'compatibility'. Treatment of simple problems and application to quantum statistics are given.

Theoretical presentations of thermal conduction in insulating solids, of the transport of energy and matter in a dense, two-component mixture of hard sphere, diffusion in gas mixtures, in *para-ortho* mixtures, molecular and turbulent diffusion processes, and diffusion in solids, and considerations pertaining to the solution of the Boltzmann equation for electrical discharges, the Boltzmann equation in quantum statistics, the approach to equilibrium in quantum statistics, correspondence principle in quantum statistics, have been given. The random motion of the intermolecular forces and other related problems have come in as well. The viscosity of helium II, transport of momentum and energy by phonons, and strong electrolytes are also to be found. Equilibrium of a system coupled to a thermostat, Onsager's reciprocal relations, principle of minimum entropy production, principle of least dissipation, cyclic processes in irreversible thermodynamics, vibrational relaxation of diatomic molecules, fluctuation phenomena as a possible bridge for going over to the irreversible phenomena by working upon the central idea that there is a close connection between fluctuation and dissipation phenomena, have all come in for theoretical treatment and discussion. The statistical theory of the asymmetric fission of nuclei has also found a place. The demonstration of the feasibility of the use of electronic computers to study the effect of multiple correlation in molecular dynamics is the subject matter of one of the papers.

Experimental methods and results on the viscosity and heat conduction in the neighbourhood of the condensation region, diffusion and thermal diffusion in gas mixtures, diffusion in a quasi-crystalline liquid, diffusion of tracers in solids, and the Soret effect have also been given.

Several other related topics find a place in this volume of very useful material; it leaves the impression that this fascinating subject has entered a period of rapid development.

D. S. SUBBA RAMAIYA

BIOCHEMICAL ENGINEERING: UNIT PROCESSES IN FERMENTATION, edited by R. Steel (Heywood & Co. Ltd, London), 1958. Pp. 328. Price 50s.

This well-produced book typifies how a group of men specialized in different branches of science and technology can make a positive contribution to lay the foundations of a new discipline, 'Biochemical Engineering', in which spectacular developments have taken place during the past decade and a half. Biochemical engineering, it has been rightly pointed out in the text, "is not applied biochemistry": it may perhaps be summed up as consisting of "industrial application of biochemical processes in which the geneticist, the microbiologist, the biochemist and the chemical engineer are intimately concerned", or simply as unit processes in fermentation.

The volume embodies a collection of an expanded version of ten postgraduate lectures delivered at the Manchester College of Science and Technology by a group of experts actively engaged in the teaching of or work connected with one or the other aspects of the subject. A glance at the list of contributors and the table of contents would suffice to indicate the scope of the book and the fields of science and technology on which the subject borders. The introduction to the book is contributed by Sir Harold Hartley, F.R.S., who has not only "leaned all his authority on the side of recognizing" this new subject, but has in his "inimitable and masterly" fashion set out the "Principles of Biochemical Engineering".

It is not possible to comment on all the individual chapters. Taken collectively they represent a good cross-section of the recent advances made in (i) microorganisms and their activities, (ii) substrates for fermentation processes, (iii) aerobic and anaerobic fermentations, (iv) recovery of fermentation products, (v) penicillin manufacture, and (vi) equipment design. Exhaustive information is also provided on the topic of oxygen supply to fermentation processes and the ways and means by which sterilization of the equipment and media may be brought about on a large scale. Appropriately, the volume includes a discussion on the present trends and the scope for the future developments in the subject. There is evidence to suggest that the various contributors have drawn on their experience gained during the teaching of, or research in, the subject in order to present their conclusions in an integrated and coherent form. The book is also well illustrated with attractive photographs and figures, and contains a wealth of information on the topics covered. The contents will surely find appeal to a wide range of research workers in both the academic and the production line, and will be particularly welcomed by students in those postgraduate institutions wherein requisite training facilities exist in the subjects of biochemistry, microbiology, genetics and chemical engineering and/or chemical technology. The volume indeed bears promise of the hope expressed in its preface, viz. "in years to come, these lectures may prove to have a place in the history of biochemical engineering

comparable to that occupied by the Davis Lectures in the chemical engineering" and as such should find a place in all libraries catering to those interested in science and technology.

J.V.B.

PUBLICATIONS RECEIVED

PAINT TRADE MANUAL OF RAW MATERIALS AND PLANT, compiled by H. W. Chatfield (H. W. Chatfield, England; *Sole Selling Agents*: Scott Greenwood & Son Ltd, London), Third Edition, 1959. Pp. xi + 379. Price 30*s*.

THORIUM PRODUCTION TECHNOLOGY by F. L. Cuthbert (Addison-Wesley Publishing Co. Inc., Reading, Massachusetts), 1958. Pp. xiii + 303. Price $ 6.50

PROJECT SHERWOOD — THE U.S. PROGRAM IN CONTROLLED FUSION by Amasa S. Bishop (Addison-Wesley Publishing Co. Inc., Reading, Massachusetts), 1958. Pp. x + 216. Price $ 5.75

RADIATION BIOLOGY AND MEDICINE, edited by Walter D. Claus (Addison-Wesley Publishing Co. Inc., Reading, Massachusetts), 1958. Pp. xx+944. Price $ 11.50

FUNDAMENTAL ASPECTS OF REACTOR SHIELDING by Herbert Goldstein (Addison-Wesley Publishing Co. Inc., Reading, Massachusetts), 1959. Pp. xvi + 416. Price $ 9.50

STATISTICAL YEARBOOK 1958 (United Nations Press Services, New York), 1959. Pp. 612. Price $ 6.50 (paper bound), $ 8.00 (cloth bound)

DECHEMA MONOGRAPHIEN, Band 30; NR.411-425 (Dechema Publishers, Frankfurt), 1958. Pp. 260

DECHEMA MONOGRAPHIEN, Band 31: NR.426-450 (Dechema Publishers, Frankfurt), 1959. Pp. 297

POTATO PROCESSING by William F. Talburt & Ora Smith (The AVI Publishing Co., West Port, Connecticut), 1959. Pp. xv + 475

THE TRANSURANIUM ELEMENTS by Glenn T. Seaborg (Addison-Wesley Publishing Co. Inc., Reading, Massachusetts), 1958. Pp. xx + 328. Price $ 7.00

CHROMATOGRAPHIC REVIEWS — PROGRESS IN CHROMATOGRAPHY, ELECTROPHORESIS & RELATED METHODS: Vol. I, edited by Michael Lederer (D. Van Nostrand Co. Ltd, London), 1959. Pp. ix + 276. Price 45*s*.

QUANTITATIVE METHODS IN HUMAN PHARMACOLOGY AND THERAPEUTICS: Vol. 3 — Proceedings of a Symposium held in London on 24 & 25 March 1958—edited by D. R. Laurence (Pergamon Press Ltd, London), 1959. Pp. xvii + 253. Price 45*s*. net

LEHRBUCH DER ORGANISCHEN CHEMIE by Hans Beyer (S. Hirzel Verlag, Leipzig), 1959. Pp. xvi + 690. Price DM 22.50

METAL FATIGUE, edited by J. A. Pope (Chapman & Hall Ltd, London; *Distributors in India*: Asia Publishing House, Bombay), 1959. Pp. xiv + 381. Price 70*s*. net

JETS & ROCKETS by A. Barker, T. R. F. Nonweiler & R. Smelt (Chapman & Hall Ltd, London; *Distributors in India*: Asia Publishing House, Bombay), 1959. Pp. xiv + 268. Price 35*s*. net

AIRCRAFT ELECTRICAL ENGINEERING — A series of text-books published under the authority of the Royal Aeronautical Society — edited by G. G. Wakefield (Chapman & Hall Ltd, London; *Distributors in India*: Asia Publishing House, Bombay), 1959. Pp. xiv + 349. Price 50*s*. net

HETEROCYCLIC CHEMISTRY — AN INTRODUCTION by Adrien Albert (University of London, The Athlone Press, London), 1959. Pp. viii + 424. Price 45*s*. net

POLYMERS & RESINS: THEIR CHEMISTRY & CHEMICAL ENGINEERING by B. Golding (D. Van Nostrand Co. Inc., London), 1959. Pp. viii + 744. Price 112*s*. 6*d*.

MATHEMATICS DICTIONARY, edited by G. James & R. C. James (D. Van Nostrand Co. Inc., London), Second Edition, 1959. Pp. vi + 546. Price 112*s*. 6*d*.

ISI HANDBOOK FOR STRUCTURAL ENGINEERS — 1. STRUCTURAL STEEL SECTIONS (Indian Standards Institution, New Delhi), 1959. Pp. viii + 187. Price Rs 12.50

BORON FLUORIDE AND ITS COMPOUNDS AS CATALYSTS IN ORGANIC CHEMISTRY by A. V. Topchiev, S. V. Zavgorodnii & Ya. M. Paushkin: translated into English by J. T. Greaves (Pergamon Press Ltd, London), 1959. Pp. 326. Price 80*s*. net

STATICALLY INDETERMINATE STRUCTURES — APPROXIMATE ANALYSIS BY DEFLECTED STRUCTURES AND LATERAL LOAD ANALYSIS by Jack R. Benjamin (McGraw-Hill Book Co. Inc., New York), 1959. Pp. ix + 350. Price $ 11.00

INTRODUCTION TO MONOPULSE by Donald R. Rhodes (McGraw-Hill Book Co. Inc., New York), 1959. Pp. x + 119. Price $ 6.00

METAL FATIGUE, edited by George Sines & J. L. Waisman (McGraw-Hill Book Co. Inc., New York), 1959. Pp. x + 415. Price $ 12.50

MECHANICAL REFRIGERATION by Norman R. Sparks & Charles C. DiIlio (McGraw-Hill Book Co. Inc., New York), Second Edition, 1959. Pp. x + 283. Price $ 8.00

NUCLEAR REACTOR PLANT DATA: Vol. II — RESEARCH AND TEST REACTORS by American Society of Mechanical Engineers, New York (McGraw-Hill Book Co. Inc., New York), 1959. Pp. vii + 297. Price $ 7.50

NOTES & NEWS

A new ionospheric phenomenon

THE RESULTS OF A SPECIAL PROgramme of radio observations at Jodrell Bank, England, in October 1958 revealed two rare radio events which required the postulation of a new type of ionospheric phenomenon to interpret the observed data. The Jodrell Bank programme provided a high degree of flexibility by using 5 separate total-power receivers, all on slightly different frequencies near 80 Mc/s. to monitor continuously various sectors of the sky. This arrangement allowed easy discrimination against localized man-made interference at any one site and against distant narrow-band radio signals.

The aerials of the five receivers used and numbered as 1, 2, 3, etc., are disposed as detailed below: 1, northerly direction at 30° elevation; 2, northerly direction at 30° elevation but of low sensitivity; 3, continuously following Cassiopeia; 4, zenithal orientation; and 5, southerly direction at 30° elevation.

The outstanding observations may be summarized as follows: During the period 3-10 January 1959, about ten instances of isolated increases in the noise level were recorded by some of the instruments, together with simultaneous decreases in the others. Further, another striking isolated event occurred on 25 March 1959 at about 14.00 U.T. In this case, receivers 1 and 2 showed strongly enhanced signal level, the amplitude being about 150 and 400 per cent the diurnal galactic change in receivers 1 and 2 respectively. The corresponding enhancement in receiver 3, with its aerial directed at this time towards the northwest, was 50 per cent. Receiver 4 recorded a marked decrease of at least 50 per cent, while receiver 5 indicated a weak increase of about 25 per cent. At the time of this event the sun was actually in the beam of the receiver 5 with its aerial in the southerly direction and hence it may be concluded that the direct solar radio frequency radiation was negligible. Coinciding with the above observations Jodrell Bank magnetometer revealed a most significant change in the horizontal component of the earth's field of *c.* 50 gammas in an interval of 4-5 hr.

This event, with its simultaneous radio frequency emission and absorption in different sectors, is more intense than any observed in the January 1959 series. However, it has the same essential characteristics. It has been suggested that this phenomenon is caused by passage through the ionosphere of streams of charged particles of very high velocity presumably of solar origin. In the upper ionosphere such particles stimulate the generation of radio frequency energy while at lower levels the result is a net absorption of the background signal. The absorption mechanism is well established, especially in polar regions, and may be attributed to the production of abnormally dense ionization in the lower ionosphere. However, very little is known of processes which can generate radio frequency noise in our atmosphere. It is believed that the impact of charged particles, both of high velocity and high density, is consistent with the environment for production of Cerenkov type radiation. Other processes are also being considered.

Events of the type described above seem to be rare. It is significant that both the first event of the group in January already reported, and the isolated event of 25 March, seemed to be the precursors of a period of intense solar activity with associated terrestrial events such as magnetic storms and aurorae. A preliminary investigation has failed to reveal any unusual solar or other terrestrial effects which may be associated with this phenomenon [*Nature, Lond.*, **183** (1959), 1178].

Photographing of single atomic particle

PHYSICISTS AT THE UNIVERSITY OF Michigan have found a way to photograph the light from the path of a single atomic particle, a light so weak that it must be intensified 100,000 times to be picked up by the most sensitive photographic film. The tiny flash, lasting only a millionth of a second, is produced along the trail left by an atomic particle speeding through a scintillating crystal, an effect similar to that occurring in an operating television set. However, in contrast to a television screen, which has many millions of electrons striking it every instant, the present device, called a luminescent chamber, has made it possible to photograph the light from the path of a single nuclear particle, say, an electron, proton, meson. The device is expected to play an important role in high energy nuclear physics studies ranking in importance with an earlier development, the bubble chamber, which led to a number of advances in the field of nuclear particle physics.

In the luminescent chamber, intensification of the tiny flash of light is achieved by a series of specially developed electron 'image' tubes (made by the Westinghouse Electric Corporation and the Radio Corporation of America), each of which, in turn, intensifies the light and focusses it with lenses on the next tube. Both the bubble chamber and the luminescent chamber record the paths of atomic particles; the luminescent chamber, in addition, can be instructed to photograph a certain particle path without recording any other events occurring in the crystal just before or after the selected particle, in time. Certain very rare types of particles or interactions of great interest can thus be studied much more easily and at will. Current development indicates that a television camera may ultimately be substituted for the film and the flashes may be picked up on video tape. The luminescent chamber could be installed in satellites equipped with remote controlled advance programming and a television camera and equipment to transmit signals to the earth to obtain pictures of far distant stars or galaxies [*J. Franklin Inst.*, **267** (1959), 361].

Nuclear thermocouple

DIRECT CONVERSION OF ATOMIC power to electric power has been

achieved by scientists at the U.S. Atomic Energy Commission's Los Alamos Scientific Laboratory, using a thermocouple composed of uranium and cesium (in gaseous form). The method eliminates all other accessories except the nuclear reactor in the production of power from fission which may lead to reduction by one-half the present cost of power reactors. It also enables reduction in the dead weight load of fuel now needed to propel a space rocket and hence allows equipping satellites with a small but long lasting electricity source for telemetering data. The simple device was tested for the first time on 3 April 1959. The development was a sequel to a discovery made in July 1958 that a very hot gas could be substituted for one of the metals in a thermocouple to largely improve its current generating efficiency.

The electric power is obtained from a nuclear reactor containing a uranium carbide source surrounded by a plasma of hot, ionized cesium gas. When the reactor is on, atomic fission causes such a release of heat that a current is produced. The current is transmitted by the cesium gas to a collector from which it can be extracted. A piece of uranium about a third of the size of a cigarette has been used in this manner to light a bulb for 12 hr much beyond the originally expected few minutes [*Sci. Newslett. Wash.*, **75** (1957), 248].

Sound waves of 10,000 Mc/s.

THE GENERATION OF SOUND WAVES, with a frequency of 10,000 Mc/s., i.e. of the highest pitch ever produced, has been reported by scientists at the General Electric Research Laboratory. This accomplishment is expected to open the way for new discoveries in solid state research by providing a new, powerful technique for observing how solid materials react to intense shaking-up of the atoms in solids.

The 10,000 Mc/s. sound waves are produced by combining techniques used in the propagation of electromagnetic microwaves with those of conventional ultrasonics. Microwave pulses are applied to a quartz crystal in a specially designed cavity-resonator. The crystal is kept at temperatures as low as 2°K. to facilitate prevention of the ultrasonic vibrations from degenerating into vibrations associated with the ' heat barrier ', one of the biggest obstacles in the path of achieving higher and higher sound frequencies.

Sound waves of all frequencies can be transmitted by solids but many of these solids reflect away and resist penetration of the electromagnetic waves in certain region of the electromagnetic spectrum. Thus the new high frequency ultrasonics produced will help fill the gap in solid state in investigational techniques. These extremely high frequency sound waves are expected to be used to investigate phenomena such as the energy levels of atoms and the interactions of electron spins in a crystal lattice [*J. Franklin Inst.*, **267** (1959), 362].

Examination of particulate matter

A SIMPLE AND EFFECTIVE TECHnique for preparing microscope slides (incorporating a sample fine filter membrane for collecting solid material suspended in a liquid) for determining the size and nature of the particles has been used at the Thornton Research centre of the ' Shell ' Research Ltd, England. The essential feature of the method is that the membrane is made transparent to permit the use of transmitted light without disturbing the particle distribution.

A water ejector pump is used to assist filtration. By keeping this pump running, the membrane may be dried in a few minutes. With the suction still applied, a fixative is poured down the side of the filter funnel so as to spread steadily across the membrane and be drawn through it. The forces acting on the particles are such that these are held against the membrane and are not disturbed by the advancing liquid front. The fixing process is complete when the fixative has been drawn through the membrane and the latter is again dry. With the correct choice of fixative the membrane retains its porosity, and is thus capable of being rendered transparent by saturation in Canada balsam diluted with xylene. It can be mounted as desired without disturbing the particles.

A solution of 0·5 per cent (w/w) ' Perspex ' in chloroform as the fixative is found to serve quite well for the purpose. A membrane exhibiting negligible grain when treated should be chosen when an automatic particle counter is used. It should be ensured that the drying processes are carried out to completion; otherwise blotches caused by trapped air or liquid other than balsam may result in counting errors [*Nature, Lond.*, **183** (1959), 1000].

New low-melting glasses

A NEW GROUP OF LOW-MELTING glass compositions with far-reaching implications in the manufacture of moisture-sensitive devices has been developed at the Bell Telephone Laboratories. Composed of varying proportions of sulphur or selenium and the heavy metals arsenic and thallium, the glasses become very fluid at temperatures between 125° and 350°C., a temperature range 300-400°C. lower than any previously known low-melting glass. In this temperature range they have viscosities approximately equal to that of castor oil at room temperature, a viscosity suitable for coating devices by a simple dipping procedure.

The glasses range electrically from semiconductors to insulators with a minimum resistivity of 10^6 ohm cm. maximum resistivity (sulphur and selenium ternary compositions) of over 10^{14} ohm cm. Chemically, the glasses show the same durability characteristics as glasses in general but are attacked by concentrated alkalies. Several compositions are stable to air oxidation up to a temperature of 250°C.

These compositions exhibit properties not normally available in organic coating materials. They have extremely low permeability to both water and helium, and possess good wetting characteristics with respect to most metals. Thermal expansion coefficients range from 20 to 50×10^{-6}/°C. Thermal conductivities are of the order of 0·0007 cal./sec. (cm.^{2}) (°C./cm.). These glasses are also unusual in that they can be evaporated and condensed as thin glass films. The selenium-containing compositions bond particularly well to ceramics and the silicate glasses.

The development of these materials has opened new possibilities of encapsulating semiconducting devices, capacitors, resistors and printed circuit boards. In most cases with proper choice of composition, design and processing, potential difficulties at very low temperatures due to mix-match in thermal expansions can be circumvented.

Coating of semiconducting devices like silicon diodes with these low-melting glasses endowed these devices with excellent initial characteristics. In addition, improvements have been observed when such units were heated or operated [*News from Bell Telephone Laboratories*].

Zinc borosilicate glasses

THE GLASS-FORMING REGION OF THE zinc borosilicate system has been investigated with a view to have glass that can resist both high temperature and thermal shock and yet maintain good optical quality. Such glasses are useful for glazing windows in supersonic aircraft so that visual and photographic observations can be made with a minimum of distortion. As the zinc borosilicate glasses can be melted at moderate temperatures, they lend themselves to the production of glasses of an optical quality which is extremely difficult to obtain with the high-melting commercial heat-resistant glasses.

Of the 42 different compositions of zinc borosilicate systems that were melted, 26 produced homogeneous glasses, the compositions of which were within the following limits in mole per cent: 50-60 per cent of zinc oxide; 20-50 of boric oxide; and 0-20 of silica. The sag points of the zinc borisilicate glasses ranged from 585° to 665°C. which is the approximate temperature range of the sag points of most commercial borosilicate and silicate glasses. All the clear glasses have liquidus temperature between 950° and 1000°C. Glasses containing less than 55 mole per cent ZnO are characterized by the presence of thin films on the top surface of the specimen. The glasses are serviceable in contact with water or neutral solutions [*U.S. Nat. Bur. Stand. Tech. News Bull.*, **43** (1959), 50].

Biological bromination

THE UTERUS OF THE PREGNANT spiny dogfish, *Squalus acanthias*, has been found to convert phenol red into a new purplish blue dye, bromophenol blue. This is the first example of biological bromination observed in a vertebrate.

Phenol red, shown by paper chromatography to be free from any contaminating dyes, is dissolved in sea water, and 50-100 ml. portions are introduced into the uteri of dogfish in the second summer of pregnancy (the spiny dogfish has a gestation period of almost two years). After 24-48 hr, most of the phenol red is converted to the purplish blue dye. The dogfish were kept alive in sea water at 14-5°C. The similarity of the blue dye with bromophenol blue has been confirmed by a number of observations. The new dye obtained from uterine fluid (*p*H *c.* 5-6) turns yellow on acidification. Further, the colour change covered a *p*H range from 3·5 to 4·5, which is in agreement with the range reported for bromophenol. Chromatographic behaviour in four-solvent system failed to show any significant difference between the blue dye and bromophenol blue. The absorption spectra of the blue dye and the bromophenol are identical in the visible region, from 400 to 600 mμ [*Science*, **129** (1959), 778].

Antibiotic and insecticidal activity of fire-ant venom

FIRE ANT'S (*Solenopsis geminata*) venom has been shown to possess strong antibiotic activity against several bacteria and moulds. It is also found to be a very potent insecticide. The venom samples are obtained by milking the ants, teasing them with a glass capillary into which poison is ejected.

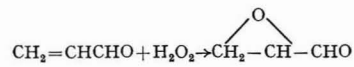
As an antibiotic the venom has proved effective against *Micrococcus pyogenes*, *Streptococcus pyogenes*, *Escherichia coli*, *Lactobacillus casei* and a variety of moulds. Antibiotic activity of the venom probably explains why pustules arising at the site of sting are antiseptic. As an insecticide, the venom is highly toxic to the fruitfly, housefly, termite, boll weevil and rice weevil. Even two species of mite are highly susceptible to it. It acts much like a tranquillizer, but exactly how it attacks the nervous system is unknown so far.

So far the exact chemical nature of venom is not known, but quite a lot is known about the material. The venom is soluble in most organic solvents, and is insoluble in water in which it disperses as fine milk-coloured globules. It is also non-proteolytic. It has two phases — an alkaline carrier and droplets, which are heavier than the carrier.

It has only aliphatic C—H chains which show that venom is non-aromatic. It contains both methyl and methylene groups, a possible ether linkage, and a carbonyl group which does not appear to be an open chain, simple ketone. The C—H/C=O ratio is much higher when the sample contains small amounts of suspended globules. This indicates that the globular component contributes most or all of the carbonyl-containing compound [*Chem. Engng News*, **37** (13) (1959), 35].

Glycidaldehyde

GLYCIDALDEHYDE, THE SMALLEST possible molecule having two reactive centres in an aldehydic group and an epoxide ring, has been synthesized by an alkaline epoxidation of acrolein with hydrogen peroxide at 8-8·5 *p*H.



(Glycidaldehyde)

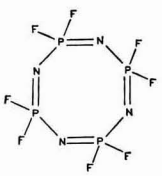
Glycidaldehyde is a colourless liquid boiling at 57-8°/100 mm. It is stable at room temperature with only slight loss of epoxide activity noticeable after several months' storage. It is miscible with water and most organic solvents.

When the compound reacts with water, alcohols, carboxylic acids, phenols, and other reagents having active hydrogens, the epoxide ring opens to form β-substituted lactaldehydes. Similarly active methylene compounds like ethyl cyanoacetate and malonic ester give glycidylidene derivatives. Primary amines form epoxy aldimines by interaction with the carbonyl group of glycidaldehyde. Certain compounds, like acetylacetone or acetoacetic ester, where keto group activates methylene group, react with

glycidaldehyde to form furfuryl alcohols [*Chem. Engng. News*, **37** (16) (1959), 49].

Phosphonitrilic fluorides

PHOSPHONITRILIC FLUORIDES, MEMBERS of a new inorganic homologous series $(PNF_2)_n$, have been synthesized, separated and characterized up to n=17. These compounds, which show a novel type of aromaticity, have been prepared by fluorination, with potassium fluorosulphite, of an undistillable residue obtained from a reaction between phosphorus pentachloride and ammonium chloride. The volatile phosphonitrilic fluorides are then separated by vapour phase chromatography. From the pentamer upward these cyclic fluorides are mobile liquids which rather resemble the fluorocarbons in some properties. They are relatively inert chemically, and have very low boiling points for their molecular weights.



Spectroscopic evidence and measurements of entropy of vaporization are consistent with the cyclic and flexible nature of these compounds. These compounds show a high degree of thermal and chemical stability. The P-N bonds are short, strong and equal in length. The aromaticity in these compounds is of different type than that found in benzene series. In the benzene series the aromaticity is confined to six-membered rings but with phosphonitrilics aromatic rings of almost any size apparently can be formed. This difference in aromaticity appears to be due to the difference in the aromatic bonds. In benzene, C—C bonds are formed by overlapping of the p-orbitals of the carbon atoms while in phosphonitrilics, P—N bonds are formed by the overlapping of the p-orbitals of nitrogen atoms with d-orbitals of the phosphorus atoms. In the case of tetraphosphonitrilic fluorides (I) the actual bonds between nitrogen and phosphorus are neither single nor double but are bonds intermediate between the two, as in the case of benzene [*Chem. Engng News*, **37** (16) (1959), 57].

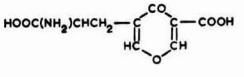
A new type of hydrophylic polymers

A NEW CLASS OF HYDROPHYLIC polymers have been prepared by reacting acrylic or methacrylic anhydrides with glucamine at −10° to 0°C. in methanol. The resulting crystalline monomers, 1-acrylamino or the 1-α-methacrylamido, are then polymerized with benzoyl peroxide to give the final polymer a long hydrocarbon chain with sugar molecules attached to every other carbon atom. The properties of the polymers can be changed when the monomers are copolymerized with the common vinyl monomers, such as acrylamide, styrene or methyl acrylate. The new polymers will have many of the properties inherent in the linear polysaccharides. But, because of the hydrocarbon backbone, the polymers will have many other properties which could make them useful to industry in many applications. The possible industrial applications for the new polymers run from textile sizing compounds to smoothing agents. The other possible uses are as adhesives, additives for oil well drilling muds, paper coatings, thickening solutions, and as copolymers to modify the properties of the existing plastics [*Chem. Engng News*, **37** (16) (1959), 41].

Stizolobic acid

TWO PREVIOUSLY UNKNOWN AMINO acids, stizolobic acid and stizolobinic acid, have been isolated from the sap exuded from the cut surface of the epicotyl tips of the etiolated seedlings of *Stizolobium hassjoo*. Stizolobic acid was isolated from the combined exudates by ion-exchange column chromatography and obtained as colourless needles which melted at 231-3°.

Stizolobic acid is a dibasic acid having a molecular formula $C_9H_9O_6N$. All nitrogen in the molecule belongs to the amino group. The acid undergoes zonolysis giving aspartic, oxalic and formic acids, showing that the stizolobic acid contains $=CCH_2CH(NH_2)COOH$, $=CCOOH$ and $=CH$ groups. The presence of γ-pyrone nucleus was shown by its hydrogenation in the presence of palladium carbon catalyst, yielding two acidic amino acids. The major product gave yellow 2: 4-dinitrophenylhydrazone. The analysis of infrared spectra of stizolobic acid and its deuterated product gave further support for the γ-pyrone structure of stizolobic acid. The formation of glutamic acid by alkaline degradation of stizolobic acid indicates that the side chain $—CH_2CH(NH_2)COOH$ might be on C_3 or C_5 position in γ-pyrone ring. This is further supported by the formation of formic acid. Similarly the second carboxyl group could occupy only C_3 or C_5 position as shown by the formation of malonic acid on alkaline degradation. On the basis of the ultraviolet absorption spectra and the electrophoretic studies, stizolobic acid has the structure β-(3-carboxy-



I

γ-pyrone-5-yl)-alanine (I) [*Nature, Lond.*, **183** (1959), 1116].

Bismuth pentafluoride

BISMUTH PENTAFLUORIDE (BiF_5), found to be one of the most powerful fluorinating agents known, has been synthesized at the Division of Inorganic Chemistry, Argonne National Laboratory, U.S.A. The new synthesis involves the direct reaction of liquid bismuth at 600°C. with gaseous fluorine at a pressure of 1500 mm. of Hg. The reaction vessel is an alundum crucible placed inside a nickel cylinder. The reaction is carried out in an all-metal vacuum system, and all external operations are performed in a dry box to prevent bismuth pentafluoride from coming in contact with moisture. The product, in the form of white needles, is purified by vacuum sublimation.

Bismuth pentafluoride reacts very readily with uranium tetrafluoride to give uranium hexafluoride, and it fluorinates halogens to form interhalogen compounds. It undergoes slow decomposition at elevated temperatures. However, it can be stabilized further by reaction with alkali metal

fluorides. This stabilization is brought about through the formation of a hexa co-ordinate (BiF_6) anion. Its reaction with alkali metal fluorides indicates the possibility of developing a new series of fluorinating agents [*Chem. Engng News*, **37** (15) (1959), 44].

A new synthesis of β-halosulphones

A VERSATILE ONE-STEP SYNTHESIS of a new series of compounds, β-halosulphones intermediates in the preparation of unsaturated sulphones, has been achieved. The synthesis is based on the new free-radical addition reactions between benzenesulphonyl halides with reactive monomers, such as styrene, acrylonitrile, acrylates, and vinyl and alkyl halides. The starting materials are commercially available.

For the reaction equimolar quantities of olefin and sulphonyl halide in a pressure flask are irradiated for a few minutes with a non-frosted light bulb. In many cases, the β-halosulphones crystallize out within a few minutes in more than 90 per cent yield, which indicates a long chain reaction. In a typical reaction benzenesulphonyl bromide plus styrene in the presence of light energy react to form 1-bromo-1-phenyl-2-benzenesulphonyl ethane. The reaction is very exothermic and must be moderated with an inert solvent to prevent explosion. β-Halosulphones are useful as flame retardants and lube oil additives [*Chem. Engng News*, **37** (16) (1959), 45].

Matrix isolation technique

THE MATRIX ISOLATION TECHNIQUE has been found to permit leisurely spectroscopic study of extremely unstable species, including free radicals. The technique uses a suspension of the species to be studied in a solid matrix, which must be chemically inert, rigid with respect to diffusion and transparent to the spectral region to be studied. The matrix materials used are nitrogen, argon and xenon. When nitrogen or a rare gas matrix is used, the sample is prepared by freezing quickly a gaseous mixture of a small amount of the material to be studied in a very large amount of the matrix. The coolants are liquid hydrogen (20°K.) or liquid helium (4°K.).

With the help of matrix isolation technique a number of new substances have been detected which have not been reported before. Thus in the photolysis of nitromethane in solid argon at 20°K., *trans*-methyl nitrile, CH_3ONO, was identified. This shows that the photolysis did not proceed according to the reaction $CH_3NO_2+h\nu = CH_3+NO_2$. Further study of several other products of photolysis led to the identification of the hitherto unknown nitroxyl, HNO, radical and stable N_2O_4 dimer [*Chem. Engng News*, **37** (16) (1959), 46].

Concentration of protein extracts

A SIMPLE, AUTOMATIC METHOD, based on the well-known principle of dialysis against substances of high molecular weight, has been successfully used for the concentration of even a few ml. of fluid containing protein.

Fluid containing protein is placed in a glass tube or container, preferably with a small protuberance at the bottom end having approximately the smallest volume to which the fluid is to be concentrated. Polyethylene glycol with a molecular weight of 20,000 is broken up and an appropriate quantity of the dry granulated material is poured into the Visking dialysis tubing. The proportion of polyethylene glycol to fluid containing protein should be 1:10. The tube containing polyethylene glycol is placed in the glass vessel containing the fluid. Better results are obtained when polyethylene glycol is moistened with a small quantity of water before it is placed in the fluid containing protein. The level to which the tubing is to be pushed down depends upon the final concentration required. The process of concentration ceases when the fluid containing protein reaches the level of the bottom of the tubing. With larger quantities of fluid the tubing containing polyethylene glycol can be bent several times, providing a larger dialysing area and accelerating the process. The electrolyte content of the concentrate will be the same as in the fluid containing protein at the start, as there is a free passage of electrolytes across the membrane.

The method has the great advantage that the concentrate can be collected from clean glass and need not be scraped out from the inside of a sticky tube. Under suitable conditions a concentration, for example, of 10 ml. of urine to about 0·25 ml. is easily achieved in 3-4 hr. The high efficiency of the method is also due to the fact that the hydrophilic agent, namely polyethylene glycol, does not contain water and has, therefore, full absorptive capacity. No denaturation effects were observed [*Nature, Lond.*, **183** (1959), 1055].

Vanadium from phosphate rock by ion exchange

VANADIUM IN 80-90 PER CENT yield has been recovered for the first time from phosphate rock along with uranium by an ion-exchange process. The method has also shown the existence of a strongly anionic pervanadyl phosphate complex previously unknown. The main requirements of the process are that vanadium should be in pentavalent state and there must be some fluoride present in the acid.

When phosphate rock is treated with sulphuric acid and sodium chlorate, most of the vanadium goes into solution in the pentavalent state. It is then adsorbed along with uranium on Dowex I, a quaternary amine type of styrene-divinylbenzene anion-exchange resin. Uranium is separated by eluting with a dilute solution of sodium chloride. After uranium has been eluted, vanadium is reduced with sulphur dioxide to tetravalent state. The tetravalent vanadium is next adsorbed on a cation-exchange resin, Dowex 50, and eluted this time with ammonium chloride. The whole process concentrates the vanadium from about 1·2 g./litre in the 30 per cent phosphoric acid to 60-70 g./litre in the cation-exchange effluent [*Chem. Engng News*, **37** (1959), 49].

British Institute of Criminology

A UNIQUE SCIENTIFIC RESEARCH organization to be known as the Institute of Criminology, with its headquarters at Cambridge, will be established in the near future.

The recognition of the two facts, that (1) crime is ubiquitous, and that (2) fundamental research which is the only effective approach to check (and prevent, if possible) crime, can only be carried out by the combined efforts of experts representing several facilities such as psychiatry, psychology and social science, led to the planning of the present institute to co-ordinate scientific research in criminal science. The useful work done and experience gained by the existing Department of Criminal Science are expected to serve as a good foundation for the building up of the new institute.

The purposes of the Institute are: to place research in criminal science on a level of importance with research in other spheres of science; to give impetus to the teaching of criminology as a graduate and postgraduate study; and to aid the interchange of knowledge and experience between students and those taking part in the administration of criminal justice.

The new Institute of Criminology will be a part of the University of Cambridge and will enjoy perfect academic freedom of research and teaching, though the connection with the Home Office in London and with its Research Unit would be maintained [*British Information Services Release No. BF.* 1123, *dated 2 June* 1959].

The Chemical Elements

THE REVISED 1959 EDITION OF THE *Chemical Elements* chart, published by the Chemical Elements Co., Box 315, South Lancaster, Mass., U.S.A., carries detailed and tabulated information on all the known chemical elements grouped as in the classical periodic table after Mendeleef. Besides giving the names of the elements in English, French, German and Russian, the tabulated statements record the derivation of the names of the elements, information regarding their discovery, the arrangement of the electrons in the atomic structure of the elements, their atomic weights, isotopes—the more abundant isotopes being printed in heavy type — valencies, various physical properties, nature of occurrence, methods of preparation, uses, etc. A considerable amount of additional information is given which is normally not to be found in a chart of this type. It includes information on transmutation of the radioactive elements, electrochemical series, identification by flame and borax bead tests, the extent of distribution in nature, critical constants of gaseous elements and mechanical properties of certain metallic elements; even the alchemistic symbols of some common chemical elements are given. A tabulated index of the elements is added to facilitate locating each element with respect to the group and family to which it belongs.

The chart, which is priced $ 1.00, should be an excellent teaching guide.

Annals of Occupational Hygiene

THE SOCIETY OF BRITISH OCCUPATIONAL Hygiene, in association with the Pergamon Press Ltd, London, has commenced publishing an international quarterly, *The Annals of Occupational Hygiene* [price £ 3 10*s.* ($ 10.00) per volume for libraries, government departments and industrial establishments and £ 2 12*s.* 6*d.* ($ 7.50) per annum for individuals]. This journal is the first of its kind specially devoted to the publication of research in occupational hygiene with special reference to its scientific and engineering aspects. The publication is of special interest and value to workers in the fields of air pollution, human engineering, health physics, ergonomics, mining, heating, ventilating and lighting engineering, and foundry, chemical and pharmaceutical industries.

Electrochimica Acta

WITH A VIEW TO HAVING A SPECIFIC and suitable medium for the rapid publicity of original communications in electrochemistry, the International Committee for Electrochemical Thermodynamics and Kinetics has started publishing *Electrochimica Acta* [price £ 6 ($ 17.00) per volume for libraries, government departments and industrial establishments and £ 3 10*s.* ($ 10.00) per annum for individuals], an international journal, published bimonthly by the Pergamon Press, London. In addition, it will include articles on metallurgy, chemical physics, electronics, and the chemical industry.

Reactor Technology

THE PERGAMON PRESS, LONDON, has commenced, since March 1959, the publication of a new journal, *Reactor Technology* (which forms Part B of the *Journal of Nuclear Energy*). The journal has been started to provide an international medium for the publication of papers on technological subjects, embracing many scientific disciplines and describing original work in the nuclear energy and allied fields.

Papers for publication in the journal will generally deal with: applied mathematics including use of computers for design purposes; applied physics including nuclear and reactor physics; chemical engineering, fuel processing and plant criticality; heat transfer and fluid flow in reactors and heat conversion equipment; metallurgy and fuel element design and fabrication; construction and design of nuclear reactors and associated equipment and their utilization, control systems and instrumentation. It will also include papers reviewing the progress in specific aspects of nuclear engineering, when the need for such a survey in a particular technological field becomes apparent.

The annual subscription for the journal is £ 7 or $ 20.00 for libraries, industry and government organizations, and £ 3 10*d.* or $ 10.00 for private subscribers if certified that it is for personal use.

Burmah-Shell and Assam Oil Company Scholarships, 1959

THE FOLLOWING TEN CANDIDATES have been selected for the award of the Burmah-Shell and the Assam Oil Company Scholarships for research and training in U.K. during the session commencing October 1959.

Burmah-Shell Scholarships — Sarvashri K. C. Varshney (*Petroleum technology*); S. P. Puti (*Mining engineering*); and S. A. Arunachalam (*Fuel technology*).

Assam Oil Company Scholarships — Sarvashri V. B. V. Rajan (*Petroleum technology*); T. Guha (*Petroleum technology*); P. N. Nayak

(*Petroleum geology and geophysics*); R. V. Gopalakrishna (*Fuel technology*); V. D. Sahgal (*Foundry practice*); M. N. Srinivasan (*Foundry practice*); and P. K. Chakravarty (*Mining engineering*).

Announcements

▪ *Dr A. K. Ganguly* of the University of Delhi has been awarded the 1851 Exhibition Scholarship for the year 1959 by the Royal Commission, London. The scholarship is for research in organic chemistry at the Imperial College of Science and Technology, London.

▪ *Shri B. Biswas* of Calcutta University (at present at the University of Southern California) has been awarded the Oliver Gathy Studentship of the Cambridge University. The award, tenable for one year, is for research in the application of physical methods to biological problems.

▪ *Dr. S. N. Bhansali Charitable Trust Prize*, 1958 — The Bombay Obstetric and Gynaecological Society invites thesis or essay on 'Any Original Work on Human Sterility' for the award of the prize for the year 1958. The value of the prize is about Rs 500. The competition is open to all registered medical graduates of any statutory Indian university.

Entries should reach the Society's office by 1 November 1959. Full details and rules governing the award of the prize can be obtained from the Honorary Secretary, Bombay Obstetric and Gynaecological Society, Purandare Griha, Chowpatty Sea Face, Bombay 7.

▪ *Award of Doctorate Degrees* — Shri G. Aruvamudan and Shri M. V. Jambunathan have been awarded the Ph.D. degree of the Mysore University for their theses entitled *Studies on phase rule* and *Some studies in statistical sampling and sample surveys* respectively.

Shri V. K. Srinivasan has been awarded the Ph.D. degree of the Poona University for his thesis on *Cytomorphological studies in the genera Zizyphus and Caesalpinia and cytological studies in the genera Carica and Gossypium.*

INSTRUMENTS AND APPLIANCES

New liquid scintillation counter

TRACERLAB, MASSACHUSETTS, U.S.A., has developed a new version of the widely used CE-1 liquid scintillation counter for tritium and carbon analyses. The new CE-1B has a top opening deep freezer, a change introduced to eliminate the problem of loss of cold air when the front door is opened for sample changing. A transistorized, stable, linear gain of 30 pre-amplifiers has been supplied, one for each photomultiplier. The pre-amplifiers increase the total available gain of the amplifier system, thus permitting the operation phototube and the stable linear amplifiers at their optimum points. The pre-amplifiers also eliminate any criticality in adjusting various operating parameters for the best sample to background counting ratio.

A servo-regulated precision high voltage power supply eliminates any drift in high voltage and permits reproducible high voltage settings. Accuracy of the system is assured by the use of a standard cell. The resettability of the settings is insured by using precision resistors and a system of stepping switches rather than the commonly used potentiometer. A scaler and a ventilated rack for all of the electronic components are also included in the new model. The background has been lowered to 150 counts/min., when set for tritium counting at 5 per cent efficiency, and the same system may also be used for carbon counting, offering 75 per cent efficiency and low background.

A sensitive interferometer

A SENSITIVE INTERFEROMETER HAS been developed which can greatly facilitate the testing of precision flat surfaces such as aircraft fixtures machine ways and layout plates, which must be carefully examined for irregularities. It not only allows quick check of surface quality but also provides a means of production control by locating the spots where added polishing or lapping is required.

The instrument examines surfaces by producing a set of interference fringes, which is, in effect, a contour map of the test area. The principal element of the interferometer is a double-image prism which separates a beam of light into two components. One component is reflected from the test surface to a plane mirror and back. On recombination with the other component, reflected from a plane mirror only, interference fringes are formed. The fringes that appear in the interferometer eyepiece represent contours of equal elevation. They lie along straight lines if the surface under test is perfectly flat, but are curved if the surface is not flat. Small irregularities which do not affect overall flatness characteristics produce serrated or ragged fringes. In the present instrument, because the light is reflected twice from the test surface, the sensitivity is double that of conventional interferometers [*Tech. News Bull. U.S. Bur. Stand.*, **43** (1959), 53].

ERRATA

This *Journal*, article entitled "New Staining Reagents for the Detection of Condensed Phosphates", **18B** (1959), 249-254: Page 251, L.H. col., line 30, '2-5 min.' should be *read* as '25 min.'.

This *Journal*, article entitled "Studies in the Enzyme Make-up of *Vibrio cholerae*: Part XIV — Organic Nitroreductase", **18C** (1959), 105-109: Page 107, R.H. col., line 30, 'o, o'-dipyridyl' should be *read* as 'α, α'-dipyridyl'.

Progress Reports

PASTEUR INSTITUTE, COONOOR

DURING THE YEAR 1958, THE PASTEUR INSTITUTE undertook a special study of encephalitis which occurred in Delhi in 1957 and which occurred in an epidemic form in Nagpur and Madras in June and July 1958. Five virus strains have been isolated from specimens tested so far from cases of encephalitis in Delhi. Three of them were identified as polio virus type I and others were labelled as ECHO viruses, as they were not pathogenic. A detailed report dealing with epidemiological, serological, mutation and recombination and laboratory studies on influenza pandemic of 1957, as it affected India, was prepared at the request of the World Health Organization for consideration by its Expert Committee on Respiratory Virus Diseases at its meeting in August 1958 at Stockholm.

A résumé of the work done at the Institute is given below.

Rabies — Studies designed to test the efficacy of 5 per cent Semple vaccine in the treatment of rabies in humans show that 8·58 per cent of persons bitten by proved infective animals developed the disease in spite of having a complete course of treatment. The mortality rate is only 3·44 per cent as compared to 50 per cent death rate among a similar group of persons who refused treatment. The mortality rate among the incompletely treated is 15·63 per cent. These results indicate that treatment with 5·0 per cent Semple vaccine is superior to that with 1 per cent Semple vaccine used during the years 1912-24. Investigations on the post-infection anti-rabies treatment of dogs, cattle and other animals have been carried out on 2575 animals. The mortality rates among them suggest that post-infection treatment of these animals is useful. Considerable improvement in the antigenicity of anti-rabies vaccine has been obtained by pooling the vaccine before ampouling. The promising results obtained in potency tests in mice as well as in post-infection treatment of guinea-pigs challenged with virulent strains of street virus has led to the adoption of the pooling method for the routine manufacture of the vaccine at the Institute.

Studies on combined serum and vaccine therapy, in rabies, have been carried out to determine the optimum conditions which would give best results and the extent to which the present dosage schedule of vaccine can be reduced when combined with serum therapy. The results indicate that when the challenge (NYC strain) is low, administration of serum in addition to vaccine does not appear to be of advantage. Treatment with a small dose of 0·25 ml. of a 1 in 30 serum (PIC) and 14 doses of 0·15 or 0·075 ml. of vaccine gives very good protection compared with that obtained with higher doses of serum and/or vaccine.

Influenza — In order to obtain a correct understanding of the behaviour of a new strain of influenza virus responsible for initiating a pandemic in 1957, the epidemiology of the disease was considered in detail in 1958. It has been observed that the epidemic started on 18 May 1957 in Madras and spread all over India in the course of six weeks. In each area the pattern has been one of sweeping spread through the most crowded capital and other cities followed by relatively slow spread across villages and other towns. An interesting feature is that the maximum incidence is in the age group 21-25 in May, in the 6-10 group in June and in 0-5 group in July. During every pandemic, unusual signs and symptoms as those of jaundice, encephalitis, psychosis, haemorrhagic states and gastro-intestinal disturbances have been reported in case of clinical influenza. While it has not been possible to rule out completely the chances of simultaneous infections with other aetiological virus agents in the cases presenting unusual clinical features, the results are satisfactory in having established the diagnosis of influenza in these cases on the basis of laboratory evidence.

Another unusual characteristic of some of the Asian strains is the effect of ether in inactivating the influenza virus. Ether is able to break down the virus into constituent parts like RNA, body protein and lipoid coat.

Preliminary studies on mutation and recombination of Indian strains of influenza virus have revealed certain intrinsic difficulties in drawing conclusions from the experimental results. It has been found that when PR8 and LEE viruses are inoculated together in the same eggs, the resulting harvest shows that much of the material reacts with both A and B antisera. This may probably be due to the ability of the virus genetic core to accept overlays or coats of specific virus material from distantly related agents like NDV.

Testing procedures — The following laboratory procedures have been standardized: (1) metabolic inhibition test for the assessment of polio antibody in sera; (2) plaque formation of polio viruses in monolayer monkey kidney cell cultures; and (3) micro method for viral complement fixation tests using antigens prepared from infected tissue culture fluids.

A new method for the preparation of standard treponemal agglutinating antigens has been evolved. The method is quicker and gives clearer suspension, without the heavy loss in treponemes. The process makes use of a magnetic stirrer for periods varying from 1 to 3 hr to distribute the treponemes uniformly in the supernatant.

INDIAN JUTE MILLS ASSOCIATION RESEARCH INSTITUTE

THE ANNUAL REPORT OF THE INDIAN JUTE MILLS Association Research Institute, Calcutta, for the year ended 31 March 1958, reveals that the Institute concentrated its efforts towards effecting improvements in jute products. Much useful preparatory work

has been carried out on the development of methods and instruments designed to assist quality control and production studies in mills. The Institute carried out a number of mill surveys on specific projects such as batching emulsions, oiling of jute, preparation of sizes and their application, mill water supplies, dyeing of jute yarns and bacterial culture softening for jute roots. These surveys have provided much valuable data of practical importance.

A number of instruments have been designed and constructed by the Physics and Physical Chemistry Section of the Institute. A sensitive photoelectric hairiness tester developed enables the detection and measurement of very small changes in yarn diameters due to hairs and slubs. The constant tension continuous tester fabricated earlier has been calibrated for sacking warp yarn. With the calibrated instrument it is now possible to test the frequency of occurrence of weak spots in hessian warp, hessian weft and sacking warp. The design and construction of two new instruments for rapid computation of the number of slubs, one based on an electronic principle and the other on an electromechanical principle, are being undertaken.

In the Section of Chemistry and Chemical Processing, the investigations under way are directed towards developing chemical treatments which will improve the appearance or modify the properties of jute fibre. Vapour phase acetylation of jute has indicated that it is possible to acetylate jute to any desired degree by the use of theoretical amounts of the acetylating reagent. Studies on the composition of α-cellulose obtained by acid hydrolysis of jute hemicellulose have indicated that a part of acetyl groups exists in combination with the α-cellulose fraction; the isolation of hemicellulose by extraction with water confirms this finding and also indicates that a major portion of the acetyl group occurs in association with hemicellulose. Chromatographic analysis of α-cellulose has confirmed the observation that though α-cellulose is associated with a number of sugar residues, only xylose and mannose occur in intimate combination with it. A similar study of α-cellulose obtained from fibre at different growth stages of the jute plant has shown that xylose and mannose form integral parts of cellulose from the earliest stage of growth of the plant. This study has also revealed that both the length and diameter of the fibre cell increase progressively as the growth of the plant proceeds, while the specific viscosity of the lignin isolated remains constant throughout the life of the plant.

Elucidation of the mechanism of deterioration of jute by fungi has been the main subject of investigation in the Microbiology and Biochemistry Section. An interesting observation made during studies on the initiation and progress of fungal growth on jute fibre under varying conditions of attack is that, quite early during the attack, the lumen of the fibre is invaded by the fungal hyphae. Fungi which normally failed to grow on pure cellulose, have been found to grow vigorously and give high yields of cellulolytic enzymes when simple sugars constituting jute hemicellulose are supplemented.

Studies on the application of dyestuffs to jute have made possible the selection of suitable dyestuffs for dyeing speciality goods such as furnishing fabrics and carpets; preliminary results have indicated that Procion dyestuffs, though expensive, give brighter and faster shades. Other investigations in progress are, finding new end uses for jute and the application of resins for modifying or improving the properties of jute yarn and fabric, and establishment of optimum conditions for impregnating resin into jute fabric and production of laminates.

SOUTH AFRICAN COUNCIL FOR SCIENTIFIC & INDUSTRIAL RESEARCH

THE REPORT OF THE COUNCIL FOR THE YEAR 1957-58 records acute shortage of trained personnel required by the laboratories under it and particularly of gifted young scientists to replace the trained research workers drawn away from the Council's laboratories by industry and universities.

The successful running of the plant, designed by the Council, for desalting brackish water, and with a capacity of two and a half million gallons per day, has shown the feasibility of water demineralization by electrodialysis on a large scale. Considerable chemical, biological and bacteriological data on the water resources of the country have been collected which will enable the best future use to be made of the country's scarce water resources and to keep a check on their pollution as industrialization progresses.

Experimental studies on the relationship between malnutrition and mental development of young children have indicated that severe protein deficiency in early childhood can have damaging effects on the development of the central nervous system.

The results of some of the important investigations carried out in the various laboratories of the Council are described below.

Chemical research — Sapogenins isolated from the saponins of the poisonous plant *Tribulus terrestris* have been identified and characterized; information on the poisonous nature of the plant has been obtained from a study of the chemical pathology of the disease in sheep. The polysaccharide isolated from the seaweed *Hypnea specifera* has many features in common with the polysaccharide carrageenin from *Chondrus crispus*. This polysaccharide has many applications in the pharmaceutical and confectionary industries. The structure of xylan in wattle wood has been elucidated.

Studies on the effect of heavy metal ions, e.g. barium, and iron, on the electrochemical properties of permselective membranes, used for electrolytic demineralization of brackish water, have indicated that negative phenosulphonate membranes show a great selective affinity for barium ion in the presence of sodium. Self-diffusion studies with radioactive labelling in the case of two binary systems, one giving nearly ideal mixtures and the other definitely non-ideal mixtures, have been completed.

Medicinal, biochemical and nutritional research — The technique of isolation of amoebae from liver abscesses has proved very successful and has provided a source of uncontaminated amoebae for research work. An important discovery made during the year is that there are at least two amoebae having the identical morphology of *Entamoeba histolytica*. One

of these, which has been named *Entamoeba hartmanni*, is non-pathogenic and must have been, in the past, responsible for a considerable amount of misdiagnosis. This observation means a new orientation in the approach to the disease and may in part explain why such a large proportion of people who are apparently carrying *E. histolytica* show no symptoms at all.

Investigations have been started on the chemical mechanism of cancer development in the livers of rats fed with azo dyes. A theory has been put forward that the binding of azo dyes to proteins may affect the relative stability of their *cis-trans* isomers and that this in turn may influence their carcinogenicity. The stability of the *cis* form of various dyes is being determined, in the presence and absence of protein, by measuring the phototropic effect to discover whether this can be related to the carcinogenicity of the dye. Investigations on experimental cancer show that thyroxin greatly accelerates the development of experimentally induced cancer of the liver in animals fed a maize diet. A quick and sensitive colorimetric method of assay of elaterase, an enzyme of the Cucurbitaceae, based on the hydrolysis of *o*-nitrophenyl-β-D-glucoside has been developed.

Physics — Recent investigations of the nuclear many-body problem have shown that the interaction of a nucleon with its neighbours in a nucleus is velocity dependent or non-local in both momentum and co-ordinate space. Using the harmonic oscillator potential for the nuclear potential, calculations in the 'effective mass' approximation lead to single particle energy level schemes, involving a re-ordering of these energy levels in the region of high angular momentum states as a result of non-local interaction. The calculated values of the binding energies of the last odd nucleon on this simple nuclear model are in striking agreement with the experimental values.

An instrument has been developed for irradiating groundnut seed with gamma radiation from a one-curie cobalt-60 source in order to increase the number of mutations available for breeding purposes.

A simplified theory of focussing of charged particles has been developed applying the principles of geometrical optics to the magnetic quadrupole lenses. The simple method allows the handling of quite complicated lens systems and will find applications specially in connection with the focussing of the extracted cyclotron beam.

A mathematical method has been developed to compare spectrochemical results, by calculating and comparing the areas of the contour ellipses which surround the points of scatter diagrams. A chemical trace element enrichment method using dithiozone, oxine and cupferron has been developed. The scheme allows for the division of the trace elements into two or more groups. A new project representing a fundamental approach to the problem of dynamic weather forecasting, using theories of dynamics of the atmosphere and aiming at important practical applications, has been initiated in collaboration with the South African Weather Bureau.

Engineering — Information concerning the type, nature and distribution of deformation in cold-worked alpha- and beta-brass has been obtained by the use of etch figure technique, as a result of the development of a new etching reagent. It has been found that deformation in the two forms of brass occurs by the successive formation of slip lines and deformation bonds.

Studies have been undertaken on the design of a calorimeter shell and supporting structure for the measurement of the storage of heat in the human body when exposed to severe environmental conditions and engaged on strenuous tasks. For such investigations, a new type of gradient layer heat-meter has been developed. For the measurement of skin temperature under high humidity conditions a radiometer, in which the measuring elements are kept at a temperature well above the dew point of the surrounding air, has been constructed. Its temperature is controllable to any desired value. Two anemometers have been developed for special measurements in aerodynamic and ventilation studies. One of these is a hot-wire anemometer in which the velocity sensing element is designed to be insensitive to flow direction over a wide range of angles.

Building and road research — A new pneumatically operated consolidometer for measuring time, strain and load ratio of soils has been constructed. The apparatus is capable of applying much larger pressures to soil than can be done with the existing apparatus, and the application of load is much uniform than has been possible before. A detailed study has been undertaken on the decomposition of series of dolerite dykes of different ages which will provide comprehensive information on the possible rapid weathering of road materials when subjected to widely varying temperatures, pressure and moisture conditions under a road surface. Fundamental work on the chemistry of lime has led to the finding that certain impurities in lime lead to a marked reduction of the rate of slaking which can be a problem in the production of sound building limes. Studies on the unsoundness of lime show that the addition of granular materials and their nature and grading play an important part in reducing expansion.

Studies on dimensional change behaviour of cement products show that changes in the relative humidity of the ambient air cause dimensional changes as large as those resulting from wetting and drying, though slower, and that the effect of humidity changes is disproportionately large at very high and low humidities.

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