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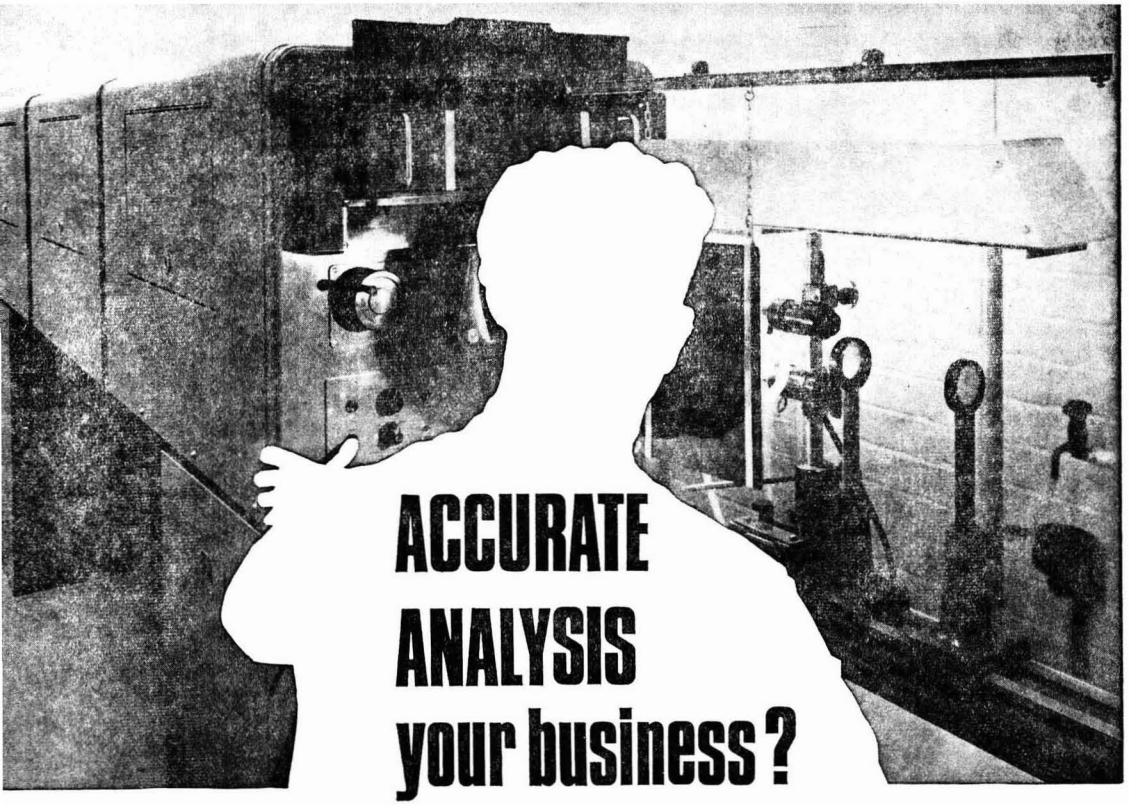

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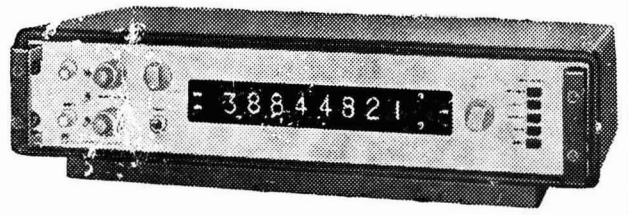

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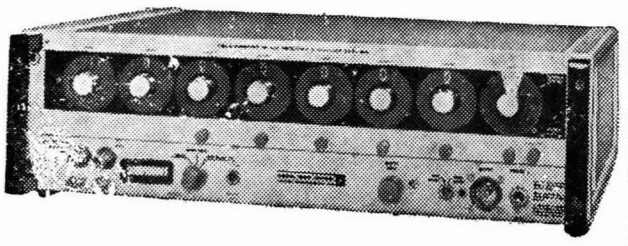

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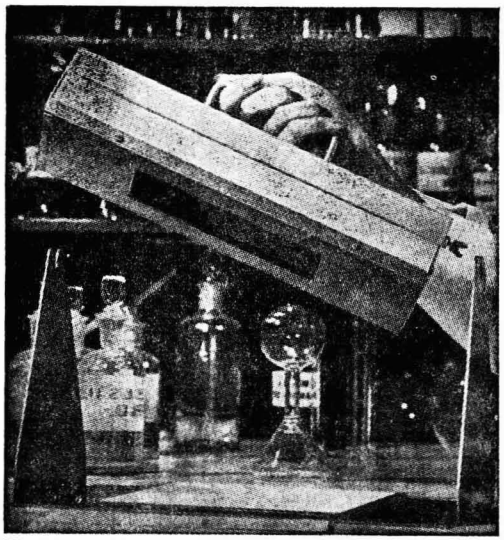

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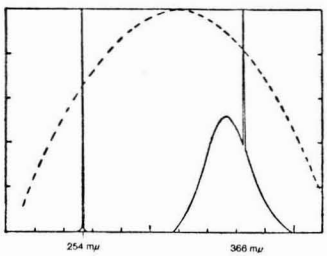

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Current Topics

Get-together on Weights & Balances

CONSIDERABLE stress has been laid in recent years on the need for greater rapport between research and industry to achieve self-reliance in industry. A useful step was taken by the Council of Scientific & Industrial Research (CSIR), by the organization of the first get-together, at the national level, of scientists and representatives of industry during December 1965 [*This Journal*, **25** (1966), 139-40]. Thereafter, several CSIR laboratories have organized a number of such conferences for different industrial sectors, such as electronics, thermometry, leather, etc. By bringing together persons with common interests and objectives, these conferences have been purposeful and have led to the forging of close links between research institutes and the users of their research output. An important feature of the deliberations of these conferences has been the stress on practical problems and their solution.

The National Physical Laboratory, New Delhi, was the venue of a get-together on weights and balances organized by its Weights and Measures Division on 19 and 20 December 1968. The main objective in holding the get-together was to create an awareness in the manufacturers of weights and balances of the importance of accuracy and precision in weights, measures and related instrumentation. Since the large-scale manufacturers of weights and balances have already established close contacts with the Division of Weights and Measures, the programme of the get-together was oriented to the specific interests of the small- and medium-scale manufacturers. Delegates from about 100 industrial units participated in the deliberations.

Some 70 and odd items put up for discussion by representatives of industry were mostly concerned with the enforcement laws or the verification procedures adopted in various states. Discussions centred round the question of keeping some items of manufacture such as equipment used in laboratories and factories for non-trade purposes, and for household purposes beyond the purview of the weights and measures laws. A plea was made by the manufacturers for the establishment of units of the Division of Weights and Measures of NPL with facilities for testing precision balances and weights in different parts of the country.

The record of achievements of the Division of Weights and Measures is an impressive one, particularly its contributions towards creating an awareness among the manufacturers of accuracy and precision in the manufacture of weights and measures. The get-together provided an opportunity to the representatives of industry to know, first hand, what the Division can offer to industry in terms of expertise, guidance, and training and testing facilities.

The basic function of the Division has been to maintain national standards of length and mass and other related derived standards and to supply authenticated copies of different grades of these standards in various denominations. The Division has also given priority to the needs of industry, in particular to developmental testing, in the formulation and implementation of its programmes of work. The development work conducted at the Division has been a major factor contributing to the growth and development of the indigenous balance industry, and has helped the industry in undertaking the production of high accuracy balances needed by the Enforcement Departments for the periodical verification of their working standard weights.

Currently, the Division's programme of work is aimed at helping the industry to attain the requisite degree of precision in the balances for their use in the verification of secondary standards against the reference standards. Work has also been undertaken on the production of accurate surfaces, gauges and balance knife-edges.

The Division has been concerned with the implementation of the metric system in the country right from the drafting stage of the Weights and Measures Act of 1956 and has played a major role in its successful implementation. The Division has made significant contributions in the formulation of standards through active participation in the committees, sub-committees and panels of ISI connected with engineering metrology, machine tools, ball bearings, screw threads, optical and mathematical instruments, commercial weights and measures, test sieves, water meters, graduated laboratory glassware, dairy laboratory apparatus, meteorological instruments, etc. This collaboration covers over 500 national standards.

Conferences of this type besides bringing about the much desired liaison between research and industry serve to pinpoint the needs of the industry. In fact, an earlier get-together on thermometry held at NPL was directly responsible for the formation of a permanent association of thermometer manufacturers. It is to be hoped that the contacts created by the present get-together would be mutually beneficial to both the weights and balances industry and the research workers in the Weights and Measures Division.

As mentioned earlier, the get-together provided an opportunity for the representatives of the weights and balances industry to get to know what facilities and assistance the National Physical Laboratory

can provide the industry. The deliberations would, however, have been more fruitful if the representatives of the industry had, instead of concerning themselves largely with the lacunae in the enforcement laws and related matters, put forward more concrete suggestions as to how the industry could better utilize the services and facilities available at NPL and what additional facilities they would require. It is hoped that the weights and balances industry would help itself by utilizing to the maximum extent the services and facilities NPL and other national laboratories can offer.

Third International Symposium on Equatorial Aeronomy

RECOGNIZING the increasing activity of Indian scientists in the study of the earth's atmosphere and its environs, a number of scientists active in the fields of geomagnetism and aeronomy proposed that the third symposium on equatorial aeronomy be held in India. The first symposium on equatorial aeronomy was held in Peru in 1962, and the second at Sao Paulo in Brazil in 1965.

The Department of Atomic Energy provided a substantial financial support to the Physical Research Laboratory (PRL), Ahmedabad, for conducting the symposium. Financial support for the travel of some of the foreign participants was received from the funds of the United States AID Program, the Air Force Cambridge Research Laboratories, and the Voice of America. Besides, the International Scientific Radio Union (URSI), the International Association of Geomagnetism & Aeronomy (IAGA) and the Inter-Union Commission of Solar Terrestrial Physics (ICUSTP) also sponsored the symposium.

The symposium was held at Ahmedabad during 3-8 February 1969. Nearly 70 foreign scientists, belonging to nineteen different nations, and 100 Indian scientists participated in the symposium. Prof Sydney Chapman, the doyen of aeronomy and geomagnetism, inaugurated the symposium.

In his opening remarks, Dr Vikram A. Sarabhai stated: "Aeronomy covers many areas of great interest to the pure scientists... It is of particular significance to the economies of the countries which depend largely on agriculture... The equatorial belt, like the polar regions, is of particular interest to aeronomy and our scientific endeavour in diverse disciplines, if focused in understanding the problems of equatorial aeronomy, would not only be rewarding to the individuals concerned but also be of great practical benefit to the nation."

The symposium discussed the following topics: The D-region at low latitudes; Ionospheric absorption; Irregularities in the equatorial electro-jet; Dynamo currents and electric fields; The neutral atmosphere at low latitudes; Ionospheric drifts at low latitudes; Ionospheric irregularities; Equatorial F-region; Total electron content; Air glow; Neutral particles and ion-chemistry; Dynamics of F-region; Ionospheric and geomagnetic tides; Magnetic and ionospheric storm-phenomena in the equatorial region; Exospheric whistlers; Micropulsations; Magnetosphere and solar-terrestrial relationships. Besides the formal sessions, there were many 'group discussions' as well as informal discussions. A few of the participants stayed at Ahmedabad for a few days after the symposium, gave lectures and held discussions. A few of them also visited Indian centres of active work in aeronomy.

The main purpose of the meeting was to stimulate scientists by exchange of ideas and results and to take a forward look at possible future investigations.

The symposium enabled the participants to appreciate at first hand the effective contribution which scientists of different countries were making to the understanding of the properties and behaviour of the earth's upper atmosphere and its environment. Personal contact and discussion with top-ranking scientists and technologists also served to stimulate and inspire young Indian workers.

An 'Illustrated Abstracts' will be published to bring together the main ideas and results exchanged during the course of the symposium.

Operational Research in Social Sciences*

A. GHOSAL†
Department of Mathematics, Monash University, Clayton, Victoria, Australia

OPERATIONAL Research was born in the Second World War out of the efforts of a team of scientists helping the military authorities in devising best strategies for fighting the enemy. After the end of hostilities, the operational research (OR) approach was increasingly tried in tackling the problems of industry and other fields of economy which all need strategies for getting the best result with limited resources. The post-war history of the development of OR was, therefore, one of developing tools for getting solutions to the optimization problems met with in management; and many of these tools have been mathematical (eg programming methods, techniques for dealing with problems in inventory management, congestion problems, replacement problems, etc). A phenomenal development in computation science helped in the expeditious performance of numerical work involved in all types of OR work. Most of the problems in OR have so far been approached as mechanical problems and solutions have been derived mostly by applying some of the new techniques developed on the information collected by a team of scientists. A tremendous benefit accrued to industry, especially in USA and UK, by applying OR methods, but during the last decennium it has been increasingly felt that no live problem in management can really be treated as a mechanical problem completely devoid of the human factors. To take stock of how best OR can be used in unison with human and other social factors in real life problems, an international conference on Operational Research and Social Sciences was held in Cambridge in 1964 under the auspices of the British Operational Research Society. This conference was remarkable from the point that it pinpointed the necessity of considering social factors on the part of OR scientists and also that of developing an OR approach on the part of the social scientists. Any OR practitioner knows that for implementing his solution on his client (an individual or organization) he must be able to motivate him for the minimal changes involved on implementation; if he fails to do so, he fails in his job too.

In an interesting paper Ratoosh[1] described an experiment in which a team was given a problem, and a member of the team was given the task of persuading the management to adopt the correct solution obtained by the team. The resistance to the new solution by the management was investigated and the manner in which the solution should be presented to the client, so that the likelihood of acceptance was high, was investigated. An interesting finding of his experiment was the recognition that something as complicated and uncontrollable as human psychology was lacking in many OR workers who were obsessed with their techniques. It is appropriate for OR analysts to take full cognizance of the human problems in implementing a solution; often a change involves a redistribution of power and consequent resistance among the people concerned (*see* also Lewis[2]).

Thus we find that for implementing any solution on any individual, organization or government, a sociological make-up is necessary; without it a brilliant work leading to the solution remains one of academic interest only. While studying the national plans for many developing countries we may not find any flaw in the framing of the plan *vis-à-vis* assumptions involved, but we may notice serious difficulty in implementation because of the passive resistance of the society on whom the plan is to be imposed. It is, therefore, of interest to measure the sociological factors involved with a view to assessing the likelihood of changes being accepted by the society. This explains the necessity of studying OR on problems in social sciences. This paper is confined to a discussion of the application of OR approach in some problems in social sciences. No attempt is made to discuss the interactions of social sciences on OR or vice versa, though a knowledge of such applications helps OR workers when they face a problem in social sciences. The first step in applying OR in social sciences is to find (or try to find) appropriate measures of intangible factors there. Kelvin said that no knowledge was perfect if we could not measure it. Though he meant this for physical sciences, perhaps the same applies to social sciences also.

Conflict Resolution

We start our applications with some problems in behavioural sciences, mainly in the direction of conflict resolution. The unfortunate reality in the present-day world is that there is always some conflict or the other, be it between countries, between different political forces in the same country, between two groups in an organization, or between members of the same family. The OR approach in understanding such conflicts will be to develop models which enable us to quantify the intensity of one's love or hatred for the other through statistical measures and then develop some inference. Interesting work in this direction has been done recently in USA by Ackoff[3] and his colleagues, Rapoport[4] and a few others. Rapoport's work on the application of the Theory of Games in a problem of conflict is described below.

The two-person zero sum game described below is called Prisoner's Dilemma, in that both the players (A and B say) will profit reasonably if they cooperate, lose if they work under the assumption

*Paper presented at the Australian Unesco Seminar on Mathematics in the Social Sciences, held at the University of Sydney, 20-24 May 1968.

†On leave from the Research Survey and Planning Division, Council of Scientific & Industrial Research, New Delhi.

TABLE 1 — PAY-OFF OF A AND B

	Coop (C)	Non-coop (N)
Coop (C)	3, 3	−5, 5
Non-coop (N)	5, −5	−3, −3

that they will go against each other. There is, therefore, reward for cooperation, penalty for non-cooperation.

Table 1 gives the pay-off for players A and B in the form of a matrix. If both cooperate with each other (state CC), each will get a positive amount of \$ 3 each; if both non-cooperate with each other (ie we have state NN), each loses \$ 3; if A wants to cooperate, but B defects, A loses \$ 5 and B gains \$ 5; similarly for state NC, A gains \$ 5 only at the cost of B. The genesis of this game is that if A and B distrust each other, each will estimate his minimum loss in the event of the other player's taking a decision of his maximum advantage only; thus in this situation we may have the state NN, because if A had wished to cooperate, perhaps B would defect with the hope of getting the maximum return \$ 5.

Rapoport conducted a series of experiments on students at the University of Michigan, asking his subjects to play different symmetrical non-zero sum games (like Table 1) with different pay-offs — two persons playing the same game 300 times in succession. He found, from the frequency distributions, that the probability of cooperative responses (ie of state CC) depended on the amounts of rewards and penalties *vis-à-vis* the gain out of temptation to defect (ie from state CN to B and from state NC to A). It is interesting to find from Rapoport's experiments that if T is the temptation from defecting (ie if A cooperates, B would gain T by defecting, and vice versa) and R the reward of cooperation (in his experiments $R_1 = R_2$, $R_1 = T_2$, etc) then greater the value of T/R, the lesser the probability of the state CC occurring (this inference is due to the present author).

It may be remarked, however, that experiments on human beings do not show the random character as those on machines, because the results of future action of human subjects depend on those of the previous experiments. Once the value of cooperation is quantified, even though crudely, the probability of both players cooperating with each other increases. It is, therefore, natural to apply a Markovian model on such a process through which we obtain the probabilities of states CC, CN, etc, given the transition probabilities of passing from one state to the other and the states obtaining in the immediate past. Rapoport, however, found Markovian model to be untenable. There is, however, scope of generalizing the Prisoner's Dilemma problem in which R varies for A and B, and so do other pay-off figures — in most practical situations we find such a situation. Some designed statistical experiments may lead to valuable conclusions.

The present author made a few studies of internal conflicts within organizations between two groups, eg administrative and technical, between two individuals in a group whose interests were

TABLE 2 — GENERALIZED PRISONER'S DILEMMA

State	Pay-off of A and B	
	C	N
C	R_1, R_2	S_1, T_2
N	T_1, S_2	P_1, P_2

clashing, etc. It was not possible to express pay-off of the conflicting members in monetary terms (though in a few cases it could be possible to do so), but some scores could be formulated for the pay-off of intangible elements like prestige, power, etc. The case studies from real life revealed in almost all the cases that the two conflicting parties were subconsciously aiming at the pay-off T (a measure of temptation — T_1 or T_2) on the presumption that the opposite party would cooperate, but the party in question would defect, ie player A assumed the state NC, and B assumed the state CN; in some cases the pay-off T could be earned, though in most cases the state NN obtained with consequent penalty to both. The penalty (P_1, P_2) in the cell NN (Table 2) was estimated roughly by the organizational loss in terms of man-hours, inability to expand work, etc. High probabilities for states C_1N_2, C_2N_1 and N_1N_2 show ineffective organizational management. A mature organization would tend to a state C_1C_2 among its two major conflicting forces after a spell of time.

Rapoport also studied the duration of conflict. From the case studies done by the present author it appeared in some cases that with the duration of conflict exceeding a limit, the chance of a conciliation fell down; in the terminology of random walk, an absorbing barrier was reached. It appears to the author that if it is possible to estimate the present value of loss due to conflict among two or more forces in an organization in rough monetary terms over a horizon of time (may be, in other terms as well) it may be possible for psychologists to utilize such figures in hastening a conciliation. The present value of loss or loss function would be of the type (calculated retrospectively for past T years or months)

$$L_r(T) = \sum_{t=1}^{T} (1+i)^t l_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots (1)$$

where l_t is the loss in period t; i, the rate of return of money or value of social return. Similarly, a loss function for the future period (O, S) could also be calculated as

$$L_f(S) = \sum_{t=1}^{S} v^t l_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (2)$$

where $v = 1/(1+i)$, so that total loss over the past and the future ($-T$, S) is

$$L(S+T) = L_r(T) + L_f(S) \quad \ldots \quad \ldots \quad \ldots \quad \ldots (3)$$

Another area which requires investigation is in the duration of conflicts, ie runs of NN state or conversely those of CC state. If we define $F(t)$ as the chance that a conflict (eg strike, organizational, etc) survives up to time t and $f(t)$, the corresponding density function, we can obtain the forms of $F(t)$ for different types of conflicts from

careful statistical analysis. Some authors have approximated $F(t)$ as an exponential distribution

$$F(t) = e^{-at} \quad (0 \leqslant t \leqslant \infty) \quad \ldots \quad \ldots \quad \ldots \quad \ldots(4)$$

But here the basic assumption is that the conflict will end at any time t with equal probability — this may not hold good in many situations. There is scope for developing a stochastic model for duration, something analogous to the duration of busy periods in queueing theory.

Ackoff[3] made interesting and useful studies on structural conflicts. Sometimes two groups within an organization have objects such that to the extent one is attained the other is not. As an example, he refers to the structural conflict between the sales and purchase departments of an industrial establishment; the sales department may fix the price of the products (p) of the company with a view to maximizing the gross profit; similarly, the purchase department may set up the quantity of raw materials (q) to be purchased for minimizing the total cost irrespective of the price decision by the sales department. Such structural conflict is stabilized due to defective way of defining the performance of each department. The feedback effects of q on p and of p on q are completely ignored. Thus, the objective of the sales department is to maximize gross profit (G) given by

$$G = \phi(p, q) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots(5)$$

that of the purchase department to minimize cost (L) given by

$$L = \psi(p, q) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots(6)$$

and that of the organization as a whole to maximize net profit (P) given by

$$P = G - L \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots(7)$$

(p, q may be vectors also).

In general, we get

$$\max_{p,q} [\phi(p, q) - \psi(p, q)] - [\max_{p} \phi(p, q) - \min_{q} \psi(p, q)] = K > 0 \quad \ldots(8)$$

where K is a measure of the inefficiency of the organization. Seldom we get $K = 0$. In other words, if the objective sub-functions, $\max_{p} \phi(p, q)$ and $\min_{q} \psi(p, q)$ of the sales and purchase departments respectively will fail to meet the overall organizational objective by K. The primary organizational defect lies in the fact that the overall objective, viz $\max_{p,q} [\phi(p, q) - \psi(p, q)]$, is seldom defined; on the other hand, only the objective sub-functions $\max_{p} \phi$ and $\min_{q} \psi$ are defined. The OR approach would be to define the overall objective $\max[\phi - \psi]$, and then to simulate with a family of sub-objective functions $\max \phi_1(p, q)$ and $\min \psi_2(p, q)$, such that K is minimum or as near to zero as possible. We can visualize this as an adaptive process in cybernetics. Ackoff aptly comments: "The behavioural sciences can contribute significantly to the reduction of inefficiency due to communication but, at present, they can make little contribution to the reduction of structural and decision-making inefficiency. The converse is true for operational research. Here, then is an important basis for cooperation between the two disciplines."[3]

Social Cybernetics

Any organization complex is composed of various elements, none of which are independent of each other, and each exerts a feedback effect on others and through others on itself. Any realistic study of social organization should take this aspect into consideration. An example of such a state of affairs is given by Eq (8) in Ackoff's work. To have a generalized model, consider a complex with n individuals whose performance is indicated by control variables $x_1, x_2, \ldots, x_n$ with objective functions $\phi_1(x_1), \phi_2(x_2), \ldots, \phi_n(x_n)$. As has been stated in Ackoff's example, $x_1, \ldots, x_n$ may be conflicting among themselves, so it is more appropriate to take the objective function of the ith individual as

$$\max_{x_i} \phi_i(x_1, \ldots, x_i, \ldots, x_n) \quad (i = 1, \ldots, n) \quad \ldots(9)$$

In certain cases we may replace 'max' by 'min'. The overall objective function of the complex would be

$$\max_{x_1, \ldots, x_n} \left\{ \sum_{i=1}^{n} \phi_i(x_1, \ldots, x_i, \ldots, x_n) \right\} \quad \ldots \quad \ldots(10)$$

Very seldom (or perhaps in no case) we get

$$\max_{x_1, \ldots, x_n} \sum_{i=1}^{n} \phi_i(x_1, \ldots, x_n) = \sum_{i=1}^{n} \max_{x_i} \phi_i \quad \ldots(11)$$

Generally we find

$$\max_{x_1, \ldots, x_n} \left\{ \sum_{i=1}^{n} \phi_i \right\} > \sum_{i=1}^{n} \max_{x_i} \phi_i \quad \ldots \quad \ldots \quad \ldots(12)$$

suggesting that if the organization had framed an objective function (Eq 10) by taking into consideration the interdependence of various elements (x_i), the pay-off would be greater than the sum of the performances of individuals working on their own. Here again the proper way of tackling the problem would be to formulate the decision-making function (Eq 10) and then simulate with a family of ϕ_i''s (where $\phi \neq \phi'$) such that the difference

$$\left[\max_{x_1, \ldots, x_n} \left\{ \sum_{i=1}^{n} \phi_i \right\} - \sum_{i=1}^{n} \max \phi_i \right]$$

is as small as possible. This concept has a wide applicability in a large number of problems, including an industrial production complex comprising various elements.

Behavioural scientists are making new inroads into the study of organizational structure, especially in the field of structural change. Here also OR can be of great help in studying the possible impacts of a structural change in the overall performance of the organization. There is another impelling reason why studies in organizational structure should be made: most OR problems are hinged on determining an optimal solution in a given organizational structure (eg with given types of personnel, given raw materials, given system of ordering, management procedures, etc). Sophisticated methods have been developed for studying the optimization problems (eg linear, nonlinear, dynamic programming), but sometimes, even practical OR work is too much obsessed with the application of these new techniques. It is very often found (as pointed out by Ackoff[5] and experienced by the present author in a number of practical

problems) that an optimal solution in a given structure is less satisfactory than a sub-optimal solution in a changed structure. In other words, if the organizational procedures are changed, it is possible to have a better pay-off than the optimal solution, in the old structure, obtained by a meticulous programming procedure. To cite a simple case, the industrial engineering department of a manufacturing organization worked out an optimal solution for the amounts of raw materials to be purchased from five different sources for achieving minimum cost, at the same time satisfying minimum quality standards (by applying linear programming), but while working on the problem completely ignored the fact that very good quality raw materials could be procured from two nearby sources. The five specific sources were considered because for three consecutive years in the past the management was purchasing only from them; a revised linear programming solution by taking in the two other sources gave a far improved result — even a sub-optimal solution, which was later on implemented by painfully persuading the management to consider new sources gave a significantly better pay-off than the previous optimal solution. Later on, the manager had remarked why such a simple solution had not been thought of earlier, because anyone with a little knowledge of regional geography should have suggested the change. It may be mentioned here that the management, in most cases, may not pay any heed to a suggestion for structural change if it comes from its own OR department, but there is more likelihood of acceptance of the suggestion if it comes from an outside consultant employed at a high fee; so the members of the internal OR department, particularly if they are young, feel hesitant to suggest any structural change, even if they realize the need for it.

Problems of social cybernetics can be visualized at national level, in which the whole society may be involved. For example, the capacity of a society to accept any change brought out by the technological advances is an important factor very often ignored, though it is a fact that technological advances and a communication system as we have in the present-day world induce the society to change. Similarly, while studying problems of economic planning for developing countries it is as much important to estimate the country's capacity to consume as it is to estimate its capacity to produce, and lastly it is also necessary to know how production affects capacity and vice versa.

The method of solving an optimization problem of n variables by breaking it up into a number of sub-problems and trying to solve each is called *Decomposition method* which has been applied in Eq (10) as suggested in the para following Eq (12). This method works well in many OR problems. A reverse problem also is encountered in many cases, viz that of combining a number of optimization problems into an overall problem; this the present author would choose to call *Integration method*. In a cybernetic approach we apply the integration method in a number of cases; further studies in this direction by the present author will be published subsequently.

A Network Planning Model

Now we discuss how cybernetic concepts could be extended to the area of economic planning. Leontief's method of input-output analysis enables us to estimate the production required of various sectors of economy from the knowledge of the amounts required from different sectors to produce a unit in the ith sector (say $i = 1, \ldots, k$). Thus, if an amount a_{ij} is required from the jth sector to produce a unit in the ith sector, c_j, the cost of a unit from the jth sector, the total investment to produce a unit in the ith sector is

$$I_i = \sum_{j=1}^{k} c_j a_{ij} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (13)$$

and the production requirement in the jth sector is

$$P_j = \sum_{i=1}^{k} a_{ij} P_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (14)$$

Eq (14) forms the basis for estimating the production target of various sectors and calculating the material balance of the entire economy. On the basis of this model, the economy is divided into k sectors and a square matrix $(k \times k)$ is drawn out showing inputs in the ith sector along the ith row and the corresponding outputs in the ith column.

The above method is useful in drawing up an approximate material balance for the entire economy; for better decision-making regarding the phasing of programmes, etc, we need more refined techniques. The Indian experience in planning over the last fifteen years brought home serious deviations from the actual performance from the planned targets, in spite of the fact that detailed material balances were worked out. This situation can be ascribed to the fact that interconnections between various elements in the economy, as would be expected in a cybernetic model, were not worked out. Besides, when we consider an economic complex as a cybernetic model, we have to consider various feedback effects. For example, it is fruitless to make a production planning for the ith sector for year $t+1$ without considering its production in year t, and production of other sectors in years t and $t+1$. If $P_i^{(t)}$ represents the production in the ith sector in year t, then we may have a model which is a mixture of a first-order Markov model and a regression model of the form

$$P_i^{(t+1)} = \rho P_i^{(t)} + \sum_{j \neq i} b_{ij} P_j^{(t)} \quad \ldots \quad \ldots \quad \ldots (15)$$

where b_{ij} are regression coefficients. The model (Eq 15) will have to be so constructed that provision is made for the stepwise continuity of the function $P_i^{(t)}$, which always has jumps at certain times arising out of the deterministic process involved in planning.

In the light of the above discussion we can conceive of a family of vector spaces $S(t)$, $t = 1, 2, \ldots$, comprising elements $\{P_1^{(t)}, \ldots, P_k^{(t)}\}$, such that $S(t)$ is parallel to the space $S(t+1)$, and each element in $S(t)$ is related to each element in $S(t+1)$; and again within each space $S(t)$, the elements have feedback relations with others. Eq (15) suggests one of the simplest models of such a process. The

concept of such a process was presented by the present author in a previous paper also[6]; there is scope for research along these lines. The practical purpose of this work is to understand the decision-making process which is intrinsic in the economy. The more we understand these control phenomena, the more realistic we construct our planning model. For example, while studying the coal industry in India, the present author[6] found the steel production (ingot steels) and production (consumption) of coking coal were governed by an approximate control process, from Eq (15), in the following form (suffix 1 stands for steel, and 2 for coal):

$$\left.\begin{array}{l}\text{(i) if } P_1^{(t)} > cP_2^{(t)}, \text{ increase } P_2^{(t+1)} \text{ over } P_2^{(t)} \\ \text{(ii) if } P_1^{(t)} \leqslant cP_2^{(t)}, \text{ do not increase } P_2^{(t+1)} \text{ over } P_2^{(t)}\end{array}\right\} \quad (16)$$

where c is a constant. It was interesting to find that the decision represented by Eq (16) was already exercised by the coal companies without being aware of the formal solution, in spite of the fact that such a decision was contrary to the production programme of the planning authorities. Such decisions are easy to explain physically also.

The author has been working on the network planning model explained above. The ultimate aim is to develop a computerized model on the basis of which we can take decisions in an industrial complex. To begin with, this model would be applied on a regional complex like the coal-steel belt of eastern India (on which the author made preliminary studies) so as to understand what should be the optimum phasing; if a programme is stalled what would be the impact on the overall complex, etc. The author may not be misunderstood that this model is an alternative to Leontief's input-output method — far from it; this model will enable us to take better decisions, if implemented at a national scale, after a proper material balance has been worked out.

Some Problems in Planning and Development

There are a number of problems in planning and development, especially in the developing countries, which require an OR approach for proper understanding and decision-making. A few problems are mentioned here, though a host of such problems are met with. It was thought proper to deal with the problems in planning, because the ultimate objective of any planning machinery is to bring about social benefits; in other words, any economic planning is a means towards social planning.

Optimal utilization for reservoir water — Most of the countries face the problem of utilization of water resources to combat the shortage of water brought about by increasing urbanization, natural calamities like droughts, etc. . For example, the recent droughts in India in 1967 and in Victoria last summer make us feel the necessity of making OR studies on this national problem. A new field in applied probability was opened up by Moran[7], who evolved a mathematical theory of dams; it now remains for engineers and OR scientists to exploit this theory to solve decision-making problems in water utilization. One such practical problem, for example, is to know, in the light of the expected inputs (rain) in the catchment area (by seasons or even by weeks), the optimal reservoir capacity in an area to meet the demands of irrigation, consumption in houses and industries and hydel power; or in the present system (with present reservoir capacities) what should be regarded as danger level. The optimal procedure of release and control in the present situation also requires quantitative studies from the knowledge of past data and all factors of nature including rate of evaporation through heat. It is difficult to tackle this problem analytically, but it is always possible to obtain valuable decisions through simulation studies which can be worked out on different alternate policies with a large number of factors on a digital computer. For example, we can cite a useful design problem worked out by Hufschmidt[8] on the optimal design of a multi-unit, multipurpose water-resource system. We apply discounted cash flow (DCF) method, which is known to actuaries for past two centuries, by calculating the present value of the net benefit ϕ_A emanating out of policy A in the next T years [$v = 1/(1+i)$, where i is the rate of interest]:

$$\phi_A = \sum_{t=1}^{T} v^t(f_t^{(1)}+[f_t^{(2)}+f_t^{(3)}-m_t]-C_A(A) \quad ...(17)$$

where $f_t^{(1)}$, $f_t^{(2)}$ and $f_t^{(3)}$ represent the expected benefits (in money, say) in year t, hence from irrigation, electricity and flood control respectively; m_t, the cost of maintenance in year t; and $C(A)$, the capital cost of the project on premise A. We work with the trial policies $A, B, \ldots$, and choose the one for which ϕ is maximum. A similar problem in inventory management was attempted by the author[9].

There are a few associated problems, for example, the problem of optimal utilization of irrigation water from a reservoir in the light of water requirement of different crops in irrigation belt. Suppose the water requirement for a crop c_i ($i = 1, 2, \ldots, N$) is r_i over a fortnight per acre, y_i, the yield per acre, then what should be the optimal distribution of crops in the region by considering a few constraints, eg the produce of c_1 should be greater than K_1, that of c_2 greater than K_2, etc. These problems can be approached by applying programming (linear or dynamic) methods.

Urban development and transport planning— Throughout the world, and especially in developing countries, there is a tendency of cities to be more overcrowded with the passage of time. With more housing and growth of new suburban areas, we have more traffic. The author found that in a city in a developing country the number of vehicles increased by geometric progression over the period 1950-65. With more traffic comes the problem: whether our roads are adequate to cope with the peak-hour traffic. To combat this problem, the metropolitan councils of a few big cities have been building wider roads by pulling down buildings. In studying problems like the optimal diversion of traffic to a new road, we can have a great insight into the problems through simulation studies. The problem of urban planning should be approached through cybernetics, because very frequently we find in new townships in developing countries lack of facilities like water, schooling for children, traffic,

etc, because the planners did not visualize that more housing would bring in its trail other associated problems.

Research and development — For any country, however small and undeveloped it may be, there is need for minimal indigenous scientific research — especially for optimal utilization of its natural resources. The decision, however, as to what research projects should be given priority over others is seldom done on a scientific basis. In very few developing countries, a scientific evaluation is made of the national needs; and very seldom the potential of the country (in men and materials) is scientifically evaluated. Very often it has been found that a high-sounding project which is worked in a developed country like USA, UK or USSR is attempted primarily to keep international prestige. A proper model-making is necessary both at the national level and at the level of smaller organizations (eg industries, farms, etc). A simple concept which needs a lot more development is for an organization to select a set A of projects on the basis of needs (properly defined and estimated), and again to select a set B of projects according to the availability of qualified personnel, equipment, etc, then the set P of the prior projects would be

$$P = A \cap B \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (18)$$

Similarly, if we select another set C of projects on the basis of their financial expectation (ie present worth discounted over next T years) we may have another set P_1 as

$$P_1 = B \cap C \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (19)$$

An interesting case study was made by Husaini[10].

It is very common for administrators and politicians to talk glibly about the money spent on R and D, the percentage of money spent on R and D to GNP, but these statistical figures as such do not make much sense. It is always necessary to study (through planned studies) how much effort (in men, money and materials) to put in a research organization to make it a viable unit. It is a pity that wastage of valuable resources is high in the developing countries; the developed countries have intrinsically better system to utilize them. The process of wastage is a chain process; if wastage is high in the current year, it is prone to be high next year, if the same organizational system continues.

Concluding Remarks

It is wellnigh impossible to do justice to all problems of the society where valuable insight can be obtained by applying quantitative methods like operation research. A few areas have been mentioned in the paper, but a host of problems are left out. The evaluation of social effects of policies, for example, requires detailed analysis; perhaps the existing method of discounted cash flow (DCF) needs more sophistication by considering the factor of uncertainty. For example, if we estimate that we shall be earning E_i in the ith year, then if v is the rate of discount, the present worth of earnings over next T years is given by

$$\sum_{i=1}^{T} v^i E_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (20)$$

Since we estimate E_i, it would be realistic to estimate the chance of earning E_i as p_i (A) if policy A is followed, when the present worth of earnings is given by

$$\sum_{i=1}^{T} v^i E_i p_i(A) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (21)$$

Similarly, if we evaluate costs, we can roughly say which policy would optimize our net benefits. Here again, caution should be exercised in using the term ' optimum ', which is always a function of structure.

Finally, we must remember that the implementation of any scientific solution depends upon the social set-up. It is not enough to suggest a solution which only considers machines and mathematics, leaving man behind. In simulation studies, we generally neglect what the attitude of the man behind the machine would be; for more realistic answers through simulation, it is always desirable to have a man-machine simulation (*see* Geisler[11]) in which the worker is given an indication as to how he should acclimatize to the changes suggested.

Summary

The paper discusses the application of operational research (OR) methods to some problems in social sciences. The interplay of social factors in effectively implementing OR solutions has been recognized only recently by OR practitioners. This fact is able to explain why some solutions are accepted in some situations (societies, countries, etc) while the same solutions cannot be applicable in other situations, in spite of the fact that the problems approached mechanically appear similar. For understanding the wider problem of the interplay of social factors, an OR approach to problems of social sciences is necessary. This paper mentions a few applications including some unsolved problems on which the author is working.

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Solar Batteries & Agroeconomy of Developing Nations

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READY availability of cheap electric power constitutes the key to the economic progress of a nation. Solar energy is the biggest single source of power and to date it has been used indirectly in the form of fossil fuels, wind and hydraulic power for large-scale generation of electricity. The overall efficiency of utilization in these types of energy conversion is indeed very small (less than 0·01%). In contrast to this, photo-sensitive devices like the solar cell can effect direct conversion of solar to electrical power with a theoretical efficiency of 20-25%. The possible large-scale adoption of power generation using solar cells can indeed bring a lasting solution of the problem of the earth's power requirement. For, it has been estimated that only 2·5% utilization, on the average, of the portion of solar radiation intercepted by the landed part of the earth's surface should provide sufficient power for a population of 3500 crores[1]. The proposition is an extremely attractive one for those regions where sunlight is abundant, but water supply scanty. However, till now the solar cell has been used largely in the field of space conquest and its potentiality as the generator of power for terrestrial application on a large scale has remained only a theoretical possibility. The present article is intended, firstly, to indicate the difficulties associated with the supply of power for minor and medium irrigation projects in India using the conventional methods and, secondly, to point out the advantages which might be gained through the development of practical solar batteries for this purpose. The difficulties which confront this development are enumerated and some results of recent investigations towards the solution of these difficulties are reviewed. The possible requirements — constructional and financial — for a substitute solar battery for a typical irrigation unit are given.

The impact of development of this type of power supply unit on the economy of developing nations is pointed out to emphasize the need for the adoption of a comprehensive programme of research in India in this field.

Existing Power Supply System and Minor Irrigation Projects

To appreciate the case for a solar battery for agricultural use it is necessary to first consider the broad features of the existing supply systems, with special reference to the requirements for small-scale irrigation units.

The existing system involves (i) generation at a central station at places with abundant water supply, and (ii) transmission of the power generated by means of high tension lines and substations. Generation is carried out utilizing storage hydel, thermal and nuclear processes. The estimated investment and cost of generation for these three types of generation are given in Table 1 (ref 2).

For transmission, usually 11 kV aluminium conductors with steel reinforcement lines of various sizes are used. The estimated costs for laying of lines in a state like West Bengal are given in Table 2 (Personal communication, West Bengal State Electricity Board).

The 0·03 size line with wooden posts offers the cheapest transmission link. But its life may be rather low, viz 6-7 years.

The investment required is thus seen to be high. This has naturally made the progress in electrification very slow. Only 10% of the villages could be electrified by the end of the Third Plan period. The total installed capacity at the same time was 10,170 MW, as against a requirement of 46,200 MW in 1981 for a sustained growth in national income at the modest 6% rate annually[2].

The number of pumps electrified at the end of the Third Plan was about 4·8 lakhs. The progress in irrigation, in general, covering about 7 million acres was, however, more apparent than real, as the existing practice in the country has been to " apply water thinly to extend the benefits of irrigation and afford protection against drought to as large an area as possible ". It is recognized that this does not serve the needs of intensive cultivation with high yield per acre. This requires an increase in density of pumps not only in regions in which underground water provides the only means of supply but also in those served till recently by surface water sources. Recalling that at least half of our available land, requiring irrigation facilities, remains yet to be served, one can foresee the use of several millions of pumping sets in any reasonable state of development of agriculture in the country.

The cost of electrification of a typical farming unit may be examined next. The current trend in irrigation of such a farm is the use of a deep tube-well requiring at least 15 kW supply. If, on the average, 2 miles of 11 kV lines have to be laid for each unit, then the minimum capital cost for

TABLE 1 — RELATIVE COST OF GENERATION OF POWER BY HYDEL STORAGE, THERMAL AND NUCLEAR PROCESSES

Method of generation	Plant factor %	Investment/ kW Rs	Cost of generation/ kW, paise
Hydel storage	60	1475	2·9
Thermal	60	1343	4·6
Nuclear	75	2222	4·7

TABLE 2 — RELATIVE COST OF LAYING TRANSMISSION LINES USING WOODEN AND IRON POSTS

Wooden posts		Iron posts	
Wire size ACSR	Cost/mile Rs	Wire size ACSR	Cost/mile Rs
0·03	11,700·00	0·05	20,800·00
0·05	14,000·00	0·075	24,800·00
0·075	18,000·00	0·1	29,500·00

generation, using thermal power, and transmission works out as follows:

Investment for 15 kW	Rs 20,000·00
Two miles of line using wooden post @ Rs 12,000·00 per mile	Rs 24,000·00
Cost of transformer with accessories	Rs 10,000·00
Total	Rs 54,000·00

This is, however, a modest estimate. Owing to the industry-oriented development during the initial stage of our planning many of the available transmission grids are now far away from regions in urgent need of electro-irrigation. For such inaccessible regions the length of the line required is often 10 miles or even more, making the cost prohibitive. In view, among other things, of this the use of shallow tube-wells, requiring less power, has been suggested by many. But such a proposition should be obviously unsuitable for dry regions of the country. Even for a state like West Bengal, short life of the well and the possible effects on surface conditions make a large-scale adoption of such pumps highly debatable. Alternatively, the full potentiality of the 11 kV line may be utilized by operating large pumps or a large collection of small pumps along with elaborate distribution canals. This, of course, is a large-scale irrigation problem, which is not within the scope of the present communication.

The maintenance cost with the present system of supply is also high because, among other things, of frequent pilferages. The high capital and maintenance expenses invariably increase the price of the power delivered. This is borne out by the fact that even though the cost of thermal generation is no more than 5·8 paise, it is heavy government subsidy alone that enables the farmer to get his required power at 12 paise per unit.

But even with all these, the reliability of the supply is poor. Prolonged and frequent failures, beyond the control of the consumer, heightened further through lack of speedy communication with the generating station, often leaves him helpless.

Solar Cells as Generators: Some Recent Advances

Solar cells convert solar energy directly into electricity. The efficiency predicted theoretically is about 25% with AlSb type material[3] with a band gap 1·49 eV. The most extensively studied cells — the Si cells — have 15% efficiency, which is much higher than that of any of the other conventional types of generators. Further, these are simple and compact devices with long life. Being free from the requirement of water for operation, these can serve as local generators with local control free from the vagaries of a central supply system with uncertain transmission link. The maintenance cost is ideally low and the cost of the power generated is determined largely by the interest on capital investment and depreciation. From the point of view of irrigation requirements these offer the unique advantage of giving a high yield at the right time, viz during the period of severe drought.

As against the above advantages the solar cells, at their present state of development, suffer from two serious drawbacks. Firstly, the use of electronic grade single crystals makes them rather costly devices, increasing the cost of capital investment. Secondly, solar energy received by the earth is itself subject to wide limits of short- and long-period fluctuations, making the maintenance of uniform output a baffling proposition. These drawbacks still make the solar cell a subject of intensive investigations. Cost is, of course, the problem that needs to be solved first. The work done up till now towards its solution is reviewed below.

The average value of the solar constant[4] being 0·1 W/cm² sec, a 10% efficiency requires a cell area of at least 100 cm² or about 50 standard sized commercial cells for an yield of 1 W. Attempts have been made in recent years to reduce this requirement through concentration of solar rays. Ralph[5] has reported an yield of 0·5 W/cm² with cells specially designed to withstand high intensities. An even more striking figure of 1·5 W/cm² has been reported by Beckman *et al*[6] using specially designed gridded cells and a closed loop water cooling system. It has been claimed that keeping the working temperature within 200°F, a 50 W unit with an area 36 cm² is practically feasible. Our own investigations show that a fivefold exposure without cooling does not produce any marked change in the performance of a cell (Deb, S. & Mukherjee, M. K., unpublished data). Theoretically, it is found that, at constant temperature, exposure to a radiant flux 10 W/cm² should not produce any marked deterioration in the collection efficiency[7]. The possibility of concentrated exposure has also been examined by other workers who pointed out, among other things, that the arrangement should also reduce radiation damage and prolong the life of the panel[8].

Cost has also been sought to be reduced through three interrelated approaches, viz the use of new materials, use of polycrystalline materials and development of large area thin film devices. The materials worth investigating include CdS, CdTe, GaAs, InP, GaP and AlSb. As large single crystals of most of these materials cannot be grown, the studies reported so far relate to cells using polycrystalline materials. A large area (27 cm²) single cell using Si sheet and yielding 3 W at 10% efficiency had been reported[9] in 1963. Vohl *et al*[10] reported a polycrystalline GaAs thin film cell constructed through vapour deposition on molybdenum and aluminium foils and claimed 4·6% efficiency for the device. Quite a number of papers on thin film solar cells were presented at the Sixth Photovoltaic Specialist Conference held at Florida[11-14] in 1967. Attention was drawn to the possible terrestrial applications of the photovoltaic type generators[15]. Shirland[16] has also reviewed the advances in the field. From the most recent review by Perkins it now appears that a thin film cell with 5% efficiency and an active area of 50 cm² has already become a reality[17]. Concentrated exposure and the use of polycrystalline material for cost reduction had been advocated earlier by Ralph and Berman[18]. The possible use of solar batteries for irrigation in southern Russia, where sunlight is available in plenty, has been discussed by Lidorenko[19].

A novel scheme, aimed at enhancement of efficiency, examined by Wolf[20] and Kagan and Lyubashevskaya[21], consists in using a multistage cell with graded band gap. For a two-stage cell an optimum relationship is shown to exist between the band gaps. A special configuration of such a device with band gaps 1·5 and 0·5 eV has been shown to be capable of working at 30% efficiency, which is about twice the value reported for commercial Si cells.

Mention might be made of the work aimed at the development of solar motors in Israel and Dakar[22] and of the suggested application of the integrating circuit process for the fabrication of high voltage solar cells[23].

It follows from the above that the problem of cost, though technologically formidable, is being tackled and a modest degree of success has already been achieved. With sustained and determined effort, a reasonable solution of the problem may be foreseen within a decade or so.

A Substitute Solar Battery for Irrigation

Keeping in view the progress outlined above, the details of a model solar battery which might replace the conventional power source for working a pump for irrigation purposes may be worked out thus. We visualize the situation in which a cell with 20% efficiency, capable of operating with a concentrated exposure 10 W/cm^2 (with or without an auxiliary water circulation system), each having an area 50 cm^2, has been developed. The situation is broadly one in which the results of researches by all the various agencies reported in the previous section have been coupled together in a single device produced on a commercial scale. To operate the deep tube-well described earlier, the power requirement should be 15 kW. Such a cell being capable, on the average, of producing 1 W/cm^2, each cell should deliver 50 W, putting the required number of cells at 300 covering an area 1·5 m^2. The concentrator system, under the assumed condition, must be able to collect light over an area 100 times as large, ie the working area of the battery must be at least 150 m^2, which, for a 10 acres farm, means about 0·3% of the available land. With drastic cost reduction it might be possible to use 100 times as many cells with normal exposure without the concentrator. Such a state of development is, however, expected only at a much later stage.

A 15 kW motor, working a 1000 ft deep tube-well, works at 9 hr/acre-ft of water and, in order to be able to irrigate effectively at least one-tenth of the farm, must be kept working for 9 hr a day. The battery and the concentrator system must be mounted on a light steerable frame. Further, certain amount of storage of generated electricity will be needed. Therefore, in order to make the solar battery competitive with the conventional method of supply, work must be directed towards achieving the following: (i) availability of 50 cm^2 cells mentioned above at the maximum rate of Rs 50 each; and (ii) development of a concentrator and delivery system costing around Rs 10,000.

Compared with the figure mentioned in the section "Existing Power Supply System and Minor Irrigation Projects", these would ensure 25% saving in the construction of a single supply unit. This, of course, does not take into account the high maintenance cost of the transmission link and the cost of the central generating station. When that is done the effective saving might come to at least 50%. For remote regions requiring 8-10 miles of transmission line, the reduction in cost should be even more striking.

Possible Impact of the Proposed Method of Power Generation

The benefit that the success of the proposed method of power generation should secure for the developing nations is almost unbounded. The cost of farm electrification would go down by about one-half. Vast uncultivable regions of semi-desert land, in particular, stand to gain most out of it. The method will bring to the farmer a supply system which he understands well and is able to maintain of his own. He will also not have to pay for electricity except by way of interest on capital and wear and tear. The public exchequer would also be freed from that invisible leak imposed on it by the supply of farm electricity at a subsidized rate. Once adopted on a large scale, the method would indeed bring about a significant advance in farming and solve, to a large extent, the food problem of developing nations throughout the world. Apart from these, the method will enable electronic technology to enter organically into the economy of nations.

The future electronic industry also stands to gain immensely through the success of the method. It will throw open a big market, capable of sustaining a huge industry, producing electronic devices and create a wide new avenue of employment.

Need for Indian Participation in the Development Programme

It needs to be emphasized that the development of a supply system using solar cells is essentially a problem of a country like India. Most of the well-developed countries are not blessed with abundant sunshine. Moreover, these countries already have elaborate distribution networks and for advancement in economy they need substitute central generators using new fuels and giving larger outputs at cheaper rates. Huge amounts of money are, therefore, being spent by these countries on nuclear power, MHD, EGD and thermionic method of generation. Studies on solar cells in these countries lean heavily towards the programme of space conquest, even though an under-current of thought towards terrestrial application is evidently there as exemplified by the developments mentioned earlier. It would, however, be unwise to wait patiently for others to convert that under-current into a tidal wave for our own benefit. We should ourselves take up the challenge and try to solve this. The problem is a gigantic one requiring intensive studies involving technological skill of the highest order. But considering the immense benefit that might accrue from a breakthrough, the challenge is worth accepting, particularly in view of the peculiar position of India in the committee of developing nations. Our irrigation and power budget in development plans runs into thousands of crores of rupees. We have also

been spending hundreds of crores of rupees for import of food for years. The required programme of research, if accepted and properly organized, would be only a fraction of that sum. Several centres in our country are already working on solar cells in a limited way. Dearth of personnel should not, therefore, be a serious handicap to the initiation of the proposed comprehensive programme of work.

Training and Research Programme

The manifold aspects of research required for a breakthrough in the field cannot be the job of a small team with limited resources. It involves basic research on materials science, applied research on materials technology, fabrication and testing of devices, design of battery and development of a delivery system. In addition to these, training facilities will have to be organized at the post-graduate level to feed the required manpower for research. The entire programme of research may be assigned to a single institute devoted mainly to the work. Alternatively, the work may be divided among the various institutes having experience in this and related problems under the formal control of a central coordinating body of experts working through a simple administrative machinery. The latter might be a more desirable course in view of the fact that it would promote mingling, and cross-fertilization and criticism of ideas which are always helpful to such work. The financial requirement is a matter of detailed calculation. But an expenditure of a few crores of rupees spread over 10 years should not be considered excessive for a vast and crucial project like this.

Concluding Remarks

Solar energy, harnessed through photovoltaic action, is seen to hold promise for an alternate power supply system for agricultural farms in large developing countries with abundant sunshine. Compared to the conventional system, this system is likely to be simpler, cheaper and much more reliable. The developments in recent years indicate that the existing technological handicaps of a solar cell may be overcome through sustained and carefully planned research work. It has to be realized that the problem of development of such a power supply system is essentially a problem of countries like India. The broad outline of the required programme of work, its possible method of execution and financial outlay have been indicated. However, these are only crude preliminaries. The precise details of these have to be worked out by a body of experts. For a speedy headway in this direction a right course would be to set up, under the auspices of an organization like the Planning Commission, a small study group, consisting of scientists and technologists to examine and to report on the various aspects of the proposed programme of work. The committee might also consider the advisability of seeking collaboration with other nations.

Summary

The difficulties associated with the problem of power supply for irrigation in a country like India using the conventional methods are discussed. It is pointed out that but for their present high cost and fluctuating output the solar cells are capable of providing an alternate system of supply free from these difficulties. The results of recent researches, aimed at reduction of cost, are reviewed briefly. The probable details of a solar battery, suitable for the replacement of the conventional supply system, for operation of a deep tube-well for irrigation, are given and the price level for this to be commercially feasible worked out. The far-reaching implications of a possible development of such a battery on the economy of a developing country like India are emphasized and the initiation of a comprehensive programme of work with this end in view advocated. The immediate formation of a body to advise on the required course of action is also suggested.

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Particle Size Measurement of Industrial Powders

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POWDERS, composed of particles of different sizes and shapes, play a significant role in many industries and in everyday life[1-3]. Gross properties of powders, such as cohesion, adhesion, etc, are more important than those of individual particles. These properties are functions of the distribution of particle size. A knowledge of particle size and particle size distribution is important in itself as also for understanding their relations to porosity, pore size, surface area, etc. The size range in particles is very large, usually from molecular dimensions to say about 1000 μ (1 mm). A glossary of the terms relating to powders is given by ISI[4]. At present there are more than eighty different methods available for the measurement of physical dimensions of particles of powders[5]. A complete review on the classifications of methods for the determination of particle size has been given by the Particle Size Analysis Subcommittee[6]. The various methods are based on different principles and as a consequence the results obtained by one method may not necessarily agree with those by another method. Most of the methods are limited in range.

Sampling and Other Factors for the Selection of Method

The sample, whose particle size analysis is to be done, should be a true representative of the total bulk of the original material[7]. Gross samples should be prepared taking many small samples and mixing them. Griffiths[8] described the importance of proper sampling in ceramic industry. He stated that if underground flint is used in the production, it could lead to an outbreak of crazing.

A review of the factors influencing the choice of a method for particle size analysis has been given by Scarlett[9]. Sometimes the choice of method is dictated by the characteristics of the materials and their particle size ranges. A compromise must be made between the simplicity of obtaining the size distribution and the accuracy required[7]. For instance, air elutriation method should be used only if the rate of settling of particles suspended in air is required.

Sieve Analysis

Sieving is one of the ancient techniques for the measurement and separation of particles of different particle sizes. It is a simple, cheap and rapid method. A sieve is a pan with a wire cloth bottom having definitely spaced square uniform openings. There are sieves with circular and rectangular openings[10]. Normally, it is not possible to make sieves of openings less than about 40 μ, because of the difficulty of weaving such wire cloths. According to Zwicker[11], the development of a method which extends sieve analysis to about 1 μ makes it possible to use it for any ceramic material. Carroll and Akat[12] discussed the use of micromesh sieves for the determination of particle size distributions. The distribution agreed well with that obtained by microscopic and photosedimentometry methods. The sieves are electroformed. Irani[13] discussed the techniques of calibration, cleaning, accuracy of results, comparison with other methods and the range of utility of micromesh sieves. Dry or wet sieving is particularly useful for the range 5-50 μ. Sieves can be shaken by hand, but mechanical shakers produce superior results because of their uniform action. Certain techniques are used to increase the rate of sieving and for minimizing the blinding of meshes. Addition of a conditioner improves the flow properties of powders[14]. Heywood[15] studied the relationship of length, breadth, thickness and volume of particles to the size of the sieve aperture through which the particles would pass. The breadth of the particle was found to be closely related to sieve aperture size. For reporting the results of sieve analysis two systems, namely the R, CR and S systems and the plus minus system, are employed. In the first system, R is the percentage retained on the largest sieve, CR is the percentage retained cumulatively on the other sieves and S is the percentage passed through the smallest sieve. In the plus minus system, the percentage cumulatively retained in the smallest sieve plus that passed through it is 100%.

Sieves are calibrated with carefully sized fractions of glass beads, but the microscopic method is more accurate. Sieving has been classed, along with microscopy, as a method which classifies particles according to their geometric similarity regardless of the density or optical properties. The practice of plotting the weight retained against the logarithm of size (rather than just size) is consistent with the practice of sizing according to a scale which is a geometric series and is preferred because it gives equal prominence to data in all parts of the size range.

Wet Sieving

A powder, which forms aggregates in natural course or during the process of dry sieving, is subjected to wet sieving for its particle size determination. The agglomeration takes place due to cohesion and surface charges. A proper dispersing liquid must be used for a particular powder in wet sieving. Keeping the sieve (wire cloth containing the powder) partially under the surface of the dispersing liquid, ultrasonic vibration can be given to agitate the liquid. Lee and Weber[16] developed a method for the measurement of particle size of a variety of powders in the range 0·02-0·12 μ, utilizing 2 kc ultrasonics to deagglomerate and disperse the powder sample in the aqueous medium. Wet sieving involves the use of vacuum and vibration for apertures below 20 μ, and vibration only for larger apertures[17]. This method of particle size measurement is specially useful for very fine or sticky industrial powders.

Microscopic Methods

Optical microscope method is direct and simple, but, at the same time, tedious and time-consuming. General procedure for the measurement of particle size by microscopic methods has been described by ASTM[18] and BSI[19]. This method can be used to measure particle dimensions in the range 0·2-100 μ. The lower limit of optical microscope can be decreased to 0·1 μ by using ultraviolet light and quartz lenses. A particle cannot be resolved if its size is close to the wavelength of the light source. Resolution can be enhanced using intense dark field illumination. The equipment for dark field observation of submicroscopic particles is known as ultramicroscope[20]. It can measure size of the particles in the range 0·01-0·2 μ. One commonly used trick in light microscopy is to examine very small particles in a fluid such as mineral oil, in order to take advantage of the increase in refractive index of the fluid.

Harwood[21] reported a method for the microscopic determination of particle size of certain powders which are difficult to disperse properly. He used electrical charges to repel the particles and fixed the aqueous suspension with a gelatin coated slide to overcome Brownian motion. He also described a method for the dispersion of magnetic materials. This involves the heating of the sample to a temperature above the Curie point, dispersing and fixing on a slide before the particles are counted. Photomicrographs of the particles can be taken and they can be counted and sized[22]. When particles are less uniform, more particles must be counted. Since microscopic particle size measurements give only two dimensions, the method is not good for platelets. One way to circumvent the problem is to count the particles after they have been dispersed and embedded randomly in a transparent jelly. There are automatic methods to scan the microscopic field to convert the two-dimensional density into varying voltage-time relation. Goldsmith[23] calculated the true particle size distribution from the sizes observed in a thin slice.

Electron Microscope

Electron microscope is used to determine the size of particles in the range 0·001-10 μ (ref 24). The application of electron microscopy to particle size measurement is reported by Walton[25]. An electron beam is used in place of visible light and electric or magnetic fields take the part of the glass lenses. Shadowing technique is the most useful method of enhancing contrast in electron microscopy. The thickness of shadowed particles can be calculated from the dimensions of the shadows and some other factors. Chatfield[26] projected photographs produced by an optical or electron microscope on to a translucent screen and compared the particle sizes with a superimposed spot of light projected from the other side.

Sedimentation and Suspension

For the measurement of particle size distribution in subsieve range, sedimentation technique is commonly used. Sedimentation method is based on Stokes' law which relates the fall velocity with the size of particles. According to Spoor[27], Wadell's formula, instead of Stokes' law, is more correct. In this formula, the fraction 2/9 in Stokes' law is replaced by 1/7. The assumptions and limitations of Stokes' law are given below.

(i) The diameter of the actual particle is equal to that of a sphere having same fall velocity.

(ii) As stated by Cadle[7], Stokes' law is valid only when the resistance to the motion of the particle is entirely due to the viscosity of the fluid. The inertia of the medium should have little effect.

(iii) Flow should be streamlined. Rose[28] stated that the magnitude of Reynolds number should not exceed 0·1 for limiting the error within 1%. Oseen's equation[28] may be used even up to a Reynolds number of 1.

(iv) Concentration of particles per unit volume of suspension should be such that the mutual interaction between the particles is negligible.

(v) The apparent viscosity of incompressible spheres in a fluid of viscosity η is given by the formula $\eta_e = \eta(1+2c)$, where c is the volume fraction of the spheres[29]. Provided c is small, the interaction of the spheres can be neglected. Kynch[29] stated that Einstein equation is not valid when concentration is above 1%.

(vi) Particles must be rigid if they are to obey Stokes' law. According to Martin[30], clay which swells when suspended in water may be an exception. According to Cadle[7], Stokes' law is concerned only with the terminal velocity. A certain time must elapse after a particle starts to settle before terminal velocity is reached. This time is negligible compared with the settling times involved in subsieve range. Griffiths[31] showed, by means of examples, that the terminal velocity is reached in a very short time.

(vii) According to Irani and Callis[20], Stokes' law can be used for nonspherical particles whose maximum to minimum diameter ratio does not exceed 4. Beirne and Hutcheon[32] discussed the determination of the shape factor which is defined as d/d_0, where d is the diameter of a sphere, measured by sieving, having the same volume as the particle, and d_0 is the diameter of the circle having an area equal to the projected area of the particle in its most stable position measured by a photo cell. Robins[33] defined the area and volume shape factors for irregular particles. Mysels[34] stated that, contrary to common belief and expectation, there is no torque at low velocities on the nonspherical particles during sedimentation, no matter what their orientation is. A size for such particles can be assigned by averaging over all possible orientation of settling. He also stated that overall resistance to the motion by an irregular particle is more than that of a sphere having same volume. Spheres have the smallest resistance. Joglekar and Marathe[35] constructed a nomograph for particle size analysis based on Stokes' law. Bares *et al*[36] discussed the corrections to be applied to the Stokes' equation. They have also discussed the integral and differential functions of the particle size distribution. Integral distribution function gives the mass of all fractions present in unit mass of dispersion fractions of particles which have a radius larger than or same as the given value. Differential distribution function $F(r)$ is

defined as the quantity which when multiplied by dr gives the mass of the fraction of particles having radius r to $r+dr$, contained in unit mass of the dispersed phase.

When the particle is of more than a critical size, fall velocity is less than that given by Stokes' law. For such particles, velocity becomes so large that turbulence occurs, decreasing the velocity more than the viscous drag alone. The law holds good as long as Vr is less than η/σ. But when it is more than the terminal velocity, given by Newton's law for bodies in turbulent motion, the fall is independent of viscosity.

Suspension and Dispersion

Liquids should be so chosen as to disperse powders properly. Usually, very fine powders are agglomerated due to surface charges, moisture, etc. If the powder is not dispersed properly in liquid, appropriate quantity of dispersing agent should be added. Joglekar and Marathe[37] gave a list of dispersing agents and suspension liquids for different powders. The list has been adopted by BSI[38]. They have also given the tests for proper dispersion. Cadle[7] stated that mixtures of acetone and vegetable oils have been used with dense particles such as iron or tungsten when it is desirable to use more viscous liquid than water. Glycerol-water mixtures have also been used for the same purpose. When water is used as a suspending medium, it is a common practice to add a little electrolyte, such as sodium hypophosphate, calcium chloride or potassium citrate (0·1 mole/litre).

Factors Affecting Sedimentation

Elton and Hirschler[39] observed that under certain conditions particles up to about 25% smaller than the majority settled at the same rate as did the majority. This may be due to a charge produced by surface ionization or preferential ion adsorption. Due to these effects, a potential gradient is formed when particles fall through the solution and this gradient resists the motion of the particles. Since the larger particles in the heterodispersed suspension carry a total surface charge more than that carried by the smaller particles, the larger particles experience a greater electroviscous retarding force. This results in the reduction of the velocity of the particles. Electroviscosity decreases with increasing electrolyte concentration. In moderately concentrated solutions, its effect is quite small. Booth[40] theoretically examined the entire subject. Wolf *et al* studied[10] many factors affecting the sedimentation of powders in a variety of liquids. On one hand, a particle experiences a force which drags it downwards owing to the flow field of a neighbouring particle and, on the other, when fluid is enclosed in a vessel, an upward flow must exist to compensate the downward flow of the particles and the fluid which drags along with them. According to BSI[38], if the difference in density of particles and that of the suspending liquid is less than 0·5 g/cc, special care must be taken to avoid convection currents. There is a change in viscosity of the suspending medium due to the suspended particles. In order to make the variation (in viscosity) negligible, the concentration of the powder should be very small. But it should not be too small to avoid errors in weighing. The concentration suggested by BSI[38] is 1% by volume. The sedimentation vessel should be large, so that variation in viscosity due to wall effect is negligible. According to Cadle[7], vessels over 1 cm in diameter have negligible effect on particles in the subsieve range. Correction should be applied for wall effect and end effect. The temperature of the room should not vary more than 0·5°C during the experiment to avoid convection. For small particles settling in air there is a slip of particles between the molecules of the fluid (air). For such particles Cunnigham's corrections must be applied. Sindair[41] suggested that true radius is given quite accurately by subtracting 0·04 μ from Stokes' radius for the particles of radii between 0·1 and 2 μ.

Pipette Method

In this method, samples from a suspension are withdrawn at predetermined times after settling starts. In the Andreasen pipette method, which is the simplest, sampling level is kept constant but the level of suspension is decreased. In some apparatus, the pipette can be raised or lowered on a graduated slide and hence sampling at a constant depth can be made. But this is not necessary since correction for the change in level is simple. In Schweyer's method[10], the sampling level is changed to predetermined depth at predetermined time. Removal of sample lowers the liquid column and might cause disturbance. To reduce this error, Stairmand[42] modified Andreasen apparatus so as to keep the upper level of the liquid at a constant level above the sampling level. He stated that the simple Andreasen pipette suffers from marked thermal and mass convection. These are reduced in the new apparatus used by him by enclosing the sedimentation vessel in a temperature controlled chamber. Griffiths[43] has described a modified pipette sampling device.

Hydrometer Method

This method is simple in operation. The hydrometer is supposed to measure the difference in densities between the pure fluid and the suspension at a particular position in the sedimenting vessel. The difference in densities is a measure of concentration of a particular particle size. Puri[44,45] described a simple hydrometer method for the analysis of soil. Griffiths[46] reported the experimental procedure and the method of calculation of particle size by means of a hydrometer. According to Rose[28], there are two main disadvantages in the method. Firstly, the bulb of the hydrometer is too large to measure density at a level and, secondly, suspension settles on the hydrometer while the readings are being taken. The second defect could be reduced by taking out the hydrometer from the suspension when no readings are taken. But this disturbs the steady settling. Most of the hydrometers are calibrated. Usually readings are taken at the lower meniscus. But when opaque suspensions are used, readings are taken at the upper meniscus and corrected. Correction has to be made for the change in the volume of the bulb due to change in temperature.

Diver Method

Divers are small sealed bulbs (usually of glass) of decreasing specific gravities. Most divers contain iron powder so that they can be brought to the sides of the sedimentation vessel by means of a magnet. The diver can be looked upon as a small constant density hydrometer which remains stationary at the level where the density of the suspension equals the density of the diver. Griffiths[47] has illustrated the use of divers by means of examples.

Manometer Method

One type of manometer[48] consists of a vertical side tube, containing the pure fluid from which the suspension is prepared, connected to the sedimentation vessel at a depth. The pure fluid column will have a greater height than that of the suspension. From the variation of height with time, the particle size distribution can be obtained. The data have to be differentiated twice before the frequency curve is obtained. Jarrett and Heywood[49] suggested the use of a differential manometer with the advantage thet the mean density of a thin slab of suspension is measured eliminating one differentiation step. In both these methods the manometer is sluggish and there is contamination of liquid in the manometer.

Layer technique — Marshall[50] discussed the method of particle size determination in which a thin layer of suspension is spread over a comparatively denser medium. The particles fall with the rates according to their sizes. The uniformity of particles at any level is ensured, though slight correction is necessary due to the thickness of the layer of suspension. Bakker and Barlok[51] used alumina dispersed in water-acetone-calgon as suspension medium and water-calgon as the sedimenting medium for the particle size determination of alumina by centrifuge.

Balance Method

Oden[10] developed a direct weighing sedimentation balance. The material deposited upon the pan at a series of known time intervals is found and thus the particle size distribution is obtained. The movement of the pan disturbs the suspension but there are ways to avoid this. Bostock[52] reintroduced the method in a more successful way. He used a lever arrangement having a pointer which moves along a scale and the movement is observed by means of a cathetometer. Rabatin and Jale[53] developed an automatic recording sedimentation balance. This type of balance makes use of a sensitive spring to weigh the particles. For the coarse powders, the results obtained from the Andreasen and balance methods agree, but for finer powders they do not show agreement due to disturbance during sample withdrawal.

Light Extinction Method

Light extinction measurements for particle size determination depend upon the application of Lambert-Beer law. The light extinction (photometric) method of particle size analysis developed by Wagner[54] measures the light energy passing through the suspension by means of a photocell. Size frequency of the material in the suspension is determined from a series of readings carried out at suitable time intervals while the sample settles. This method of measurement is specially useful when the quantity of powder available is very small, say less than 1 g and the particle size is not below 2 μ. Marathe and Joglekar[55] described this method for the determination of the fineness of cement. The major disadvantage of the technique is that the powder under test must sediment and hence the time for the experiment is very long. The time can, however, be reduced by lifting the light source parallel to the depth of the sedimentation vessel at predetermined time intervals. By this operation, the depth for the finer particles is reduced. Other questionable assumptions in this method are that all particles are absolutely opaque and that there is no reflection from the surface of the particles and the walls of the container. Talvitie and Paulus[56] used an automatic recording apparatus along with the photocell. Photography is also used in conjunction with the sedimentation apparatus for determining particle sizes. A portion of the suspension is photographed with a prolonged exposure of known duration and then enlarged. The lengths of tracks are proportional to the velocity of fall and, thus, the particle size is determined.

According to Skinner and Boas-Traube[57], the light extinction method is the best for the calculation of specific surface. Mosur and Schmidt[10] used light extinction in order to determine particle size distributions within the range 1-10 μ. Krasnov[58] used centrifugal sedimentation during the photoelectric analysis of the particle size distribution of finely dispersed particles (<1 μ). Schteusener and Read[59] investigated the application of turbidimetry to layered sedimentation for use in small particle sizing. He-Ne gas laser is used to detect the low light losses experienced during layer sedimentation test. According to Baeza[60], the method introduces some errors due to varying reaction of different materials to light. However, if the turbidimeter is used for a single material such as copper powder or aluminium powder, it can serve very well for the particular powder under examination. Serious errors are likely to occur when data determined on analysis of one material are applied to another which has entirely different characteristics towards light. Wulfi[61] stated that, from a practical point of view, the turbidimeter is a very useful tool for comparing the fineness of similar materials, such as different grades of cement or powders of same metal manufactured under different conditions. It has been shown that a transparent particle behaves as though opaque, provided there is sufficient difference between the refractive indices and also the photosensitive surface subtends a sufficiently small solid angle at the centre of the suspension. This method breaks down for a flaky, transparent material since the flat slab cannot deviate a light beam, but even so, since no real material consists of perfectly transparent parallel-faced slabs, it is probable that the method will prove satisfactory for most materials.

X-ray Method

Brown and Skrebowski[62] and Colin *et al*[63] described methods for measuring particle concentration using

X-ray activation. They split an X-ray beam into two parts, one being the reference beam passing through pure liquid and the second passing through a sedimentation cell and finally falling on a fluorescent screen. They found a relation between the intensity of the emerging X-ray through the pure liquid and the suspension and particle concentration. This method is suitable only for chemically homogeneous materials. Arnott[64] used small angle X-ray scattering method for particle size analysis of clay minerals. Particle shape can also be obtained by this method.

Centrifugal Methods

The fall of particles below 1 μ under gravity, in the suspension, takes too much time. Brownian motion and convection effects on such particles become dominant. In order to minimize the error due to convection effect and to accelerate the rate of fall, gravity effect can be increased many times. Lee and Weber[16] developed a continuous flow centrifuge applying forces up to 60,000 g. According to Zwicker[17], the centrifugal sedimentation is limited to particles of 20 μ or less, which prohibits its use for materials containing larger size particles unless the large particles are first removed by sieving. By this method, mixtures of materials having different densities can be determined for routine control, but the results may not be accurate. A number of tubes containing suspension are centrifuged. After each predetermined interval, one of the tubes is taken out, its contents firmly settled and supernatant liquid determined. Each centrifuged tube will contain finer particles in the firmly settled portion than those calculated for the particular speed and time, since some smaller particles had to travel a smaller distance than the height used in the calculation. Oden's method of tangential intercept as stated by Jacobsen and Sullivan[65] can be used to find the amount of such particles. They discussed the effect of milling, vehicle and particle shape in relation to the centrifuge method. A very practical technique that employs both gravity settling and centrifugal sedimentation in the range 0·05-100 μ was developed by Whitby[66]. Berg[49] used divers for the measurement of finer particles in the centrifuge. Kamack[67] used a built-in pipette to remove samples. An extensive investigation of centrifugation was conducted by Johnson[68]. By this method, particles of nearly molecular diameter can be studied if ultra high speed centrifuges are employed. Griffiths[69] described the requirements of a centrifuge in which concentration is measured photoelectrically. According to Irani and Kaelble[70], the Conifuge technique is more applicable in the size range over 0·5 μ requiring less expensive equipments and offering a fool-proof operation. Yet in a few cases of metal oxides this is not used because of the large bulk density correction. Conifuge method developed by Sawyer and Walton[71] is similar to the centrifuge method.

Elutriation

This is the reverse process of sedimentation. Particles smaller than a certain size are removed by passing a current of fluid against gravity through the well-dispersed powder. They are collected by filtration. It is assumed that the fluid velocity is equal to the terminal velocity of the particles held stationary. Air and water are generally used as elutriating fluids. General procedure has been described by BSI[72]. Dallavalle[73] has described a simple elutriator for the separation of coarse particles. There are many commercial variations of the elutriators to classify the particles into different sizes. Multiple-tube elutriators make use of the principle that same current of fluid assumes different rising velocities when passing through conical cylinders of different sizes. The separation of particles of different diameters, therefore, could be effected in one operation. It is not suitable for many powders because of flocculation. Air elutriators are used in pigment industry, ceramic industry, etc. Elutriation by means of air flow is the only means at present available for separating (into graded fractions) subsieve particles without wetting.

Radiometric Methods

Radioactive tracers and other active materials have been used in particle size analysis with sedimentation techniques. In this method, extremely low concentration of the suspension can be used. By irradiation the activity induced in a particle is proportional to the number of atoms in the particle. Abraham *et al*[74] used gravitational activation analysis method to measure the particle size distribution of powdered uranium dioxide. They measured the activity with a scintillation counter versus time at a fixed distance from the top of the suspension through a collimating slit positioned in a lead seal. The ratio of activity yields the cumulative undersize weight distribution. Bate and Dyer[75] measured the particle size distribution of thoria in the range 10-2000 μ by this method along with the sedimentation method.

Automatic Counters

A survey of automatic counting methods has been given by Walton[76]. Particle size and the number of particles have been determined by the change in the electrical resistivity[77-79]. A very dilute suspension in an electrically conductive liquid is used. The suspension is allowed to pass through an aperture (in a tube) having electrodes on either side. The concentration is so low that normally only a single particle can traverse the aperture at a time. Depending on the size of the particle, resistance between the electrodes changes. This change produces a voltage pulse proportional to particle volume. The resulting series of pulses is amplified, scaled and counted using pulse height analysis.

Methods of Finding Mean Particle Size

Adhesion

Mean particle size has been determined by a simple determination of the angle at which a mass of powder slides along a surface. Cremer *et al*[10] found the forces of adhesion between particles to increase as particle size decreased.

Permeability

The external surface area determined by permeability can give the mean particle size. Kozeney

equation is used for the calculation of permeability. According to Emmett[80] there is some indication that Knudsen flow for nonporous particles will give better agreement with the particle size deduced from nitrogen surface area measurement than flow measurements made at high pressure. This area includes the area of the capillaries formed by particles but very little of cracks and pores within the bodies of porous particles. Blaine[81] attached a cell containing powder bed to one side of a U-tube containing a manometric liquid of low density. The level of the liquid in the arm attached to the cell is displaced up to a mark and then allowed to fall, such that during the fall air is sucked through the bed. Rigden[10] also developed a fundamentally similar apparatus. Lea and Nurse[82] reported the details of their permeameter for the measurement of fineness of powders. In this method, air is forced through the sample by means of a pump. The amount of air passing through the sample has to be measured by means of a flowmeter. Carman[83] stated that if large pressure differences are used, compressibility can no longer be neglected. These apparatus are not suitable when the powder is coarse. Where small changes in the distribution are critical, and especially where the amount of coarse material requires control, this method is inadequate. John and Sekhon[84] modified Blaine's apparatus to measure the permeability of coarse powders. They allowed air to flow at a constant low pressure head.

Dodd *et al*[85] used liquid permeability to measure area of coarse powders. Lakhanpal *et al*[86] used an elaborate apparatus to test several powders having mean diameters in the range 5-150 μ. The results were found to be comparable with the microscope values. Rigden[87] showed that liquid permeabilities and slip corrected gas permeabilities lead to the same result. John and Sekhon[84] found that the surface area of various powders determined by them using the Lea and Nurse method gave values about 10% higher than those determined by the constant pressure head and Blaine's method. According to Cadle[7], there is a tendency for surface area to increase with decreasing value of porosity of powder in the cell. John and Sekhon[84] found that the surface area of granular carbon powders can be determined from the oil retained after extruding oil by suction pressure from a mixture of the powder and anthracene oil. The suction pressure must reach a critical value. According to Zwicker[17], the mean particle diameter given by permeability methods never indicates the critical amounts of coarse material or a change in the slope of the distribution curve.

Hindered Settling

When the powder concentration is more than about 10% by volume, the powder settles with a common boundary. The liquid above the boundary is almost clear of the powder. From the rate of movement of the common boundary, Steinour[88] derived some empirical relations for the calculation of Stokes' velocity and, consequently, the mean particle size. The method is particularly suitable for field experiments in mines, soil testing, etc. The method is also discussed by others[89,90].

X-ray Method to Determine Mean Particle Size

Specific surface areas have been calculated from X-ray scattering data. Alexander and Iler[91] found satisfactory agreement between X-ray and electron micrograph size indications in the case of silica particles. In the case of pigments, Marculaitis[92] found agreement between X-ray determined sizes and sizes calculated from nitrogen adsorption measurements.

Adsorption Method

Mean particle size, from surface area of nonporous fine particles, may be determined by adsorption method[93]. Generally, nitrogen at −195°C is used as adsorbate. Many other gases and vapours can also be used for the same purpose. Dye adsorption in the colorimeter technique is also used for the purpose[94]. Allingham *et al*[95] have reported a number of dyes and their molecular areas which are used for adsorption on inorganic surfaces.

Heat of Wetting Method

Harkins and Jura[96,97] exposed powders to the vapour of adsorbates until saturation was reached, such that a film of liquid of area equal to that of particles was formed around the particles. The powder was then immersed in the liquid and, as a consequence, the adsorbed film disappeared, releasing the surface energy in the form of heat. Dividing the total surface energy given out by the known value of surface energy per unit area, total area and, consequently, the mean particle size can be calculated.

Particle Size of Solid Aerosols

Nonhygroscopic aerosols are involved in industrial hazards. Hence, a short description of the important methods for the measurements of their sizes and size distribution is very essential.

Cascade Impactor

This apparatus is commonly used to study the aerosols in factories, industrial areas, etc[10]. It can be used to measure aerosols between 0·5 and 20 μ. In this method, aerosols are forced in succession through a series of jets with decreasing orifices directed at microscope slides perpendicular to the jets. The aerosols of bigger sizes, having least velocity, will be retained on the first slide, while the smallest particles will be retained on the last slide because of their maximum velocity. The slides are then tested under microscope.

Thermal Precipitator

The method makes use of the repulsion of fine particles by a hot body[98]. Air is sampled down slowly (by an aspirator or an elutriator) across an electrically heated wire. The particles are deflected on a glass slide and are then observed under a microscope.

Electrostatic Precipitator

This type of apparatus has been used to measure aerosols in the range 1-20 μ[99,100]. The apparatus consists of a needle point electrode and a plate

anode connected to the two sides of a high potential dc line. The space between the electrodes becomes charged with electricity of the same sign as the needle point and, hence, aerosols brought into this space acquire a charge, also of the same sign. They, therefore, move towards the plate, discharge and collect on the plate. Cellophane strips can be placed on the anode to allow the particles to deposit on them. The strips are then transferred to the microscope for observation.

Optical Methods

There are photoelectric spectrometers which compare the intensity of light transmitted at two wavelengths through a sample of aerosols[7]. From the intensity variation, the particle size can be calculated. This type of apparatus can measure particle sizes between 0·3 and 1 μ. The polarization ratio of scattered light can indicate the sizes of particles between 0·1 and 0·4 μ in diameter. This apparatus also uses an angular distribution of colour to indicate the sizes of particles between 0·4 and 2 μ in diameter. The apparatus consists of a small chamber for aerosol, a light source and a low power microscope as a polarization photometer. A costly commercial instrument known as 'automatic aerosol counter' is based on light scattering[101]. Particles in a suitable stream are passed through a sensing region of an optical system where the region is intensely illuminated. Particles scatter light and a fraction of it proceeds to photomultiplier tube. Since the particles travel the illuminated region in a few seconds, the electrical signals at the photomultiplier appear in the form of pulses. These are set on an electronic pulse height analyser for pulse amplitude. This method gives at least relative sizes of the aerosols.

Summary

The principles used in mechanical, electrical, optical, electronic and thermodynamical methods to measure particle size and mean particle size are discussed. Various methods of measuring and types of instruments developed, eg sieve, optical and electron microscopes, pipette, hydrometer, diver, turbidimeter, balance, manometer, X-ray, hindered settling, adsorption, permeability and heat of wetting, etc, are reviewed. Importance of proper selection of method and various factors affecting the methods of measurement along with recent advances, advantages, limitations and criticisms of various methods of measurement are also discussed.

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Enzyme Extraction from Plant Tissues Rich in Phenols/Phenolases

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THE *in vitro* activity of enzymes in plant tissues may be either totally inhibited, or significantly decreased, or the localization pattern altered, in consequence of enzymatic or non-enzymatic oxidation of phenolics. According to Mason[1], quinones readily enter into covalent bonding with sulphhydryl groups which may also be oxidized. Even more important, the quinones polymerize spontaneously and enter into comparatively stable covalent linkage with proteins[2]. The hydrogen bonding between phenolics and protein is reversible, but the covalent bonding of quinones and polymerization products with protein is irreversible*.

If an enzyme were to be totally inhibited, tests with homogenates and extracts prepared in the conventional media would lead to the conclusion that the enzyme was absent in the tissue. A decreased activity of a soluble enzyme, as tested in a supernatant fraction, may be due to direct inhibition of the enzyme by the phenolic material, or partial precipitation and removal of the enzyme from the residual fraction. A decrease in the total activity of a particulate enzyme (system), as in the case of the mitochondrion, may be due to inhibition by the phenolic material, whereas a decrease in the specific activity may be due to coprecipitation of inert proteins complexed with phenolics. The association of enzymic activity with a particulate fraction may be an artifact, resulting from precipitation of a truly soluble enzyme, with only partial, or without any, inactivation. Admixture of a truly particulate fraction with inert protein can result in the enzymic activity being apparently localized in a fraction sedimenting at a lower centrifugal force.

In the broader sense, the solubilization of protein from plant tissues is influenced by the nature and the concentration of the phenolics and oxidases.

The Browning Reaction

Enzymic browning results from the polymerization, or the oxidative polymerization of quinones formed from simple mono or dihydric phenols by the action of polyphenol oxidase (EC 1.10.3.1, *o*-diphenol O_2 oxidoreductase). A clue to the interference by phenolics in the extraction of enzymes (and solubilization of protein) is provided by the browning of homogenates prepared in water or other unsuitable media. However, browning need not necessarily accompany enzyme inhibition; nor does the prevention of browning necessarily prevent enzyme inactivation[3,4].

*Unless otherwise specified, the term 'phenolics' is used to designate all oxidized and polymerized forms of phenols. The term plant 'extract' is used in the general sense of a preparation suitable for enzyme assay, or for processing for isolation of enzyme.

Experimental Approach

The methods employed to overcome the effect of phenolics fall under a few broad categories — the 'fixing' of phenols by preferential binding with exogenously added material, the actual separation of phenols from the tissue, the prevention of oxidation of the phenols and the prevention of the linking of phenols with the enzyme. The above classification, adopted solely for the purpose of discussion, is arbitrary and by no means rigorous, there being considerable overlapping between and among the groups. The various techniques are considered in some detail in the following pages.

Fixing of Phenols

Polyvinylpyrrolidone

The soluble and the insoluble forms of polyvinylpyrrolidone (PVP), a non-ionic polymer, have been employed extensively in protecting enzymes against inactivation by phenolics. PVP is believed to complex with phenols by hydrogen bond formation[5-7]. Loomis and Battaile[8] considered that PVP was specific in this regard, reacting only with phenols. The observations of Andersen and Sowers[9] that the complexing of phenols with PVP was optimal at *p*H 3·5 was inhibited by concentrations of methanol above 10% and was reversed by urea or guanidine hydrochloride, furnished additional support for the binding of phenols to PVP by hydrogen bonds. According to Jones *et al*[10], PVP may also function by inactivating phenolases.

Soluble PVP — The use of the soluble form of PVP for the isolation of particulate enzyme is based on the assumption that its complex with tissue phenols will be soluble[11,12]. According to Jones *et al*[10], soluble PVP-phenol complexes are formed when PVP combines with tissue phenols before polymerization occurs. In case oxidative polymerization first sets in, PVP forms insoluble complexes with the phenolics. Obviously, endogenous polymerization products of phenolics, when present, may form insoluble complexes with soluble PVP.

Soluble PVP has found special application in the isolation of plant mitochondria[7]. It has also been successfully employed in studies on a few soluble enzymes. The activity of soluble malate dehydrogenase and pyruvate carboxylase could be demonstrated in extracts of apple fruit only by incorporating soluble PVP in the extraction medium[10,12]. Walker and Hulme[13] conducted studies on soluble phenolase of apple peel in PVP-containing supernatants. Goldstein and Swain[14] found that samples of soluble PVP with average molecular weights 11000 and 25000 were among the most effective reagents in the solubilization of β-glucosidase from the insoluble complex formed with tannic acid. Frydman *et al*[15] could detect in potato the activity of soluble

starch synthetase only when soluble PVP was incorporated in the isolation medium. Guerrtore *et al*[16] were able to demonstrate the activities of glucose-6-phosphate, malate and isocitrate dehydrogenases, triosephosphate isomerase and glutamic oxaloacetate transaminase in the bark of *Pinus pinaster* by using 10% PVP (mol wt 24000) in phosphate-EDTA-mercaptoethanol medium. Simultaneously, there was a 10-fold increase in the protein in the extract.

Insoluble PVP — Insoluble PVP has the advantage over soluble PVP in that it could be used in excess without (under ideal conditions) leaving extraneous material in solution. 'Polyclar AT', a form of the cross-linked polymer of high molecular weight, is most commonly used.

Loomis and Battaile[8] obtained soluble preparations of glutamyl transferase and mevalonic kinase from the leaves of *Mentha piperita* (which contain a high level of polyphenols) when 1·25-1·5 parts of Polyclar AT were used in the extraction medium. The technique consisted in freezing the leaves in liquid nitrogen, powdering, adding the powder to a chilled slurry of (hydrated) Polyclar AT, buffer (pH 7·4-7·5) and sodium ascorbate, stirring gently, squeezing through silk and freeing from residual solids by centrifugation at 35000 g for 30 min. The protein content was increased by about 25%, but the activity of mevalonic kinase increased 200% in comparison to an extract prepared in the absence of Polyclar AT. Sanderson[17] obtained a soluble preparation of 5-dehydroshikimate reductase from the growing shoot tips of *Camellia sinensis* (in which the flavanoid compounds comprise 20-35% of the dry weight) by grinding the frozen tissue with phosphate buffer (pH 7·0) in the presence of 0·6 part of Polyclar AT and centrifuging the cloth filtered homogenates at 3000 g for 20 min.

Although insoluble PVP has found application essentially in the extraction of soluble enzymes, it may be successfully employed in the isolation of enzymes associated with subcellular particles which settle at centrifugal speeds higher than that needed for sedimenting the added polymer[10], or which pack differently under a density gradient.

Analytical aspects of the use of the soluble and insoluble forms of PVP — Care has to be exercised about the purity of PVP. Hulme *et al*[18] reported that commercial grades of soluble PVP contain impurities which lead to inactivation of mitochondrial preparations. According to McFarlane and Vader[19] and Andersen and Sowers[9], Polyclar AT must be purified prior to enzyme studies.

The amount of PVP to be used will obviously depend on the amount and nature of phenols and the enzyme under study. Low pH values[9], which facilitate the efficient removal of phenols by the polymer, cannot be used in studies on the majority of enzymes. At pH values generally permissible in enzyme extraction, the efficiency of hydrogen bonding is decreased, necessitating the use of larger amounts of PVP, especially when the insoluble form is employed. The use of large quantities of insoluble PVP sets an upper limit (say 20% wt/vol) to the concentration of homogenates feasible with a given tissue when ground in a Waring blendor. Mechanical removal of cellular constituents by the bulky residue is also likely, whether the polymer is added during grinding or following dispersion of cellular contents. An unforeseen complication in the use of Polyclar AT was its breakdown to soluble PVP as a result of grinding with tissue in a mortar or Waring blendor[8].

Although the inhibition of phenolase by soluble PVP[13,20] is advantageous in enzyme and protein extraction, it is essential to avoid excess PVP in view of the likelihood of inhibition of enzymes under study[10], or interference in enzyme assay[15]. There is no easy means of eliminating dissolved PVP from enzyme preparations. Soluble PVP is nondialysable[21], and cannot be removed completely by gel filtration, ammonium sulphate fractionation or high speed centrifugation[15,22].

The precipitability of soluble PVP by TCA or other deproteinizing agents has not been studied in detail; any contamination of the enzyme with PVP will lead to complications in the determination of protein from total nitrogen[8,18]. Phenolics held in solution by PVP will be precipitated, along with the protein, by the addition of TCA. On treating the precipitate with alkali, both protein and phenolics will be solubilized. The latter will then interfere in the determination of the former with the Folin-Ciocalteu reagent[23].

The density and viscosity of the medium alter on the addition of soluble PVP and this may alter the sedimentation characteristics of particulate enzymes. Due attention has not been paid to this aspect in the isolation of plant enzymes.

It is also known that PVP does not effect total removal of phenols[7,18]. Pierpoint[20] considered that PVP did not adsorb chlorogenic acid or the quinones derived from it.

Polyamide

Polyamide (nylon) has been used in the extraction of soluble enzymes from plant tissues. According to Endres and Hormann[24] and Egger[25], phenolic compounds, in general, are adsorbed on polyamide by hydrogen bonding. Quinones are bound irreversibly[26]. The polyamide samples have to be specially treated to render the amide groups accessible for binding. According to Gustavson[6], nylon is as effective as PVP in binding tannin. As in the case of PVP, the linkage is broken by ethanol, acetone and dilute alkalis.

Sanderson[27] found that when frozen tea shoot tips were ground with cysteine and buffer (pH 7·0) in the presence of 1-1·5 parts of 'Polycaprolaktam' powder, the catechol oxidase activity of the cloth filtered homogenate was increased. In the absence of the polymer, the enzymic activity was associated with the 2000 g residue, but in its presence in optimal concentration, about 90% of the enzymic activity was in the supernatant. Hence it was concluded that catechol oxidase was a 'soluble' enzyme in tea leaves and that Polycaprolaktam functioned by combining with the polyphenolic substances, which otherwise reacted with the enzyme and other proteins precipitating them. Somewhat similar conclusions were arrived at by Takeo[28].

Polyamide suffers from several of the disadvantages referred to above in connection with Polyclar AT. Comparative studies with PVP (soluble or insoluble) and polyamide revealed that the former was a more satisfactory phenol-fixing agent[10,17,18,29].

Proteins

Based on the principle that proteins, in general, enter into hydrogen bonding and covalent linkage with phenolics and transformation products, exogenous proteins have been added during the isolation of enzymes, or in studies on enzymes *in vitro*. As in the case of PVP, the soluble and insoluble forms of protein may be expected to have special application for insoluble and soluble enzymes respectively. It is also to be expected that since the exogenous proteins have to compete with the endogenous proteins for linkage with phenolics, large excesses of the former, especially when insoluble, have to be added.

Serum protein or egg albumin[8,30,31], gelatin[32], and thiogel[33] have been added in solution. Bovine serum albumin has found special application in the isolation of mitochondria[34]. Among insoluble proteins, collagen[8], and more especially hide powder[8,32,35], have been used. According to Gustavson[6], hide powder has the same binding capacity for tannin as insoluble PVP and hydrated nylon.

The use of foreign proteins in the extraction medium, even when apparently insoluble, is not desirable because of contamination of extracts with these proteins. Proteins, in general, have less affinity than PVP and polyamide for phenolics.

Other High Molecular Compounds

Polyethylene glycol (PEG)[8,14,36], polyvinyl alcohol[14], cellulose derivatives[14], dextran[10] and carbowax[34,37] have been used as phenol-fixing agents in enzyme isolation or studies in *in vitro* systems. Goldstein and Swain[14] reported that on weight basis, PEG (mol wt 20000) was as efficient as PVP or Tween-80 in releasing β-glucosidase from a complex with tannic acid, but its lower analogues were less effective. A disadvantage with PEG is that it might inhibit some enzymes.

Low Molecular Agents

Caffeine and nicotine, which form insoluble complexes with many tannins, have been used in enzyme isolation studies[14,32,33,38].

Removal of Phenols from Tissues

Acetone treatment — The rupture of the hydrogen bonds between proteins and phenols forms the basis for the preparation of active acetone powders by repeated extraction with aqueous (generally 80%) acetone[39-42]. Covalently bonded phenolic material may not be removed by aqueous acetone. Aqueous dioxane has been reported to be a better detanning agent than acetone[43]. The presence of a reducing agent during organic solvent treatment may have distinct advantages[44].

The success with acetone treatment obviously depends on the enzyme protein not getting denatured by the reagent. Solubilization of the enzymes from the powder may cause uncertainties[14,45]. The removal of phenolic compounds from plant tissue by acetone may not be complete and the residual phenolics may cause uncertainties in the assay in acetone powders[46] for enzymic activity and for protein with the Folin-Ciocalteu reagent. Yet, another complicating effect of the use of a lipophilic reagent is the likely alteration in the activity of structurally bound enzymes by extractive removal of essential lipid components[47].

Gel filtration or dialysis — Another means of overcoming the effect of phenols is through their removal by gel filtration on Sephadex or polyacrylamide columns, or by dialysis[8]. It is necessary in these experiments to have a reducing agent such as cysteine or 2-mercaptoethanol incorporated into the medium and to have the filtration carried out preferably after removal of the major part of the phenols with an insoluble fixing agent such as Polyclar AT. Gel filtration or dialysis will remove such phenolic compounds as catechol derivatives or free tyrosine which do not form strong hydrogen bonded complex with PVP[7], but are readily oxidized to quinones. These techniques have the additional advantage of removing endogenous substrates[48], low molecular components of the extraction medium such as detergents and reducing agents[49] and inhibitory material[50].

Mechanical removal — Since phenols are present exclusively or largely in the vacuoles[51], it is to be expected that rupture of the vacuoles under conditions of minimum mixing with protoplasmic constituents, as in a hydraulic press, would provide a satisfactory means of removing the major part of phenols.

Since phenols are concentrated in specific parts in some fruits and tubers, it is possible to eliminate the major portion of tissue phenols by rejecting the parts containing phenols as, for example, the peels of apple[52], banana[53] and potato[54]. Young[33] pointed out that in the banana fruit a leucoanthocyanin-type tannin is concentrated in the latex cells, which need more drastic measures for disruption than other cells. Controlled conditions for tissue grinding may sometimes be helpful in decreasing the effect of tannins.

Prevention of Linkage between Phenols and Protein

Use of alkaline pH — Both condensed tannins and hydrolysable tannins are known to enter into hydrogen bonding only to a limited extent at *p*H values 8 and above[8]. This principle was apparently operative when an alkaline medium was employed during cell rupture, such as tripotassium phosphate[31] and buffer (*p*H 8·4-9·9)[52].

The alkalinity of the medium may also influence enzymic activity by retarding harmful reactions and promoting the reactions conducive to the stability of the enzyme under study. The *p*H optimum for polyphenolase activity is 5-7, so that a distinctly alkaline *p*H may reduce its activity markedly. Polyphenolase action is arrested completely by *ortho* methylation of the polyphenolic substrates. Methyl transferase of the plant tissue

has an alkaline *p*H optimum and hence a spontaneous methylation may occur during cell rupture in an alkaline medium[55]. The operation of this biological mechanism depends on the availability of methyl donor and the affinity of the transferase as compared to that of polyphenol oxidase for the substrate. Exogenous ATP and methionine have been used with some success in preventing browning of fruits and vegetables; however, this technique has not been tested for enzyme extraction.

A markedly alkaline *p*H in the extraction medium cannot be recommended as a routine practice, since sensitive enzymes are likely to be inactivated, although the protein may be solubilized. Also, the rate of autoxidation of polyphenolic substrates may be enhanced.

Use of borate — The beneficial effect of meta- and tetraborate in minimizing the browning of apple tissue, reported by Bedrosian *et al*[56], was apparently by complexing with quinones. Tannins react with boric acid and borax on account of the tri(3,4,5)-hydroxybenzoic acid group[57]. In general, the solubility of the phenols is increased on account of complex formation with borate. Boric acid was one of the several compounds tested by Goldstein and Swain[14] for solubilizing β-glucosidase from the insoluble complex with tannic acid, though it was not of any special advantage.

A drawback of the use of borate is the potential inhibition of metal requiring enzymes and enzyme systems.

Use of detergents — Although the principal use of detergents has been in the solubilization of enzymes and proteins, there have been isolated reports on their use in the breaking of the linkage of enzymes with phenols. Goldstein and Swain[14] tested the effect of non-ionic, anionic and cationic detergents on the solubilization of β-glucosidase from an insoluble complex with tannic acid, suspended in phosphate buffer (*p*H 6·0). Only the non-ionic and cationic detergents proved to be effective, Tween-80 being the best, leading to complete solubilization. Goldstein and Swain[14] believed that Tween-80 functioned by altering the local charge on the tannin or protein leading to rupture of linkage. The simultaneous use of detergent and PVP has also been tested. Walker and Hulme[13] studied the regeneration of the phenolase activity of PVP-inhibited mitochondria by the action of synthetic detergents and found that anionic detergents not only reversed the inhibition, but further activated the preparation. The phenolase activity of the PEG-precipitate from supernatant was also increased markedly in the presence of anionic detergents. It was suggested that the anionic detergents functioned not only by weakening the links binding PVP to the particle-bound phenolase, but also by effecting changes in the tertiary structure of the enzyme protein and by modifying the hydrogen and hydrophobic bonding.

Among the disadvantages of the use of detergents may be mentioned the likely exposure of latent phenolase[58-60] and their disorganization of phospholipid-protein interaction, leading to alteration of activity of membrane bound enzymes[47].

Unlike in the first two techniques in which the phenols are either fixed or are removed by suitable treatment, the methods considered in the present section (and in the following section) have the disadvantage that the phenols are retained in solution along with the enzymes. In consequence, potential oxidation of the phenols is possible during processing for the enrichment of enzymic activity.

Maintenance of Tissue Phenols in the Reduced Condition

Use of reducing agents — Reducing agents have been incorporated into the grinding medium with a view to maintaining the phenols in their unoxidized non-inhibitory state. According to some workers[8], reducing agents do not prevent the oxidation of phenols, but function more by rapidly reducing any quinone that is formed. Ascorbate reduces the quinones[61], but also inhibits oxidative formation[20]. Thiols also react with quinones to form thioethers[1,20]. According to Anderson and Rowan[4], thioglycollate functions in the extraction of peptidase and amino acyl-s-RNA synthetase from tobacco leaves by partially inactivating *o*-diphenol oxidase and metabisulphite by total inhibition.

Thiols — Cysteine and thioglycollate have found extensive use in enzyme extraction[3,4,48,62].

Metabisulphite and dithionite — Anderson and Rowan[4] found that metabisulphite was more efficient than thiols in extracting peptidase from tobacco leaves. Dithionite was equally effective.

Ascorbic acid — Ascorbic acid has been known to prevent the browning of sliced potatoes by reducing the quinones formed in diphenol oxidation[63]. Its efficacy in this respect was slightly less than that of thiols[64]. Loomis and Battaile[8] obtained maximum enzymic activity in the leaves of peppermint when the adsorption by Polyclar AT and the subsequent removal of residual phenols were carried out in the presence of ascorbate. However, alkaline phosphatase was sensitive to storage in the frozen condition in the presence of ascorbate. Takeo[28] incorporated isoascorbate in the extraction medium employed in the isolation of polyphenol oxidase from the leaves of the tobacco plant.

Reducing agents and phenol-fixing agents used together — It is to be expected that with some tissues there will be less chance of phenolics reacting irreversibly with tissue proteins if a phenol-fixing agent is present along with the reducing agent during homogenization. Jones *et al*[10] concluded from their investigations on the isolation of apple peel mitochondria, that the effect of cysteine, though marginal, tended to reinforce the effect of PVP. Frydman *et al*[15] employed 0·001*M* β-mercaptoethanol along with 5% soluble PVP in the extraction of starch synthetase from potato.

Analytical Aspects Attendant on the Use of Reducing Agents

Success by this technique depends on the endogenous phenolics of the tissue being non-inhibitory. Rose petal preparations are virtually free of

phenolase, but contain considerable amounts of ellagic acid[18], which by itself is inhibitory[7].

Reducing agents activate the *ortho*-hydroxylation of monophenols by phenol oxidase (oxygenase activity) in the presence of oxygen[65], while inhibiting the oxidase activity. The tissue preparations will contain an increased concentration of potentially inhibitory dihydroxyphenols, which may inactivate the enzyme during assay or processing, unless removed from the system.

The presence of a strong reducing agent may inactivate some enzymes by opening up the –S–S– bridge in the protein.

Since cysteine interferes in the determination of tissue phenols by reacting with Folin-Denis reagent, the cysteine content of the tissue must be separately determined and corrected for.

Thioglycollate interferes with the estimation of orthophosphate; this interference can be corrected by KIO_3 treatment[66].

Miscellaneous Agents

The use of metal chelating or complexing agents in the extraction medium to inhibit the metal mediated enzymic or nonenzymic oxidation of phenols should afford a means of protection[8,67] in enzyme extraction. It is a common practice to add EDTA to the PVP-containing extraction medium used in the isolation of mitochondria[18]. Cyanide also has been used, though not always with success[68]. Other agents which form stable complexes with copper, such as diethyldithiocarbamate and phenyl thiourea and phenyl thiouracil[69], may also be employed to inhibit the browning reaction. The use of DIECA permitted the demonstration of sucrose synthetase activity in sugarcane leaves, by preventing the inhibition by phenol oxidation products[3].

Sodium chloride at concentrations as low as 0·1% has been reported to inhibit powerfully the browning reaction, as tested *in vitro* in the action of polyphenol oxidase on chlorogenic acid at *p*H 5·0 (ref 70).

Nucleotides such as NADH or ATP are helpful in preventing the browning of potato slices[71], but cannot be recommended as routine reagents in enzyme extraction.

Oxygen Exclusion

By operating in an inert atmosphere, it is possible to prevent the oxidation and polymerization of phenols. While the technique is feasible on a small scale for the demonstration of enzymic activity[8], observance of inert atmosphere during enrichment of enzymes and large-scale isolation is attended with considerable technical difficulties. Also, endogenously occurring phenolics exert an inhibitory action and have to be removed.

Conclusion

A number of techniques are available to overcome, or to minimize, the interfering effect of phenolics in the extraction, assay and localization of enzymic activity in plant tissues. The particular method, or combination of methods, best suited for a specific study depend upon the tissue and the enzyme under study. A general procedure for a soluble enzyme would be disruption of the tissue in the presence of a reducing agent and treatment with Polyclar AT, followed by gel filtration. In case particle association by the artifact is suspected, a detergent may conveniently be employed prior to treatment with Polyclar AT. A particulate enzyme may be isolated in the presence of a reducing agent and a suitable soluble phenol-fixing reagent such as PVP or serum albumin.

Summary

The oxidation of phenols during cell disruption, or the presence of endogenous polymerized phenolics, may interfere with the assay of enzymes, their localization and their purification. The phenols may either be removed from the reaction system, or they may be prevented from reacting with the enzymes. The available techniques have been classified and reviewed.

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REVIEWS

PROBABILISTIC INFORMATION THEORY — DISCRETE AND MEMORYLESS MODELS by Frederick Jelinek (McGraw-Hill Book Co Inc, New York), 1968. Pp xiv+609. Price $ 19.50

This text in eleven chapters and seven appendices is devoted to a study of problems encountered in information generation, storage and transmission.

The first chapter contains a brief history of the information theory and prerequisites in probability theory needed to understand the book. The second and third chapters deal with digital information transmission and encoding problems. The concept of entropy and its application to coding are considered in Chapter 4. Some well-known results in probability theory are explained and used in the computation of upper and lower bounds of decoding error in Chapters 5-8. Parity check codes and sequential decoding form the subject matter of Chapters 9 and 10. Chapter 11 deals with transmission of information within an allowed distortion tolerance.

The book gives a good description of the fundamental work done by Shannon in the field of communication theory. His coding theorems are stated, proved and applied in the derivation of some results. Most of the codes introduced in the book are non-algebraic in character and their performance properties are deduced by probabilistic methods. The emphasis throughout is on discrete and memoryless models.

The appendices contain very valuable information on special topics in coding theory, inequalities; optimization of concave functions and tables of functions for the computation of entropy.

The book is well written and gives a good account of certain areas of information theory.

C. R. RAO

INTRODUCTION TO MODERN OPTICS by Grant R. Fowles (Holt, Rinehart & Winston Inc, New York), 1968. Pp x+304. Price $ 11.95

The book under review is intended as a text-book and the subject matter is treated accordingly in eight chapters spread over 291 pages. Illustrative numerical problems at the end of each chapter are a welcome addition in a book intended for course work.

Chapter 1 is a vigorous review of the more common aspects like the electromagnetic nature of light, group velocity, Doppler effect and relativistic optics. Chapter 2 deals with light vectors, plane, circular and elliptical polarization, Fresnel's theory of reflection, refraction and total internal reflection, Brewster angle and polarizing components. One finds a rather straightforward lucid exposition without going into complicated details. It appears that the author is preparing the ground for the optical components of a laser system which is described in the last chapter.

Chapters 3, 4 and 5 refer to the conventional topics of interference, diffraction, double refraction, dispersion and optical activity. The starting point is the em equations of Maxwell. There is adequate stress on reflecting and antireflecting coatings, multiple beam interferometry, multiple layer coatings and nonlinear optics observable in non-cubic crystals. Polarizability tensor notation is introduced at the appropriate stage and matrix methods are employed in deriving the results. However, there appears to be some overlapping with the matter in Chapter 2 and this could have been avoided. Greater coverage could have been given to the rotary dispersion, Faraday rotation, its variation in an absorption band and allied topics. However, the problem of second harmonic generation using high intensity laser beams has been adequately discussed from the point of view of nonlinear optics.

Chapters 6 and 7, dealing with emission of light from a hot body, atoms and molecules, could have been conveniently omitted and greater emphasis should have been laid on the Einstein emission and absorption coefficients and a quantum mechanical evaluation of the same. The space saved by omitting these chapters could have been better utilized for describing the theory and construction of atomic and molecular lasers. Essentially the scope and content of Chapter 8 which deals with lasers should have been increased.

The well-known aspects are coherently presented to make a good text-book. The presentation is lucid. There does not seem to be any significant departure from the existing text-books, except that Maxwell's electromagnetic equations and matrix methods are employed.

The book also serves as an elementary introduction to lasers. More than anything else, one gets the impression that the subject matter is so arranged and those aspects are emphasized which help in the understanding of the working of the components of a laser system and its applications.

C. RAMASASTRY

RADIATION PROTECTION IN THE MINING AND MELTING OF RADIOACTIVE ORES (International Labour Office & Internal Atomic Energy Agency, Geneva), 1968. Pp vi+108. Price Rs 15.00

The publication under review comprises a code of practice pertaining to the mining and milling of radioactive ores, prepared by a group of experts at the instance of the International Labour Organization and the International Atomic Energy Agency. After defining the terms used and the mining and milling operations to which the code relates, the publication summarizes the general duties of employers and workers, sets out maximum permissible doses and proposes an administrative classification for workers exposed to different radiation levels. A section dealing with the general provisions for the protection of workers engaged on all processes involving exposure to radiation is followed by detailed sections on external and internal radiation surveys, on medical surveillance and on protective

measures and equipment (dust, transportation, personal protection, etc).

An addendum provides technical information useful in the practical application of the control measures recommended in the code of practice.

THIN FILM TECHNOLOGY by Robert W. Berrg, Peter M. Hall & Murray T. Harris (D. Van Nostrand Co Inc, Princeton), 1968. Pp xxi+706. Price $ 15.00

In the present state of advancement of science and technology, thin film plays an important role and has crossed the frontiers of laboratory investigations to practical applications in industry. In fact it has become the backbone of the present-day electronics industry. By and large it is pervading almost all the branches of physical investigations and has resulted in the development of such devices as thin film transistors, memory elements for computers, interference filters, etc, and their superior performance as regards sensitivity and reliability is well established. For such an important tool of physical investigation and industrial application the literature available is too poor — specially from the point of view of experimental details. At this juncture, the appearance of the book under review is very timely and the authors should be congratulated for presenting the material in a very lucid form.

As emphasized by the authors, the book has been written with a specific objective, viz to serve the purpose of a text-book for that part of integrated circuit technology which deals with the application of thin films.

The book may be broadly divided into three parts. The first part (Chapters 1-5) begins with an introductory chapter which gives an excellent summary of thin film properties, methods of preparation and their industrial applications. The next chapter deals with the principles of vacuum technique — a subject of paramount importance to the development of thin film technology. Chapters 3, 4 and 5 deal respectively with the preparation and properties of vacuum deposited, sputtered and chemically deposited films. In each chapter the historical growth of the subject has been briefly surveyed, the relevant theory discussed and the practical aspects of design problems considered. Along with this the physical properties, including the nucleation and growth phenomenon, the influence of various deposition parameters, etc, are discussed in detail.

In Part 2 (Chapters 6-9) the reader is introduced to the basic theory of electrical conductivity in solids and thin films followed by a discussion of the design problems associated with the fabrication of passive circuit elements from the available materials.

The third part (Chapters 10-12) deals with the actual process of thin film passive circuit fabrication wherein the various problems associated with each process step, such as mask fabrication, circuit and device design and lead attachment, are fully appreciated and solutions presented, keeping in view the limitations imposed by the available techniques and material characteristics. The last chapter winds up the subject with a discussion of the practical aspects of thin film passive circuit manufacturing problems; the limitations and advantages of various process steps, including the economy of batch production, are fully brought out. On the whole, the book has been well planned and presents an exhaustive and detailed description of experimental work. The authors have been careful in appreciating the motivation and merits of each experiment. In addition to this, wherever necessary, a theoretical discussion relevant to the particular topic in view has been given, which serves a useful purpose in providing the necessary 'physics' to the non-specialist.

However, the book is by no means a comprehensive treatise on the subject, nor was it intended to be. In choosing the subject matter the authors have emphasized the main application of thin films in integrated circuit technology. This may be a bit of disappointment to those working on 'optics' of thin films, but in no way the authors should be blamed for this.

The reviewer feels that a detailed discussion of film thickness monitor should form an essential part of such a book. However, the space devoted to this topic is too small, keeping in view its importance. The shortcomings of resistance monitoring, viz the inherent unreliability due to ageing effect and its limited application to conducting films, are not indicated.

The authors have not only maintained the high traditions of Bell Telephone Laboratories in their lucid presentation of the subject matter resulting partially from their own researches in the field, but have done a splendid job in presenting a comprehensive account of the manifestation of thin films in integrated circuit technology.

This book, which is most informative to both the experts and the beginners, is a must for all the laboratories engaged in thin film research.

V. V. SHAH

HETEROCYCLIC CHEMISTRY by Adrien Albert (The Athlone Press, London), 1968. Pp xii+547. Price 84*s*

The first edition of this valuable book, published in 1959, was warmly received and the German and Japanese translations became available. The author has brought the material up to date. Prof Albert's style of treating heterocyclic chemistry is unconventional, but more rational and systematic. The stress is on principles rather than on isolated facts. His is an admirable text on introduction to heterocyclic chemistry.

Part 1 introduces the general heterocyclic chemistry and this constitutes the bulk of the book. Heterocyclics are divided into paraffinic (completely saturated, eg piperidine, tetrahydrofuran), ethylenic (partly hydrogenated heteroaromatics, eg 1,2-dihydropyridines, 2,5-dihydrothiophen) and heteroaromatics (completely unsaturated) categories for a meaningful approach to a discussion of their structure-activity relationships. Chapter 2 on paraffinic heterocycles has been expanded and now includes more of synthesis and an account of conformational studies. Chapter 3 emphasizes the theoretical

concepts of heteroaromatics. Chapters 4, 5 and 6 classify the systems as π-deficient N-heteroaromatics (eg pyridine), π-excessive N-heteroaromatics (eg pyrrole), and π-excessive O- and S-heteroaromatics (eg furan, thiophen and thiazole). Ethylenic heterocycles have been expanded from one to three chapters (7-9). The last chapter is devoted to pyran and related substances.

Part 2 covers special topics, viz tautomerism (Chapter 10), ultraviolet and visible spectra (Chapter 11), infrared and Raman spectra, nuclear magnetic resonance, electron paramagnetic resonance, microwave, and mass spectra (Chapter 12), ionization constants (Chapter 13), dipole moments (Chapter 14) and oxidation-reduction potentials (Chapter 15). The chapter on tautomerism is new and the discussions on infrared spectroscopy and nuclear magnetic resonance have been expanded. The classification of the ultraviolet spectra is in terms of Platt's free electron model. The last chapter (16) is on devising of new syntheses.

Over 2000 alphabetically arranged useful references to recent literature on heterocyclic chemistry are listed; these will come in handy for the readers serious about further study. The index is adequate. At the end of the book, formulae of some common heterocyclics are printed for a ready reference to the IUPAC system of numbering.

The book can be of use to the postgraduate students of chemistry at the Indian universities who have had some prior preliminary study of heterocyclic chemistry, may be at the undergraduate level, and have an adequate understanding of the modern concepts of organic chemistry. One full paper based on the course content covered in this text should provide a sound base for subsequent independent study in chosen topics of heterocyclic chemistry. The research workers in the subject, including those pursuing work in biological and medicinal chemistry, will find the perusal of this book fruitful and rewarding.

The text on the whole is well done and well illustrated, but the price of this useful book will come in the way of Indian buyers, particularly the students. One wishes that a reasonably priced Asian edition of the book will be made available.

HARKISHAN SINGH

PUBLICATIONS RECEIVED

THE FREEZING PRESERVATION OF FOOD, Vol II, edited by Donald K. Tressler, Wallace B. Van Arsdel & Michael J. Copley (AVI Publishing Co Inc, Westport), 1968. Pp ix+397

THEORY AND DESIGN OF IRRIGATION STRUCTURE by R. S. Varshney, S. C. Gupta & R. L. Gupta (Nem Chand & Bros, Roorkee), 1969. Pp xvi+632. Price Rs 22.50

SYMPOSIUM: DAIRY LIPIDS AND LIPID METABOLISM edited by M. F. Brink & David Kritchevsky (AVI Publishing Co Inc, Westport), 1968. Pp xi+233. Price $ 17.00

ELECTROMAGNETIC RADIATION IN SPACE edited by S. G. Emming (D. Reidel Publishing Co, Dordrecht), 1967. Pp viii+307. Price f 58

THE STRUCTURE OF THE QUIET PHOTOSPHERE AND THE LOW CHROMOSPHERE edited by C. de Jager (D. Reidel Publishing Co, Dordrecht), 1968. Pp 240. Price f 30

INDUSTRIAL MICROBIOLOGY by L. E. Casida, Jr (John Wiley & Sons Inc, New York), 1968. Pp xi+460. Price $ 14.50

HANDBOOK OF EXPERIMENTAL PHARMACOLOGY: Band XXIII—NEUROHYPOPHYSIAL HORMONES AND SIMILAR POLYPEPTIDES edited by B. Berde (Springer-Verlag, Berlin), 1968. Pp vi+967. Price $ 48.00

HIGHWAY MATERIAL TESTING by S. K. Khanna & C. E. G. Justo (Nem Chand & Bros, Roorkee), 1969. Pp x+167. Price Rs 7.50

EXCITON MEGANONS AND PHONONS IN MOLECULAR CRYSTALS (Cambridge University Press, London), 1968. Pp xi+224. Price 70s

LABORATORY MANNUAL OF PEDIATRIC MICROBIOCHEMICAL TECHNIQUES by Donough O'Brien, Frank A. Ibbott & Denis O'Rodgerson (Hoeber Medical Division, Harper & Row Publishers, New York), 1968. Pp xiv+367. Price $ 11.90

PIGMENTS — AN INTRODUCTION TO THEIR PHYSICAL CHEMISTRY edited by David Patterson (Elsevier Publishing Co Ltd, London), 1967. Pp xii+210. Price 65s

FIBRE REINFORCED MATERIALS by G. S. Holister & C. Thomas (Elsevier Publishing Co Ltd, London), 1966. Pp xiv+154. Price 45s

NOTES & NEWS

International conference on high energy physics

Recent developments in high energy physics were reviewed and discussed in the 900 and odd contributed papers presented at an international conference organized by the European Centre for Nuclear Research (CERN) and held in Vienna during 28 August-5 September 1968.

A prominent feature of the discussions was the confirmation, through accurate experimental results, of some of the old fundamental principles in the field of high energy physics, whose validity has been considered doubtful. Need has particularly been felt for revising old ideas in electromagnetism, so as to explain the difference between the electron and the mu meson. Results were presented on wide angle electron-positron production which have established the validity of the present theory of electromagnetism down to distances of nearly 10^{-15} cm. A new value for the magnetic moment of mu meson, differing from the theoretical value by less than two standard deviations (the agreement being one part in 10,000) was reported.

Several papers were concerned with the invariance of the motions of the elementary particles under the reversal of the direction of time. No violation in inelastic electron-proton scattering was reported. Many experiments were reported, whose object has been to understand the violation of time reversal invariance, indirect evidence for which was obtained some years back in the existence of the decay of long lived K mesons into two pi mesons.

No instance of any process violating the symmetry principle relating the change of charge to that of 'strangeness' in weak decays of hadrons going under the name 'the $\Delta S = \Delta Q$ law' was reported. There was also additional evidence in support of the law determining the change of isotopic spin (I) of strongly interacting particles entering in a weak decay process — the $\Delta I = \frac{1}{2}$ law.

Among the new particles reported were seven hadrons and one meson, which fit relatively easily into the present symmetry schemes.

There was considerable controversy in respect of the evidence from cosmic rays that a new particle may be involved in the creation of the mu meson in cosmic rays. The evidence is from the variation of the number of mu mesons with vertical angle. If the mu mesons rise from pi mesons, then the pi mesons will have a chance to decay into mu mesons than to suffer nuclear interactions if they travel through the rarer part of the atmosphere. This is achieved best by pi mesons travelling nearly horizontally. Thus more horizontal mu mesons may be expected than vertical ones. Against this, in an experiment conducted underground in Utah, little angular variation of mu meson production was observed. This was explained by supposing the mu meson to be one of the decay products of a new particle produced in the primary proton-nucleus collision in the upper atmosphere. Such a new particle might even be the intermediate vector boson suggested to mediate the weak interactions in a similar way to the mediation of the electromagnetic interaction between charged particles by the photon. Conflicting experimental evidence was presented from India, based on an experiment conducted at the bottom of a gold mine at Kolar. The angular variation of the mu meson intensity was found to agree with that expected if the mu mesons arise from the decay of the pi mesons [*Sci. J.*, **4** (11) (1968), 34].

Progress in the field of liquid crystals

The proceedings of the Second International Conference on Liquid Crystals, held at Kent in August 1968, have revealed several novel applications for such crystals in industry and medicine and indicated a wide scope for further research in the application of the crystals in several fields. Liquid crystals exhibit both the fluid characteristics of a liquid as well as the optical properties of a crystal. There are three types of liquid crystals: (i) nematic, (ii) smectic, and (iii) cholesteric. The molecules in a nematic type crystal are arranged like the pencils in a long box and this arrangement permits the rolling of the molecules back and forth slipping lengthwise, while being parallel to each other. In the smectic type, the molecules are arranged in neat rows, comparable to a field of corn. A common example of the smectic type liquid crystal is the layers forming the inner and outer surfaces of a soap bubble. The cholesteric type crystals have a structure characteristic of a large number of compounds containing cholesterol (which does not have a liquid crystal phase by itself) and are packed with molecules in the same pattern as in the nematic type, ie with the long axes parallel; their direction, however, is displaced slightly in adjacent layers, with the result that the overall effect is that of a helical path. Most cholesteric substances are colourless liquids.

The most striking feature of liquid crystals is the series of vivid colour changes they undergo with even very slight variation in temperature. When cooled through their liquid crystal phase they undergo a series of bright colour changes. The rate of change from colour to colour as well as the exact temperature at which specific colour changes occur are invariable for any given compound. Mixtures of these materials have, therefore, found application for measuring surface temperatures as well as temperature variations. This property is the basis for non-destructive testing of such industrial equipment as metal casting semiconducting devices, printed circuit assemblies and other items in which flaws produce differential heat flow.

Using liquid crystals it would be possible to determine if blood circulation improves in cases where surgery is resorted to in order to relieve chronic pain. Pain arising

from various kinds of spasms can often be relieved by blocking the sympathetic nervous system. This block is followed by dilatation of those vessels whose nerve supply has been cut off. If circulation is not improved amputation may be necessary. The ability of liquid crystals to reflect very small temperature changes in the human body is also being used in cancer research to determine whether tumours are malign. Areas of suspected cancer are coated with carbon black and then covered with a layer of liquid crystals. Warmer regions indicating malignancy appear blue, benign tumors appear reddish. By pre-painting the suspected areas, surgeons can determine the exact locations needing surgery.

Changes in the colours of liquid crystals coated on air frames in wind tunnels give detailed and subtle observations not possible with conventional techniques. Liquid crystals also offer a solution to the problem of detecting imperfections in microelectronic circuits, some of which have densities of some 20,000 elements per sq cm. The entire integrated circuit can be sprayed with the appropriate mixture of organic compounds, depending upon the temperature sensitivity desired. When an electric current is applied, detective components show colour differential [*Sci. News*, **94** (No. 13) (1968), 321].

Stress effect in crystals produced by illumination

An unusual phenomenon of stress effect produced by illumination in crystals has been reported from the Institute of Solid State Physics, USSR Academy of Sciences. During an experiment, two rectangular prisms ($3\times3\times6$ mm) of semiconducting cadmium sulphide placed between two plungers were deformed along one axis by applying a compressional force of the order of a few tens of grammes per sq cm for periods up to 30 sec at the rate of 10^{-5} cm/sec. When the deformation reached the plastic flow stage, the crystals were illuminated with a 500 W lamp. While the illumination continued the crystals became appreciably stronger, with the result that greater stress was needed to maintain the plastic flow. When the light was turned off the effect was found to be reversible.

Crystals grown from melts and also by sublimation of the gas phase behaved similarly. The stress decreased with increasing temperature. The effect depended also on the wavelength of the light employed, the greatest stress effect occurring at the wavelength corresponding to the maximum intrinsic absorption of light by cadmium sulphide.

It has been suggested that the effect may be due to the change in the ease with which lattice dislocations, responsible for plastic behaviour, move through the crystal. This change may occur due to the change in the number of free electrons that interact with the dislocations or due to the ionization of the atoms in the cadmium sulphide crystal. However, the new effect is presumed to be different from a similar effect in coloured crystals, in which light generates local centres that check the passage of dislocations [*New Scientist*, **33** (No. 604) (1968), 41].

Anomalous X-ray emissions from electrical insulators

During studies on the characteristic X-ray excitation caused by proton bombardment on certain targets, conducted at the Central Research Laboratory, Tokyo Shibaura Electric Co Ltd, Kawasaki, it has been observed that some electrical insulators like Al_2O_3 and SiO_2 emit extraordinarily intense characteristic X-rays. Targets of ruby (Al_2O_3) and quartz glass (SiO_2) showed respectively X-ray yields of 2500 and 10,000 times the yields in the case of pure aluminium and silicon targets. In addition, the intensity of the X-rays from the insulators presented a time dependence which varies with the strength of the incident proton beam. When the quartz glass was coated with a thin carbon film, this anomalous phenomenon was observed to cease and the X-ray yields were of the same order as in the case of a silicon target.

During the studies, the protons accelerated by a 200 kV dc accelerator were led to the target through an analysing magnet. Energy analysis of the emitted X-ray was done by means of pulse height analysis and confirmed by Bragg reflection with a KAP crystal.

The observations made so far indicate that the process of X-ray production in the electrical insulator is quite different from that in the case of an electrical conductor. For interpretation of this anomalous phenomenon, it is supposed that the X-ray emission from the insulator is associated with the electrical ' charge-up and discharge ' on the insulator surface due to the incident protons. The doped positive ions and protons produce intense electric field in the insulator. The spiked secondary electrons in the insulator are accelerated and multiplied by that electric field. These electrons contribute to the generation of very intense X-rays [*J. phys. Soc. Japan*, **25** (1968), 1199].

Gadolinium molybdate — A new type of ferroelectric crystal

Recent work done at the Advanced Electronic Devices Branch, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio, has indicated that the ferroelectric properties in gadolinium molybdate, $Gd_2(MoO_4)_3$, originate from a new mechanism completely different from that in conventional ferroelectric materials. This substance is observed to be ferroelectric even below 159°C (the Curie point T_c). In conventional ferroelectricity the function χ_{33}^x (dielectric inverse susceptibility at constant strain) is a decreasing function of T, passing through zero near T_c. In the case of $Gd_2(MoO_4)_3$, however, measurements of χ_{33}^x (or what is equivalent, ϵ_c^x, the dielectric permittivity of the crystal in the clamped condition) show no change throughout the whole range of temperature from 25° to 180°C, and in particular give no indication of a Curie point at 159°C. The crystal shows a discontinuous behaviour in its elastic constant c_{66} at T_c and a changeover to a state of finite strain. The variation of ϵ_c^x with temperature exhibits a weak anomaly at T_c.

It would thus be seen that while the dielectric properties of $Gd_2(MoO_4)_3$ are normal, the spontaneous polarization is the consequence of an elastic instability

giving rise to a spontaneous strain in the original piezoelectric paraelectric phase. This spontaneous polarization is what makes $Gd_2(MoO_4)_3$ a completely new class of ferroelectric substance, in which spontaneous polarization and deformation occur without high permittivity, giving properties which may be exploited in device applications. Since the spontaneously deformed state is controlled by the higher order elastic constants, and the deformation is 'labelled' by an easily measured polarization, materials of this type may contribute quite effectively to a better understanding of elastic properties at large strains [*Phys. Rev. Lett.*, **21** (1968), 812].

A new method for determining reflection coefficient of an inhomogeneous layer

An explicit expression for the evaluation of the reflection coefficient of an inhomogeneous layer has been reported by S. Kolník and K. Macák of the Natural Science Faculty, Comenius University, Bratislava. Since the velocity of wave propagation in an inhomogeneous medium depends on physical parameters which have different values depending on their coordinates, it is difficult to arrive at a correct solution. For this reason, attempts made till now to solve problems relating to propagation of mechanical, electromagnetic or de Broglic waves through inhomogeneous media have been mostly limited to the one-dimensional case, ie the case when a wave passes through a layer whose parameters depend on only one coordinate. Even this problem is in general difficult to solve. Problems conforming to this case are often encountered in optics, typical examples being (i) in the geometrical optics approximation where the refractive index changes very slowly with the layer thickness, and (ii) in Drudes' formula which is associated with the rapid change of refractive index for the transition layer. The new method of determining the reflection coefficient makes use of an idea reported earlier by A. Vašíček [*Optics of thin layers*, NCSAV, Praha, 1956]. According to Vašíček, the inhomogeneous layer can be replaced by a system of N-1 thin homogeneous layers for the calculation of the final reflection coefficient. If one takes a sufficiently large number of layers, the calculated resulting reflection coefficient $R^{(N)}$ will be practically independent of their choice and can be considered as a good approximation of the real coefficient of reflection R.

In the new method, the procedure suggested by Vašíček is made use of along with an expression derived by one of the authors for R. It is assumed that $R = \lim_{N\to\infty} R^{(N)}$ [*Czech. J. Phys.*, **B18** (1968), 749-62].

Oxygen determination in nuclear fuels

An inert gas fusion-gravimetric method for the estimation of oxygen content in mixed plutonium and uranium oxide fuel materials has been developed at the Los Almos Scientific Laboratory, USA. In the new method 1 g of the oxide is ground and pelleted with 0·2 g of carbon. The pellet is slowly heated to 2000°C in a graphite crucible kept in an inert gas fusion apparatus. The carbon monoxide and carbon dioxide evolved are swept by an inert gas, argon. Carbon dioxide is absorbed in an Ascorite tube and carbon monoxide is oxidized over hot copper oxide to carbon dioxide, which is absorbed in a second tube. The oxygen content is calculated by the increase in weight of the two tubes.

The pelletization of the oxide and carbon eliminates the need to use a platinum bath and as the pellet contains excess carbon the crucible can be used repeatedly. The accurate determination of oxygen permits calculation of oxygen-to-metal ratio in the fuel materials. Many important properties of the refractory oxide fuel materials depend on these ratios [*Chem. Engng News*, **46** (No. 44) (1968), 22].

Bis-(trimethylsilyl)-diazine: A new compound

An organometallic diazine with silicon atoms substituted on both nitrogen atoms has been synthesized by Dr Nils Wiberg and his coworkers at the University of Munich. Starting with a silyl hydrazide and using low temperature oxidation technique, a blue liquid which decomposes above −35° was obtained. It is a highly active compound and sensitive to oxidizing agents.

Equimolar quantities of tosylazide and N-lithium-tris(trimethylsilyl)-hydrazide were combined in ether solution at −78°C. At this temperature the mixture yielded one mole of nitrogen gas per mole of tosylazide within 2 hr. Ether was subsequently removed via high vaccum at −45°C. The residue, a green solid, under high vacuum gave a blue liquid at −30°C leaving behind a yellow solid. Analysis of the liquid confirmed it to be bis-(trimethylsilyl)-diazine. Mass spectrometer analysis gave molecular weight that agrees with the calculated value; NMR studies show a single sharp signal in the region of the trimethylsilyl protons.

The metal substituted diazine $(CH_3)_3SiN = NSi(CH_3)_3$ could exist in three isomeric forms — *cis*, *trans* or linear — but which of the forms it actually takes has not been determined.

The diazine hydrolyses quickly and the end products are nitrogen and hydrazine. It burns in oxygen with a bright flame and decomposes quickly at room temperature. It is very unstable in the presence of oxidizing agents and, unless suitable precautions are taken, can react with them giving violent explosions [*Chem. Engng News*, **46** (33) (1968), 39].

Method for suppressing the process of rejection of transplanted organs

A technique which prevents the body of a rat from rejecting a transplanted organ, while at the same time preserving the immune reaction responsible for fighting infections, has been developed by a medical research team of the Pritzker School of Medicine, University of Chicago. Currently the rejection process, caused by the normal action of white blood cells, is controlled through powerful drugs. The drugs, however, suppress not only the response to the transplants, but responses

to all other antigens also. Consequently, patients with transplanted organs are extremely vulnerable to many kinds of infection. The new technique has the advantage of specifically suppressing the cell type response to the transplant without affecting the reaction to other antigens.

The method is based on two principles. First, antibody regulates or controls the immune response to its antigen. This involves that the antibody acts as a feedback control to limit the response to the antigen. When antibody produced in one individual is given to another who has not been exposed previously to the antigen, the immune response is markedly suppressed. Secondly, antigen can be given so that an antibody rather than a cell type of response predominates. In practice, rats are treated with an antidonor antibody and with donor antigen at the time they receive a kindly transplant; no additional treatment is necessary. The transplanted kidney survives indefinitely and functions normally. The animal's response to infectious organisms is not affected. The antibody partially suppresses both the antibody and cell type responses to the transplanted kidney. The donor antigen directs the response of the host, so that only harmless antibody against the graft is formed [*Sci. J.*, **4** (11) (1968), 4].

Indian Institute of Petroleum, Dehra Dun

The annual report of the Institute for the year 1967-68 records its major research and development activities and achievements in the fields of lube oil evaluation, catalytic reforming, hydrogen processing, speciality products and additives, process design, catalysts, performance evaluation of lubes and fuels, and proteins from petroleum. A survey of the demand of petroleum products and projections up to 1975 was made. Market surveys were conducted in respect of paraffin wax, catalysts for ammonia manufacture and refinery processes, and speciality greases. The Institute undertook consultancy work on behalf of the Indian Oil Corporation for a lube oil blending plant at Madras capable of blending 70,000 tons/year base-stocks available from the Madras refinery. Systematic evaluation of crudes from Rudrasagar, Lakwa and Kalol fields was carried out.

The octane requirements of Indian cars have been regularly evaluated with the buildup of mileage. It has been found that the gasoline presently marketed does not adequately meet the requirements of cars. Studies are in hand on the production of a variety of products of interest to the petroleum industry. These include cyclohexane, alkyl phenols, 2,6-di-*tert*-butylphenol, *p*-*tert*-butylphenol, octyl and dodecyl phenols, and ichthammol. The production of high impact polystyrene by graft polymerization of styrene with natural rubber has been investigated.

A batch reaction apparatus flask has been set up for the preparation of reference grade iso-octane for engine testing by liquid phase conversion of *tert*-butyl alcohol. In the project relating to the production of protein concentrates from petroleum sources, a satisfactory method for treating the cream with a mixed solvent system has been developed; the yeast cells obtained are free from hydrocarbon odour. By maintaining the temperature during drying below 60°, yeast cells are obtained as a fine pale yellow powder. The data obtained in respect of solvent treatment were made use of in designing the solvent treatment and solvent recovery units of the protein pilot plant. The mixed solvent composition required for obtaining yeast cells free from oil has been correlated with the percentage paraffinic carbon of the oil to be treated. The pilot fermentation unit supplied by the French Institute of Petroleum was installed and test runs started.

Among the equipment and appliances developed during the year are: (1) a device for adjusting the fuel feed into automotive CI engines at high altitudes for power boosting; (2) a fuel/air mixture correction device for varying the fuel supply rate for jeeps; and (3) burners with pulsating and continuous combustion.

A method developed for estimating small quantities of CO and CO_2 in combustion exhaust gases involves their quantitative conversion to methane, which is analysed by gas chromatography using a flame ionization detector.

In connection with the evaluation of anti-knock performance of fuels in automotive engines in actual practice, facilities have been developed for determining the Road Octane Number of the fuel. The possibility of using naphtha as fuel in cement kilns has been investigated. Preliminary studies have indicated that using pressure jet burners, it is possible to obtain flame characteristics comparable to those with I.DO, by choosing proper nozzle design, operating conditions and air swirlers.

Complete design was prepared for a lube reclamation plant with a capacity of 500 tons/annum.

For undertaking liquid solubility determinations in polythene for various hydrocarbons, an apparatus has been designed and fabricated which measures vapour solubility at various pressures and temperatures. In connection with the project on the study of flame structures, a set-up for obtaining shadowgraphs was standardized. A set-up for making burning velocity measurements was designed.

Structural Engineering Research Centre, Roorkee

The annual report of the Centre for the year 1967-68 records the large-scale adoption of hot-rolled and cold-worked deformed bars developed in its laboratories as substitutes for mild steel in concrete reinforcement as its major achievement. A handbook on reinforced concrete dealing with the working stress method was published during the year.

A plane torsion-free profile has been developed for northlight shell roofs with centre of gravity and shear centre nearly on the same vertical line. A comprehensive testing programme on the mechanical properties of deformed bars and the behaviour of structural members reinforced with them has been taken in hand. The method of twin cantilevers developed earlier for the analysis of shear walls has been extended to include the effect of shear deformation in walls and interconnected shear walls. Work has been completed on the standardization of precast prestressed bridge girders in the

span range 7·5-36 m. A method has been developed for the direct design of prestressed concrete sections in flexure. A device has been designed for the direct measurement of pressure on grain storage silos.

Based on the plastic theory, portal sheds of spans ranging from 6 to 18 m in steps of 3 m have been standardized. Computer programmes were developed for the complete automatic design of transmission towers. Improved programmes were developed for the analysis of pin and rigid-jointed space frames. A programme for the analysis of grids has been written to accommodate as many as 200 joints utilizing orthogonal and circular symmetries that may be present in the structure.

A slope measuring device has been designed and fabricated; the device measures the tilt of power house floors over a long period of time (over 5 years). A simple and sensitive mechanical device capable of measuring slopes as small as 5 sec was designed for the purpose. A Moire's fringe apparatus for the analysis of plates and slabs was fabricated.

Announcements

▪ *Sir C. V. Raman, N.L.*, is among the six foreign scientists to be conferred the honorary membership of the Club de Mineralogia, Recife, Brazil, on the occasion of the tenth anniversary of the Club in recognition of his contributions to structures of diamonds and studies on gem stones.

▪ *A Seminar School in Physics of Condensed Matter* will be held at the Indian Institute of Science, Bangalore, under the auspices of the Tata Institute of Fundamental Research, Bombay. Lectures will be developed by Prof K. S. Singwi, Argonne National Laboratory, USA, on 'The theory of atomic motions in liquids' and by Prof A. T. Stewart, Queen's University, Canada, on 'Position annihilation in solids and liquids'. Further details regarding the summer school can be had from Shri V. G. Kulkarni, Tata Institute of Fundamental Research, Colaba, Bombay 5.

▪ *A Conference on the Design and Analysis of Chemical Process Systems* will be held at the Department of Chemical Engineering, Indian Institute of Technology, Kanpur, during 23-27 October 1969. The tentative programme of the conference includes technical sessions on (1) Process development and pilot plant studies; (2) Process simulation (with emphasis on analogue and digital computers, machine storage and data handling); (3) Scale-up (dimensional analysis, simulation, uncertainty of safety factors); (4) Process dynamics and control (including control studies based on analogue and digital simulation, controlled cycling, process transients, on-stream analysis and computer control); (5) Process design (performance and layout of complete and integrated process systems, process economics, project engineering, mechanical and structural considerations, thermodynamic analysis of process cycles and flowsheets, computer calculations of energy and material balances for complex systems, etc); (6) Modification, improvement and scale-down of existing (commercial) processes (process analysis, simulation, control, trouble-shooting, technological updating, improving process performance and economics); and (7) Optimizing (experimental, mathematical and computer methods for approaching optimal economic performance of chemical process).

Further details can be had from the convener, Prof M. Gopala Rao, Head, Chemical Engineering Department, Indian Institute of Technology, Kanpur.

▪ *The Fourth International Congress on Pharmacology* will be held at the University of Basel, Switzerland, during 14-18 July 1969 under the auspices of the International Union of Pharmacology (IUPHAR). Prof K. Bucher of Basel is the President of the organizing committee. Further information regarding the congress can be had from the office of the Congress on Pharmacology 1969, Postfach 30, 4000 Basel 4 (Switzerland).

▪ *A Symposium on the Physiology and Biochemistry of Muscle as a Food* will be held during 13-16 July 1969 at the University of Wisconsin, Madison, Wisconsin, USA. The broad subjects of discussion at the symposium will be muscle cell development, red and white muscles, muscle membrane systems, myofibrillar proteins, stromal and sarcoplasmic proteins, muscle adaptation, muscle metabolism and biology of muscle as a food. Further information regarding the symposium can be had from Dr E. J. Briskey, Muscle Biology Laboratory, College of Agricultural & Life Sciences, University of Wisconsin, Madison, Wisconsin 53706.

▪ *The 1969 International Clay Conference* to be organized by the Science Council of Japan under the auspices of the Association Internationale Pour l'elude Des Argiles (AIPEA) will be held in Tokyo during 5-10 September 1969. The main areas of discussion at the conference will be clay mineral structure, clay mineral genesis, clay water system and ion exchange, clay organic compounds, and industrial applications of clays and clay minerals. The following fields will also be covered: Interstratified clay minerals — structure and origin, non-crystalline minerals in soils, wall rock alteration, and infrared study of clay minerals. The official language of the conference will be English.

Further details can be had from the Organizing Committee, 1969 International Clay Conference, Science Council of Japan, Ueno Park, Tokyo 110, Japan.

SUPPLEMENT

to

Glossary of Indian Medicinal Plants

by

R. N. Chopra, I. C. Chopra & B. S. Varma

In the year 1956, the Council of Scientific & Industrial Research, New Delhi published a Glossary of Indian Medicinal Plants with a view to presenting concise information regarding their properties, uses and important constituents. Over 2600 species, belonging to about 1350 plant genera, have been dealt with. The information is given under the botanical names of the plants, which are arranged in their alphabetical sequence; trade and vernacular names are also mentioned. The Glossary gives distribution of the plants, diseases for which the particular plant is used, and the active principles. Adequate literature references to the sources of information are also provided. The book ends with two comprehensive indexes: one pertaining to the vernacular and trade names, and the other to the chemical constituents.

In order to bring the Glossary up to date, this Supplement has been brought out. It follows the style of the Glossary and covers all relevant information published during the period 1955-64. The Supplement provides additional information on over 700 species already mentioned in the Glossary, and includes about 380 new species. Indexes covering additional vernacular and trade names and chemical constituents have been provided. The Supplement, like the original Glossary, will be useful not only to the practitioners of indigenous system of medicine, but also to all others who are interested in drugs of vegetable origin and common bazaar medicines.

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