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MAN, ENERGY AND LIFE

By

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For the past ten years we have been living in the most rapid and universal expansion of economic activity that the world has ever seen. Recently, there has been a little slowing down but there is no reason to think that the upward progress will not continue provided that the spirit of world co-operation of one nation with another is kept alive. Nature's erratic and unequal distribution of her resources among the peoples of the world makes this essential. One result of this expansion has been to make us all energy conscious. Previously in the older industrialized countries with abundant cheap coal, energy was something that people took for granted. That is no longer possible. Today every source of energy is being brought into service and there have been great changes in the pattern of its use. People have realized too that a country's consumption of energy per capita is a measure of its productivity and standard of living. So the provision of energy is vital to progress.

The driving force in this great period of economic expansion has been scientific research and its applications by the technologists to meet human needs. This century has seen amazingly rapid progress in man's understanding of nature's ways which has made possible a much closer partnership with her on which man's material future so largely depends. And all these new developments have demanded a greater and more diversified use of energy which has involved changes both in the sources of the input of primary energy and in the forms of secondary energy in which it has been ultimately utilized. In the XIX century coal supplied nearly the whole of the world's input of commercial fuels. Today it supplies only 48 per cent of the input of commercial fuels, while crude oil accounts for 34 per cent, natural gas 11 per cent and hydro-electricity 7 per cent.

Turning to the points of use, nearly 70 per cent of this primary energy is used in the forms of electricity, liquid fuels or gas. The reason for this is clear.

* Lecture delivered at the 45th Session of the Indian Science Congress, Jan. 1958.

It is due to the versatility and efficiency with which these forms of energy can supply the varied needs of the consumer, including his new mobility by land, sea and air, for which he has to thank the internal combustion engine in its various forms. One most striking fact has been the steady growth of electricity, almost unaffected by booms and slumps. In recent years it has grown by $7\frac{1}{2}$ per cent compound. Oil and natural gas too have grown by over 5 per cent compound, while the world input of primary energy has only been increasing at $2\frac{1}{2}$ per cent compound.

With mankind's increasing dependence on energy, with the growing costs of winning and transporting fossil fuels and with their unequal distribution among the nations, the future of energy supplies has become an urgent problem for many countries. It is a paradox of human destiny that war and the threat of war should have quickened so much the urge to research and development. Never has there been such a concentration of scientific and technological effort on a single issue as on the development of atomic weapons, and in turn on the application of all that knowledge to peaceful ends. As the result nuclear energy is beginning to be available just when it may be so badly needed to supplement the conventional sources, especially in countries like India lacking oil and natural gas and where coal deposits may be distant from consuming areas with a heavy cost of transport.

The individual circumstances of the energy resources and demands of each country are so varied that these world statistics are of little direct significance except in showing the changing pattern of the energy economy and the prospects of the availability of imported fossil fuels where they are needed. India, like every other country, has her own energy problems on which her development is inevitably dependent.

At the recent meetings of the World Power Conference in Vienna and Belgrade I drew attention to the importance in our discussions of getting the right balance between the energy needs of industry and agriculture. This seems to me of special significance for countries in an early stage of industrialization where the example of the older industrialized countries might be misleading as the conditions of employment and manpower are so different. The lure of mechanization may have its dangers. Each country has to base its energy policy on its own conditions. Energy is not an end in itself, it is only the means to an end, the optimum development of the natural resources, both living and inanimate, of each country with the object of raising the standard of living of each individual and adding to the human satisfactions and happiness of his or her life.

Machines and their energy requirements have been the major factor in the evolution of our modern civilization. There are many things that only a machine can do, things on which modern industry is based and on which agriculture is becoming increasingly dependent. There are others which can be done equally well manually and relative costs will decide. There is a third class in which the machine is more efficient than human labour, for example in agriculture for harvesting, for the elimination of weeds and for sowing seeds, but circumstances may make it expedient to use manpower.

In Belgrade at the World Power Conference I suggested "that the optimum relationship of man to the machine is one of the basic problems in the planning of development for each country. Great changes in the social fabric are involved. With the onset of industry come the factory system and urbanization, and the development of agriculture will involve some system of co-operative working.

Now which is the better objective, a quick transition to the automatic factory, cutting out the intermediate stages through which the older industrialized countries have passed, or a fresh stimulus to village and small industries by the provision of power and transport? Circumstances will decide, bearing in mind that a basic consideration is the raising of the purchasing power of individuals to enable them to benefit by the change." It was with these thoughts running in my mind that I read your *Second Five-Year Plan* which I know owed so much to the broad approach and wise judgment of the "frame plan" which was compiled by Professor Mahalanobis and his colleagues. I read too the Handbook of your Central Water and Power Commission, *Planning for Power Development in India*.

I was naturally glad to find that your planning is based on just the considerations that I had in mind. It is directed to increasing both production and productivity so as to meet the growing needs of India and to raising continuously the standard of living at all levels. The four ways in which energy can contribute most directly to these objectives are:—

1. To provide the power and heat needed by industry.
2. To increase the efficiency of agriculture.
3. To provide the necessary communications and transport.
4. To raise the standard of comfort and health in the home.

Without energy there can be no large scale industry, so that the location of industry and the progress of industrialization are dependent on its availability. The main trends of modern industry are towards mechanization, continuous processes, automaton, and the more scientific processing of raw materials, all involving an increasing use of energy.

In agriculture too, energy is playing an increasing part. The availability of power on the farm means higher efficiency and it is essential in most irrigation schemes for pumping, and for the sprays that provide the most economical use of water. In the development of new areas of cultivated land, machines have an immense advantage over human labour in the initial clearing, levelling and ploughing and they are needed too for the modern methods of road making.

Communications and transport are a necessary preliminary to development in order to make accessible the indigenous resources of each country and to facilitate the movement of raw materials and manufactured goods.

One of the main features of progress in the more advanced countries has been what I once called the Domestic Revolution of the XX Century—the provision of heat and power in the home which has done so much to raise the standard of health and comfort and relieve the housewife from unnecessary drudgery. This is now becoming an objective in every country.

These are general observations and turning now to India's Second Five-Year Plan, I see that of the capital expenditure 12 per cent goes to agriculture including community development and support of village panchayats, and in addition 10 per cent goes to irrigation and flood control for the benefit of agriculture and 4 per cent to village and small industries. Of the rest 9 per cent goes to power and 29 per cent to transport and communications, both of importance to agriculture, leaving 14 per cent for industrial and mineral development and 20 per cent for social services. That seems a very realistic distribution of your

development resources taking into account that 71 per cent of the population is engaged in agriculture and of the need to develop village and small scale industry to give much needed widespread employment, even at the sacrifice of some efficiency. Again it is the optimum relationship of man and machine power. But in every aspect of the plan energy has its part to play.

Considering her population and her great area Nature has not endowed India with rich reserves of the conventional forms of energy as compared with other countries. You have a great water power potential of which only a fraction, possibly 2 per cent, has been developed, but much of it is far from centres of consumption. Your population is scattered over great areas, much of it in small villages, and costs of distribution will be high. You have considerable deposits of coal, but a limited amount of good coking coal which should be reserved for your iron and steel industry, for which it is essential, but again much of the coal is far from where it is needed and transport costs of solid fuel are high. The lack of oil and gas, which you share with Britain, is a handicap with the growing importance of these fuels. That is a very brief summary of the short term estimate of your conventional energy resources—fortunately you have in the future another alternative.

At the meeting of the British Association in Dublin last September Dr. Bhabha gave us a most illuminating sketch of the probable course of the development of atomic power in India. Your reserves of Uranium and Thorium (the latter the greatest in the world) are equivalent in energy value to more than 30 times your reserves of coal. You have also rich reserves of Beryllium and Zirconium which are likely to find important applications. Dr. Bhabha showed us that even at the present costs of large atomic units there are parts of India where an atomic station could today compete with a thermal station owing to the heavy cost of transporting coal over long distances. He pointed out that India needs in addition a number of smaller stations of say 20 megawatt capacity, presenting a more difficult design problem towards which your experimental programme is at present directed. Atomic minerals with their high energy content will be relatively cheap to transport, and when nuclear reactors are economic sources of power, even in smaller sizes, and also of industrial heat, one can foresee great changes in India's energy economy. But that is not just round the corner. It will take time and money. Fortunately the use of atomic energy for peaceful purposes is a field in which the nations of the world are ready to co-operate and share their secrets, with the quickening of progress that must result. Atomic energy may not be the immediate solution of your energy problems but it will certainly occupy an important place in long term plans, but at the same time the conventional sources must not be forgotten.

At Vienna in 1956, Professor Thacker, your President this year, told us that the greater part of India's consumption of energy in 1953, in fact nearly 80 per cent, was met from non-commercial sources, wood, bagasse, and mainly from the dung which is so badly needed by the farmer to manure his crops. Coal contributed 19 per cent, hydro less than 1 per cent and oil just over 3 per cent on a calorific basis. It must be difficult to estimate the contributions from the various non-commercial sources, but as some 78 per cent or more comes from dung it is not surprising that your consumption of energy per capita (about one-third of a ton of coal equivalent), even taking into account the large proportion of your population engaged in agriculture, is at present extremely low compared with that of more industrialized countries. Raising the level of energy supplies is obviously an important factor in your development. Your existing centres of industry have naturally developed near to coal fields or water

power and their future energy supplies are mainly dependent on the investment available. The provision of more energy for domestic use, for village industry and agriculture is one of the objectives of the Five-Year Plan. In your warm climate energy for cooking and heating water is probably the main domestic demand. We are just beginning to explore the use of solar energy, of which you have so much, for these purposes. The papers read at the Symposium on "Solar Energy and Wind Power" at New Delhi in 1954 showed that there are great possibilities both for the solar cooker and water heater if the cost can be reduced.

The future of your villages must depend increasingly on co-operative action and turning to practical account the community spirit of village life. The village well may find its counterpart in a solar heater for village hot water to be used in the preparation of food. You need afforestation for many reasons set out in the Five Year Plan. Trees grow quickly in your climate when conditions are favourable. Might it not be possible by planting quick growing trees on the common land of villages to supply a greater amount of village fuel in future by waste wood and cuttings and thus save the waste of precious dung?

Water is perhaps your greatest limiting factor today in spite of the great resources of your rivers of which only a small fraction is harnessed. Clearly the development of multipurpose water schemes, like those of the Damodar Valley Corporation, combining power production, flood control, soil conservation and irrigation will meet some of your most pressing needs. The Second Five Year Plan will treble your hydropower capacity and add 40 per cent to your irrigated area. The benefits of these multipurpose schemes which are integrated with the human needs of the communities they serve can far transcend the direct material advantages they bring. The Damodar Valley Corporation, modelled on the Tennessee Valley Authority, is a good example of the close link between energy and social values.

I am not forgetting that in your great continent there are half a million small towns and villages with less than 5,000 inhabitants, many of them remote from generating stations. They will need small scale power for village industries and even more urgently for lift irrigation. For the latter, the papers at New Delhi showed that in many parts of India windmill driven pumps or water lifts will in time be a valuable supplement to the bullock driven Persian wheel, just as they are in South Africa. There are, in addition, three possible alternatives to diesel sets, which will not need imported fuel. Small steam engines can be run on wood or waste materials, or these may be burnt in a producer to give producer gas as a fuel for an internal combustion engine. The third alternative is the fermentation of agricultural wastes to give methane which is an ideal fuel for engines.

There remains the problem of the supplies of liquid fuel needed for transport. Two refineries are now in action in India working on imported crude, and home made fermentation alcohol is blended with motor spirit. Unless indigenous oil resources are found, the time will come when oil will be made from coal or lignite by synthesis. This is already being done in the Sasol plant in South Africa, and the synthetic chemical industry, which is of such rapidly growing importance, must in time be based on synthesis gas made from coal rather than from oil and natural gas. The world reserves of coal are immensely greater than those of oil and India is well supplied in certain areas with low grade steam coal, non-coking coal and lignite.

PART II

So far I have been dealing with man's uses of energy to supply his needs of heat and power. His concern with energy does not end here as a constant supply of energy is necessary for the existence, not only of man, but of all the living organisms on which he is dependent in so many ways. To start with man himself: the body is akin to an internal combustion engine in its dependence on food and oxygen but its mechanism is very different as it works at constant temperature. It is significant that we estimate our need of food in terms of calories. This varies, depending on the muscular effort exerted by the individual. The body of a normal man requires about 1,600 kilocalories a day to keep it ticking over—to maintain the body temperature, to circulate the blood and to supply the energy needed for the chemical reactions of the body. In addition a man doing heavy work requires 100 to 250 kilocalories an hour, which the body can use with an efficiency of roughly 22 per cent, corresponding to a mean output of work of one twentieth of a horsepower. The average daily consumption of food varies from country to country, depending on the climate and the standard of living. In some it is 3,000 kilocalories or over, in others below 2,000, in India it is 1,850 kilocalories in recent years. The total annual human food consumption of the world contains about 200×10^{13} kilocalories which is equivalent to 7.5 per cent of the input of primary energy in fuel and water power. This is the food actually consumed by human beings, in addition much is lost in storage, transit and preparation and a large quantity is fed to animals, of which only a small proportion re-appears as food. So that the energy content of the crops, including grass, which are consumed or harvested might easily be as large as 25 per cent of the primary energy consumed as fuel or water power. This is a world figure and would vary greatly from country to country.

Now I said that the mechanism of the body is very different to that of an internal combustion engine as it works at constant temperature, though its efficiency for muscular work is of the same order. How does it do it? How is the energy of the chemical reactions in the body converted into muscular effort. The key to so many of the energy changes in living organisms is the existence of certain compounds of phosphoric acid containing energy rich bonds, of which adenosine triphosphate, A.T.P. for short, is the most important. They act as carriers of the energy originating in the oxidation in the body of compounds like glucose, and they play a vital role in the life of the organism in many ways. How that chemical energy is converted to mechanical effort by the muscles is still one of nature's secrets. There are many speculations as to how she does it, but we do not know.

However researches have revealed one most interesting point. We can measure the ratio between the force developed by a muscle per square centimetre of cross section with the energy used per cubic centimetre of muscle in developing it. This ratio has the same value in the leg muscles of frogs and toads as in the retractor of the pharynx of an edible snail. The muscles are structurally and in speed totally different, and any common ancestor of frogs, toads and snails must have existed many hundreds of millions of years ago in the remote biological past. The near equality of the ratio in this case is much closer than physicists would be content with in most of their arguments. The inference is clear. Nature chose the best possible device and then developed it for a great variety of purposes. There is one curious difference. Man, like the frog, uses creative phosphate as his source of muscular energy at some stage of the contraction, crabs and others use arginine phosphate, with quite a different constitution. But we don't know why.

Now the muscles are controlled by messages from the brain sent in response to messages from the sensory organs or originating in the brain itself, the nerve centre of our existence. What is the brain's consumption of energy, how does it vary with its activity? That has been measured by the flow of blood to the brain and its consumption of oxygen in a most ingenious investigation by Dr. Kety in America. Several facts, surprising at first sight, emerge from these measurements. First the flow of blood to the brain is greater during sleep than when the brain is alert, but the consumption of oxygen is practically unchanged. Then it has been found that there is no perceptible increase in the brain's consumption of energy when it is engaged in continuous work such as mental arithmetic. However the brain needs much more energy than a corresponding weight of the body to keep it alive. Roughly one fifth of the blood thrown out by the heart passes through the brain, which means that it consumes ten times as much energy per unit of weight as the rest of the body. Why does the brain need this large supply of energy both sleeping and awake? No doubt because it is the integrating unit, the control room on which depends the marvellous efficiency of the body, the accurate co-ordination of sense and action. That energy is maintaining the active state of the ten thousand million nerve cells of which the brain is composed. And the memory, that vast storehouse of impressions, must be kept alive like the automatic memories of electronic computers, but with an immeasurably greater efficiency. It is not surprising, therefore, that there is no correlation between mental activity and cerebral energy consumption. The message consumes a negligible amount of power compared with that required to maintain the brain in readiness to receive it.

Even in sleep the unconscious mind is working with the flow of energy, and who can say how much we owe to it. In our researches we can plan our measurements and observations, accumulate new facts, but the flash of inspiration that marks the great advances comes from the 'deep wells of unconscious cerebration'; it is not at our command.

Life is dynamic and the slender thread on which it hangs is that ceaseless flow of energy.

Coming back once more to the large content of energy in the world's food supply, its primary source is the sun's radiation with the help of which plants are enabled to synthesize the carbohydrates and proteins which are consumed by the herbivora and handed on in turn to the carnivora. The plant actually utilizes in photosynthesis only one per cent of the sun's radiation falling on it. This sounds inefficient, but in addition as much as 40 per cent of the radiant energy provides the latent heat for the transpiration of water from the plant on which its life and growth depends. Penman has shown how largely transpiration is a function of the sunlight hours. The other half of the solar energy is lost in reflection, radiation and transmission. One of the main reasons for the low efficiency of photosynthesis is the small content of carbon dioxide in the atmosphere, but if there were more we should all be panting. Now there is a striking contrast between the productivity of the plant and the factory. For instance, a farm may produce just over a ton of wheat per acre per year, while a steel works can produce 15 tons of steel per acre per day. So the food problem that many countries are facing prompts the question—is there any hope in the future of producing food by synthesis in the factory?

Some twenty years ago I was discussing with Karl Bosch, the head of the great German chemical combine, the I.G., the prospects of tropical agriculture and the future competition between the natural and synthetic products. "Let

me tell you", he said, "what Steinmetz once said to me". Steinmetz was the genius who contributed so much in its early days to the General Electric Company's research laboratories at Schenectady. "Bosch", he said, "I know you can make indigo cheaper than God, someday you may make rubber cheaper than God, but you will never make cellulose cheaper than God." That set me thinking and made me realise that there are limits, economic limits at any rate, to the man-made synthetics. We can synthesize comparatively simple molecules economically, and we can join them into regular polymers like terylene, but we can never hope to make commercially without the help of living organisms the complex proteins and polysaccharides on which nature in the long course of evolution has decided that man must live. And yet living organisms make them so cleanly and efficiently by their template methods with the aid of enzymes, nature's catalysts, whose accurate workmanship is such a frustrating contrast to the clumsiness of the man made catalysts and chemical agents.

An old friend of mine, Gilbert Lewis, who did more for chemical thermodynamics than anyone since Willard Gibbs, used to ask the question—"does Nature cheat in the game of entropy?" Does Nature obey her own laws of energy in her living processes? Forty years ago we assumed she did obey though it was difficult to see how she managed it. Today the biochemists are just beginning to learn how Nature does solve this problem and photosynthesis, the use of radiant energy, is a particularly good example.

Professor Melvin Calvin at the University of California with the aid of chromatography and radioactive tracer elements has been able to take a series of snapshots of what happens when carbon dioxide is absorbed by the plant in sunlight and thus to trace the cyclic process from which it emerges eventually as sucrose. This cycle of operations is typical of Nature's ways. As Sir Cyril Hinshelwood has put it "a growing cell constitutes a manufactory with numerous departments, the conveyor belt leading from one to the other being represented simply by the concentration gradients. Raw materials are broken down and built up into fresh forms in a series of changes." We can appreciate today the reasons underlying the methods which nature has adopted in the long course of her evolution. She has broken down each operation into stages, each of which involves a relatively small activation energy and therefore with its own enzyme catalyst can proceed rapidly at ordinary temperatures. Equally from a thermodynamic aspect each involves only a small free energy change of the order of 10 to 15 kilocalories which can be provided or removed by an interlocking cycle at the appropriate point.

In the Calvin cycle of the photosynthesis of sugar from carbon dioxide and water, the carbon dioxide enters the cycle at one point, reduction made possible by the radiant energy absorbed by the chlorophyll takes place at another, and during a complicated series of rearrangements of sugar molecules, sucrose passes out of the cycle while the carrier molecules continue to circulate. The cycle has to be repeated six times for each hexose molecule that it produces. The necessary free energy is supplied at appropriate points by the transfer of rich energy bonds from adenosine triphosphate (A.T.P.) to the circulating molecules, the A.T.P. being reformed at the expense of degradative actions which are taking place simultaneously.

We can thus see why plant life is dependent on a supply of oxygen as well as sunlight, as oxidation supplies the additional energy required for the synthesis of the products of plant growth. So nature doesn't cheat in the game of entropy and we are just beginning to understand her amazingly complicated but efficient means of building up the complex molecules on which human and animal life depend. Energy is an essential factor at each stage.

The same is true of the myriads of micro-organisms without which life as we know it could not exist as they help in so many ways. For example, in nature's carbon oxygen cycle, plants, having absorbed carbon dioxide, fix the carbon and liberate oxygen, thanks to the input of solar energy. The process is then reversed by the respiration of men, and animals and micro-organisms, and the composition of the atmosphere remains relatively stable. But Rahn has pointed out that the return of carbon dioxide to the air by the respiration of man and animals only accounts for five per cent of the carbon dioxide absorbed by plants, hence there must be roughly 20 times as much microbial protoplasm engaged in breaking down carbon compounds and returning carbon dioxide to the air, otherwise the supply of this gas would soon be depleted. Some micro-organisms, like the unicellular algae, derive their energy largely from the sun, others by the oxidation of photosynthetic products. Some of these micro-organisms have already taken their place in the production line and possibly those with the power of photosynthesis, like the algae, may, in time, be used with higher concentrations of carbon dioxide to utilize solar energy more efficiently than the plant can in the open to produce proteins and fats. This is one of the fascinating problems of the biochemical engineering of the future.

These are some of the most significant relationships between energy and life as we know it today. By whatever chain of circumstances life first originated on this planet, energy was the driving force, not only as the basis of the affinity of the elements that determined the chemical reactions that took place, but also through the input of ultraviolet light and possibly radiation from radioactive atoms. Both would have produced activated molecules and atoms that would have assisted the natural synthesis of a huge variety of molecules containing carbon and nitrogen. Conditions for the survival of such molecules were very different then, for as Darwin first pointed out there were no micro-organisms to destroy them. Geochemists agree that in these pre-vital ages the earth's atmosphere contained no oxygen and consequently it was transparent to those ultraviolet radiations which are now, fortunately for mankind, absorbed in the ozone layer of the upper atmosphere, for the formation of which they were responsible. And so possibly in the sea, which must have been a soup of organic compounds, there may have gradually developed complex molecules with the property so universally manifested by nature of reproducing their own pattern, as in the phenomenon of the growth of crystals on a simple scale. At some period some association of these complex molecules like the nucleoproteins must have been formed with the power of photosynthesis, leading in time to an atmosphere containing oxygen which permitted the development of primitive aerobic life. At each stage energy must have been the determining factor. It was as Clarke Maxwell so well defined it "the go of things".

I have spoken of our greater understanding of nature's ways and the possibility of a closer partnership with her. She is not an easy partner. Nature made one world and man is making another. Largely by the use of energy he is changing his environment. Today he is often interfering with nature and he must watch her reactions very closely, with all the help that science can give. We split the nucleus with a neutron and nature hits back with dangerous radiations. We dam the rivers and irrigate the land, nature may silt up our reservoirs and unless drainage is good, the water table rises and salty land develops. We destroy pests with new insecticides, nature breeds resistant strains. There is no finality. Moreover the supply of food energy seems to me to bring us face to face with a dilemma of human destiny. The supply of the energy we need for heat and power with all its problems is under our control, for the supply of food we are dependent on living organisms, on agriculture with all its uncertainties and limiting factors. The trouble arises because man has

changed while nature remains herself, beautiful, marvellous but cruel, with her inexorable struggle for existence and the urge to reproduction which is her safeguard of continuity. Man through the ages has developed what we call human nature, with its humanity and conscience which characterize all the great religions of the world. He is eliminating the checks by which nature maintained a balance, famine, flood and pestilence. You can view it as another interference with nature removing some factors while leaving another, the urge to reproduction, unchanged. The result is seen in the difficulty of raising food supplies of energy to an adequate level. For some years after 1945 the main increases were in the industrialized countries where they were hardly needed and food surpluses were the result. By 1954 the production in countries like India had reached its pre-war level per capita, and lately production has increased more rapidly in Asia than in the industrialized areas. But even so, the difficulty is to keep pace with the increasing numbers. Your Second Five Year Plan recognizes this danger. "Given the overall shortage of land and of capital equipment relatively to population as in India" it says "the conclusion is inescapable that an effective curb on population growth is an important condition for rapid improvement in incomes and in levels of living." Even for slow improvement it seems to me inevitable. This is a clear example of the danger of interfering with nature without taking action to counter her reaction.

In this talk to you I have tried to outline some of the main problems of the relationship of man to energy, both as regards his needs of heat, and power and of energy as the secret of life. I have tried to touch on their bearing on your own individual problems in India. That is more difficult as I have only seen them from afar. You may well differ from me in what I have said. That will have the merit of starting discussions, and discussion lies at the basis of the advancement of science, the objective of your Congress. India has great resources and great problems. You are a great nation with a great history and on the successful solution of your problems much depends. We all admire the bold, imaginative way in which you are facing them. The presence of your guests at this Congress is a token not only of goodwill and co-operation but of hope and confidence that you will succeed.

INDUSTRIAL DEVELOPMENT IN INDIA SINCE INDEPENDENCE *

By

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Because the highest priority was given to Agricultural development including the building up of the necessary basic services like irrigation and power in the First Five Year Plan, 1951-56, it does not mean that Industrial development, has in any sense, been less important. For a country like India with an under-developed economy, there is really no conflict between agricultural and industrial development. Improvement in agriculture cannot proceed beyond a certain point unless the surplus working force on the land is progressively diverted to industries and services.¹ As early as 1883, the Famine Commission grasped the fundamental issues at stake when it pointed out that the only remedy for the recurring disasters of famine in India was rapid industrialization of the country providing diversified employment to large groups of the population. But, unfortunately, this is still no more than a vision and a dream. Progressive countries as they grow in civilisation and prosperity reduce the proportion of the population engaged in agriculture, as for example, the U.S.A. where the agricultural population has decreased from about 70% in 1850 to less than 15% in 1950, the actual production at the same time having increased by 250%. A decrease in the total number of people employed as farm-hands is likely to augment agricultural output. But alternative employment in industry, transport and trade, has to be found for these persons so diverted from agriculture. The growth and development of industries is of very great value, not merely because of the increased economic output, but also because it keeps the hands and minds of educated youths in creative work, without allowing them to drift, as a result of discontentment into undesirable political activity.

Leaving out the problem of disguised unemployment and under-employment among the cultivators, about 3.4 million people are wholly unemployed and there is a volume of under-employment equivalent to 4.9 millions of man-years, the incidence of both of these being much greater in the rural areas than in the urban centres. To make matters worse, there is also the annual addition into the labour market of about 1.8 millions, as a result of the normal growth of population.²

The relative backwardness of the industrial development in India may be judged from the fact that even as late as 1953-54, industry (mining, manufacturing, and hand trades) account for 16.1% and commerce, communications and transport, together constitute only 17.7% of the total National Income, while the exploitation of animals and vegetation accounts for 51.3%.³ The total labour force engaged in mining and industrial establishments in 1955 was

* A paper submitted to the International Geographical Conference at Tokyo, 1957.

¹ Planning Commission, First Five Year Plan, p. 420.

² Second Five Year Plan, The Framework, p. 134, July 1955.

³ National Income Committee Report, 1954, p. 106.

about 2.6 millions or 1.8% of the working population.⁴ While in the aggregate, India's industrial output may look massive, per head of population, it is very much lower than what it is in advanced countries. India, which at one time was highly skilled in the crafts and industries, and a great emporium of trade—so famous as to be sought after by the various East India Companies—is now condemned to a perpetual holiday.

The industrial growth and progress of a country is dependent upon the organised development of power resources. Besides solar power and atomic energy, in both of which India is certainly well endowed, she has immense potentialities for hydel-power development—about 30 to 40 million kW—but her resources in coal are meagre and in oil, even more so. Remarkable progress has been achieved in the generation and distribution of hydel-power. The major river-valley projects like Bhakra-Nangal, Damodar Valley, Hirakud, Tungabhadra, Machkund, Kosi valley, and a host of smaller ones, all put together are now generating 3.4 million kW, an increase of 1.1 million kW since 1951, an achievement which, indeed, gives room for optimism. Needless to say that in a land of villages like India, by a planned distribution of electrical energy, industry could be decentralised and the worker allowed to remain in his village home, in itself, a desideratum. Furthermore, it could do much to advance rural development by providing power for tube well irrigation, for the processing of agricultural products, and for the establishment of cottage industries, which would offer opportunities for fuller employment to the agriculturists, now only seasonally employed.

Prior to the First World War, the only major industries were cotton and jute, for both of which exceptional natural advantages existed. The industrial development since 1920 is associated with the adoption of a more progressive industrial and fiscal policy, which in its wake, resulted in the birth of several new industries like iron and steel, sugar, cement, etc. The Second World War created conditions for the maximum utilisation of existing capacity in Indian industries, which resulted in an increased industrial output, but the climate was not favourable for the establishment of large scale equipment and plant for new industries. Industrial development during and after the Second World War, till 1951, was largely influenced by the prevailing inflationary conditions and scarcities, with the result that long term factors such as the most advantageous location, the availability of power and raw materials, the size of the market and adequacy of the financial and technical organisation for successful operation, all these did not receive the attention they deserved. In the established industries, the need during the war period to work multiple shifts and the difficulties of securing imports for depreciation and replacements, led to a large accumulation of arrears which it will take the country, several years to make good.

⁴ J. J. Anjaria, *Industrial Planning in India*, Current History, (Philadelphia), Feb. 1956, p. 98.

With such a large proportion of workers in the low productivity sector, the level of *per capita* income is inevitably low, about \$57 per year. See also Second Five Year Plan, Framework, July 1955, p. 97.

Out of a total working force of 143.2 million persons, 103.6 millions (72.3%) were employed in agriculture and allied occupations, the remaining 40 millions being employed as follows:—Mining, 0.8 million; Consumer goods industries 2.4 millions; Producer goods industries 0.6 million; Small scale industries 1.2 millions; Construction of roads, buildings, irrigation works and skilled artisans like carpenters, brick-layers, masons, etc., 4.4 millions; Textiles and tailoring 3.2 millions; Metal working and allied enterprises 1.2 millions; Food and tobacco industries 1.5 millions; Transport 1.5 millions; Commerce and trade 1 million; Government administration, professions and liberal arts 1 million; and the others, mainly in domestic services.

The developmental emphasis has mainly been on consumer-goods at the expense of basic capital-goods industries. The output of consumer-goods industries such as cotton textiles, sugar, soap, matches, etc., may be said to be sufficient to meet the existing low level of demand. In the case of capital-goods industries and industries manufacturing intermediate products, the available capacity is inadequate even for present requirements. The production of iron and steel is hardly 50% of the existing volume of demand and in planning the development of a basic industry like iron and steel, account is to be taken not only of the immediate requirements, but also of the needs of the country over a long period. A high rate of industrial advance cannot be achieved without increasing substantially the production of iron and steel, aluminium, ferro-alloys, caustic soda, fertilisers, petroleum, etc., for all of which demand at present is far in excess of domestic supply.

In the Second Five Year Plan, industrialisation is given a very high priority. The Central and State Governments are proposing to incur during the five-year period of 1956-61, an outlay of Rs. 48,000 million (\$10,000 million) which is more than twice the outlay of the First Plan. 15% of this is to be devoted to industry and mining, and 20% for expansion and improvement of the Railway system. Investment is to be made for improving the productivity of the traditional handicraft and cottage industries and also for small scale industrial units. All these assembled together are expected to amount to 57% of the total outlay of the public sector. Besides these, there are also plans for industrial development in the private sector. It is estimated that all put together, the investment in modern industry and mining, will be approximately \$2,500 million, a fourth of the Government outlay and a fifth of the aggregate investment envisaged over the five-year period.

TEXTILES

The cotton textile industry is not merely the largest industry in India, but ranks third in the World as a yarn and cloth producer, and is the World's second largest consumer of raw cotton. There are really two important sectors, the mills and the handlooms, the former with a labour strength of 936,000 and the latter with as many as 10 million workers.

In 1951, there were 451 mills with 10.5 million spindles and 195,000 looms; but by 1955, there were 461 mills, with 12 million spindles and 207,000 looms. Against a minimum requirement of 5 million bales of raw cotton for the full rated capacity of the mill industry, the actual production of indigenous cotton was only 3 million bales, the consequence of partition, indeed, a prohibitive price for political independence. At the present time, it is estimated that there are 2.85 million handlooms, and 23,800 power looms. For an estimated population of 377 millions in 1955, the cloth production was as follows:—mill-made 5,094 million yards; handlooms 1,480 million yards, power looms 273 million yards, imports 6 million yards,—Total 6,853 million yards—Exports 873 million yards, carry over 29 million yards, a total of 902 million yards, leaving a balance of 5,951 million yards, i.e. 15.9 yards *per capita*. The mill production is likely to have gone up to 5,300 million yards by 1956. The targets for 1961 are, a *per capita* consumption of 18.5 yards for an estimated population of 400 millions, and an export of 1,000 million yards totalling about 8,400 million yards.⁵

⁵ The additional allotment is as follows:—

700 million yards by handlooms from mill yarn, 300 million yards from *Ambar Charka*, 200 million yards from power looms, 300 million yards from mills, the rest being left over to be allotted later by Government.

The next important textile industry is Jute, which has been even more hard hit as a result of partition. There are 110 mills in India of which 101 are in the State of West Bengal, the others being widely distributed over Eastern India. For full capacity production, the mills require 7 million bales of raw jute; the home production with governmental filip and industrial assistance reached the peak figure of 3.3 millions in 1950-51. Since then, it has declined. Furthermore, Indian raw jute is of poor quality and improvement of quality is as important as increase in quantity. It is likely that this industry will, in the next few years, have to face a more severe competition as a consequence of the recent developments in manufacturing in Pakistan, Philippines, South Africa, Brazil and Japan, all of whom are installing modern plants. The total loomage is about 73,000. The aggregate capacity of the mills is more than a 100,000 tons per month, but the actual production falls far short of it, for want of raw material—the 1954-55 figures were the best at 1.1 million tons. The industry has a normal labour force of 306,000 persons.

IRON AND STEEL INDUSTRY

The First Five Year Plan accorded a very high priority for the expansion of the Iron and Steel Industry and against a production of 1 million tons of steel in 1951, a target of 1.65 million tons was fixed for 1956, to be accomplished by the three main producers—Tata Iron and Steel Co., Jamshedpur (TISCO), Indian Iron and Steel Company (IISCO) with which is associated the Steel Corporation of Bengal (SCOB) at Burnpur and Asansol, and the Mysore Iron and Steel Company at Bhadravathi. The industry is almost exclusively centralised in Bihar and West Bengal, in close proximity to the deposits of coal and iron. The local ores are rich, with 60 to 70% iron content and they can be extracted by open cast, or adit methods. The dolomite and manganese ores also have similar conditions of occurrence. The one serious handicap for further development of the Iron and Steel industry is the limited resources of good coking coal, which is almost exclusively confined to Jherria.

To fulfil the objectives of the Second Five Year Plan, it was decided, (1) to promote expansion in the private sector, and (2) to establish three new State enterprises. The Tata plant was remodelled and expanded to increase production of steel from 750,000 tons in 1950, to 931,000 in 1957. Likewise, the capacity for IISCO was increased from 225,000 to 300,000 tons and plans have been designed for further augmenting production to 620,000 tons of steel and 500,000 tons of pig iron. The steel capacity of Bhadravathi is being raised from 40,000 to 100,000 tons and of pig iron by 30,000 tons. Being located far away from the centre of coal supplies, electric smelting of iron ore, based on hydel-energy from the Jog falls has been embarked upon. On the whole, the Indian Iron and Steel industry is very favourably situated with respect to the quality and availability of the raw materials. As raw materials account for 80% of the cost of pig iron and 60% of the cost of finished steel, the low cost of Indian iron and steel is easily explained.

A customary measure to evaluate the efficiency of an industrial unit is obtained by dividing the total output of iron and steel by the number of workers employed: judged in terms of this measure, the industrial productivity of India has gone down substantially since 1939 by about 20 to 30%. The productivity of labour has fallen low, the annual average production at the Jamshedpur plant has diminished from 28.9 tons of steel per worker in 1939 to 23.2 tons of steel in 1954. Similarly in the factories of the Steel Corporation of Bengal, the

average annual output per worker has diminished by more than 30%.⁶ This means that the cost of production in terms of real resources has substantially increased. The strain on machinery and equipment during the war, the irregular supplies as well as inferior and non-uniform quality of the raw materials, have all contributed to the diminished output to some extent; but the managements have thrown the responsibility on labour and stated that labour is working below capacity, while labour has protested that the plants are antiquated they have not been properly reconditioned, and that managerial efficiency is at a low ebb. It must be confessed that the number of workers employed in this industry appears to be excessive, especially on a comparison with foreign producers, but the industry has not been able to reduce the numbers to a reasonable level. A curtailment of the present complement of labour appears to be a *sine qua non* before prices can come down. In any case, this is a matter which requires careful study and investigation.

The annual production of metallurgical coal is about 10-11 million tons, of which only 4 million tons is consumed by the Iron and Steel industry. It is essential to conserve the meagre coking coal resources of the country and metallurgical coal should not be allowed to be used for such purposes like the generation of electricity, or railway transport. It is also possible that pig iron production can be based on low grade coal as in the Krupps Works in Germany, thereby effecting an even better conservation of the resources in coking coal.

In the public sector, three new plants are being established, each with one million tons ingot capacity, one at Rourkela in Orissa, in association with Krupp Demag of West Germany, the second at Bhilai in Madhya Pradesh with Russian assistance and the third at Durgapur in West Bengal, with British assistance. The composition of the three new projects has demonstrated that whatever be the form and nature of the ownership of the industry, private or State, in the present state of Indian industrial development and foreign exchange, its growth must be a fruit of international co-operation, both financial and technical.

It looks as though TISCO is amply provided with the essential raw materials, iron ore and coal, but the conditions for the three new steel plants and IISCO are certainly not so good. The steel programme necessitates a stepping up of the coal output from the present level of 37 million tons to 60 million tons. A programme of raising 8 million tons has already been worked out by existing producers, the additional 15 million tons are to be produced under public ownership and managements. These developments in steel and coal will make large demands on railways which in turn have also a heavy investment programme. India's natural resources appear to be large enough to warrant the hope that these developments can be secured at fairly favourable competitive cost.

ALUMINIUM INDUSTRY

Aluminium is the only non-ferrous metal which India can produce in large quantities. In addition to the extensive deposits of bauxite which occur widely distributed in the Peninsula, adequate supplies of bulk power can be obtained at reasonable rates from the new river valley projects, the two together providing the basic requirements for the aluminium industry. There are two manufacturing units in this country, one at Alwaye, based on local hydel-power from Pallivassal, and the other at Jaykay Nagar near Asansol, based on cheap thermal power. For the former, the raw material comes from the alumina plant at Muri in Bihar, which is converted into pig aluminium at Alwaye in Kerala, and

⁶ ECAFE: Economic Survey of Asia and the Far-East, 1949, p. 88. See also the TISCO 48th Annual Report, 1954-55, pp. 18-20.

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the ingots are finally rolled into sheets and finished goods at Calcutta—indeed, a colossal waste of transport. The factory at Jaykay Nagar, however, has an integrated plant which takes in the bauxite at one end and gives out the rolled metal and finished products at the other. The aggregate capacity of the alumina plants in India is about 15,000 tons; the annual production has risen from 3,850 in 1951 to 4,000 tons in 1956.

Several problems confront this industry, the foremost being its dispersed character, involving transport of alumina and aluminium ingots over very long distances. Secondly, the plants, one with a capacity of 2,500 tons and the other with 1,500 tons are far too small to be economic, the optimum size being 15,000 to 20,000 tons. Thirdly, the Indian bauxite costs more to mine, requires more grinding and higher temperature concentration of the digesting liquor, all of which increases the consumption of bauxite per ton of aluminium manufactured. Other raw materials like petroleum coke, are very expensive. Finally, electrical energy which is consumed in abundant quantities for the production of both alumina and pig aluminium, is costly in India. These factors operating together militate against the possibility of the industry becoming economic on world standards and the development of an export market is not as simple or straight forward as it is thought to be.

CEMENT INDUSTRY

In addition to the two combines, the Associated Cement Company owning 12 factories (capacity 2.3 million tons) and the Dalmia group owning four factories (capacity 825,000 tons), there are six independent manufacturers (with a total capacity of 670,000 tons) and a government owned factory at Mysore (capacity 86,000 tons). Since 1915, the capacity of the Cement industry has steadily doubled itself in every decade and during the last few years, it has increased even more rapidly, from 2.29 million tons in 1948-49 to 3.29 million tons in 1951-52, and to 5 million tons in 1956-57. All the same, imports are necessary to meet the local demand.

The Second Five Year Plan has set the annual target of production at about 15 million tons. Good deposits of lime stone, by far the most important raw material, occur only in a few places and the easily accessible supplies are being rapidly consumed, with the result that the factories are now obliged to transport limestone over considerable distances. In future, it is certain that factories will have to be located on lime stone regions, i.e., in Saurashtra, Rajasthan, Madhya Pradesh, and the coral reef coast of South East Madras. All of these sites are extremely far away from coal resources, necessitating long distance transport and expensive haulage of coal. The industrial belt of Bihar and Bengal has no lime stone and the consuming markets of the Gangetic Plain are far away from all the raw materials. Furthermore, there may be a shortage of gypsum in view of the increased quantities of this substance being required for the fertiliser industry. The cement industry will be forced to use inferior qualities of gypsum, which in its turn would tend to enhance the cost of production.

The *per capita* consumption of cement in India is among the lowest in the world, 27 lbs. as against 90 lbs. in Japan, 400-500 lbs. in U.K. and U.S.A. and 700 lbs. in the Scandinavian countries. About 40,000 persons are now employed in the industry. The man-hours per ton employed in India is about 15 to 20 times the corresponding figures for U.K. and U.S.A. and the cost of labour, per ton, is actually much higher in India, in spite of the so-called cheapness of Indian labour—a repetition of the conditions of the Iron and Steel industry.

FERTILISERS

The application of adequate quantities of fertilisers to soils is essential for stepping up agricultural production, especially because most agricultural soils in India are tired and exhausted as a result of continuous cultivation. Mostly deficient in humus, they demand application of organic fertilisers, but for good results, this has to be supplemented by adequate quantities of Nitrogen, Phosphorus and Potash. For application on a country-wide basis, the normal annual requirements of Ammonium Sulphate have been estimated at 12 million tons. Originally produced as a by-product in the coke ovens, now there are seven or eight units, and among them, two are particularly significant, one sponsored by the Mysore Government at Belagula, with a capacity of 6,600 tons per annum; another at Alwaye, jointly sponsored by both Madras and Kerala governments, with a rated capacity of 46,000 tons, the synthetic ammonia being converted into sulphate, partly by use of gypsum and partly by reaction with sulphuric acid. The manufacture of ammonium sulphate normally requires either gypsum or some cheap resources for producing sulphuric acid. On the basis of utilising the gypsum resources at Khewra, Punjab, now in West Pakistan, apparently at the rate of 21,000 tons per day, the Sindri factory was designed in 1945. On partition, India has had to look for alternative resources for gypsum and the present requirements are being obtained from Bikaner and Jodhpur.

It was under the stimulus of a large deficit of food and a growing population that emphasis was being made on the production of chemical fertilisers. By 1949, the output of fertilisers showed a remarkable increase to 46,000 tons of superphosphates and 55,000 tons of ammonium sulphate. The Sindri Fertiliser Factory, 15 miles from Dhanbad, the largest of its kind in Asia and one of the largest in the world, was commissioned in 1951 when the production was 35,000 tons. In 1954, it produced 250,000 tons, and since 1955, has produced its capacity production of 350,000 tons per annum, which will stimulate the production of 875,000 tons of food grains in a year. One of the difficulties at Sindri has been the problem of transport. It has been linked with Jherria with a single track railway line, but this alone is found to be inadequate to meet the growing demands of traffic. In spite of all the unemployment in the country, both educated and uneducated, the major problem of the industry has been to find suitable qualified workers in all grades from the highest to the lowest, indeed, a great paradox. The Second Five Year Plan envisages three more Sindris, but it looks as though this is over optimistic.

To complete this account it is necessary to discuss the several other industries that have sprung up in the recent past; but time and space militate against it and mention is here made only of a few industries affecting agriculture: The use of tractors to reclaim lands which had been infested with grasses like *Kans* and *Hariali* has led to a tractor manufacturing industry. M/s. Hindustan Motors were licensed to manufacture them and plants were established by 1953 with an initial outlay of 1,000 tractors per annum and an ultimate capacity of four to five thousand. The demand was expected to increase up to 15,000 by 1956; but actually the use and sales have fallen far short of expectations.

Pumps for lifting water and other implements are manufactured in India. For the manufacture of pumps, although there are 20 factories, three are important, viz., Jyotis, Kirloskars and Johnstones. Production of pumps has increased from 14,000 in 1949 to 85,000 in 1956. The industry is now almost entirely concentrated in Bombay, and it would be desirable to have a better geographic dispersal. Likewise, small Diesel Engines are being manufactured in India, 73,000 in 1952 and it was estimated that the demand will increase to 50,000 or 60,000 by 1956; but actual figures of consumption have fallen far short of

these estimates. Whether it be tractors or diesel engines, the demand appears to be shrinking.

TRANSPORT

At the end of March 1952, there were 5,225 Broad Gauge and 2,676 Meter Gauge locomotives in service and of them 1,200 Broad Gauge and 800 Meter Gauge vehicles were more than 40 years old. The Government of India formulated a policy of self-sufficiency after 1955, in pursuance of which two locomotive works were established, one an entirely government owned factory at Chittaranjan, near Asansol costing Rs. 140 million (\$29 million) and the other the Tata Engineering and Locomotive Co. (TELCO), owned jointly by Tatas and Government, with a capital of Rs. 60 million (\$12.5 million) of which a third is government owned. Chittaranjan has started manufacturing up to its full capacity of 120 locomotives per annum, since 1954, actually a year ahead of schedule, and TELCO now manufactures annually 50 locomotives and 50 spare boilers.

The average number of wagons in service during 1950-51 was 146,693 Broad Gauge and 47,434 Meter Gauge, while those undergoing repairs were 10,678 Broad Gauge and 4,095 Meter Gauge. Those over 40 years old totalled 8,580 Broad Gauge and 11,302 Meter Gauge, and the average number requiring replacement is 3,787 Broad Gauge and 1,088 Meter Gauge, per year. Manufacturing capacity is rated at 6,000 wagons per year, sufficient for meeting the normal demands of replacement and an addition of 1,000 new wagons.

In connection with the developmental activities envisaged in the Second Five Year Plan, the most serious bottleneck appears to be transport. Would it be possible to assemble all the raw materials required at the five steel centres, of TISCO, IISCO, Bhilai, Rourkela and Durgapur and remove the manufactured goods from there to the markets, solely by these Railways? It looks as though a third of the entire strength of goods wagons of the Indian Railway systems will have to be commissioned for transporting coking coal from Jherria and Raniganj, but even then, multiple lines will have to be laid to link these industrial centres of Jamshedpur, Asansol, Durgapur, Bhilai and Rourkela with Jherria and Raniganj. If the demand which the steel industry makes on other raw materials like iron ore, dolomite, etc., are added to this, it would be found that nearly half the wagons in the country will have to be commissioned solely for the purpose of the iron and steel industry. In its wake, it is bound to upset the distribution of other commodities like foodstuffs, raw materials for other industries, etc. It looks as though the construction of canals and transport through barges is the only solution to this serious bottleneck and this demands a thorough investigation.

During the First Plan period, effort was concentrated on the improvement of agricultural productivity to overcome the famine in food and shortage in raw materials, which were then acute. By 1956, food production increased by 10 million tons and agricultural output has increased from 50 million tons to 60 million tons, i.e., by 30% and an additional 17 million acres of land have been brought under irrigation. Many examples could be cited to show that in the industrial sector the results were also equally satisfactory. Textile production has increased by 37.2% from 3,718 million yards to 5,102 million yards, in the bicycle industry by 429% from 97,000 in 1951 to 513,000 in 1956, etc. But, however, the growth of employment opportunities has tended to lag behind the increase in the labour force. The National Income rose by 17.5% but more than 13% of it was during the first three years, probably the result of better agricultural conditions, the increase in 1955-56 was only nominal, a condition which gives room for scepticism.

RAINFALL PATTERN IN NAGERCOIL

By

C. BALASUBRAMANIAN AND M. STEPHEN DORAIRAJ

INTRODUCTION

There is a Paddy State Seed Farm in Nagercoil. In this farm the cultivation of the short duration paddy, known otherwise as Kar Paddy, commences under dry conditions, the timeliness of sowing depending thereby mainly on adequate receipt of summer showers. A month after sowing, the crop is treated as a wet crop. This is an important farm for paddy cultivation in Kanyakumari district. So a statistical study has been attempted to assess the nature of rainfall pattern of Nagercoil.

Nagercoil is in Agastheeswaram taluk of Kanyakumari district, which comprises in addition Thovala, Kalkulam and Vilavancode taluks. The total annual rainfall of this district ranges from 20" near sea-coast to 150" on the hills. Most of the rainfall is received during the North-east Monsoon period. In consideration of the peculiar distribution of rainfall in this district of forest and agricultural wealth, the daily rainfall data collected at the State Seed Farm, Nagercoil have been taken up for a preliminary statistical examination to get an idea of their variations.

MATERIALS AND METHODS

Materials :—The daily rainfall data collected at Nagercoil for a period of thirty six years from 1921 have been compiled. Simultaneously the data on the number of rainy days in the different months were also collected. A day with ten cents and above of rain has been considered as a rainy day.

Methods :—The range of variation of monthly rainfall and its contribution towards the annual rainfall were worked out separately for the twelve months. For the twelve sets of monthly rainfall data, standard deviations and coefficients of variation were estimated.

Considering the year as comprised of four seasons, namely, Dry Weather period (January and February), Hot Weather period (March to May), South-west Monsoon period (June to September) and North-east Monsoon period (October to December), the range of variation of seasonal showers and their relationship with the annual rainfall have also been assessed. Further, their individual standard deviation and coefficient of variation were also computed.

Inter-monthly and inter-seasonal correlations were worked out to know all about their intrinsic relationship.

A rainfall pattern chart was prepared to bring out the nature of intensity and distribution of rainfall in the different months.

What all have been done in regard to the total rainfall, whether monthly, seasonal or annual, have been repeated, *in toto*, with the number of rainy days as well to know the similarity of relationship between intensity and distribution of rainfall.

TABLE I. CHARACTERISTICS OF MONTHLY AND SEASONAL SHOWERS

S. No.	Month or season	Rainfall in inches			Number of rainy days **						
		Average	Range of variation	Percentage on annual rainfall	Standard deviation	Coefficient of variation	Average	Range of variation	Percentage on annual number of rainy days	Standard deviation	Coefficient of variation
1.	January	0.77	Nil to 6.59	2.03	1.26	163.64	1	Nil to 13	1.79	2.22	189.74
2.	February	0.73	Nil to 6.79	1.92	1.25	171.23	1	Nil to 8	1.79	1.51	142.46
3.	March	1.82	Nil to 11.20	4.79	2.25	121.96	3	Nil to 9	5.36	2.49	96.51
4.	April	3.28	Nil to 6.75	8.64	1.74	53.05	5	Nil to 10	8.93	2.45	50.10
5.	May	3.75	Nil to 18.30	9.88	4.36	116.27	5	Nil to 20	8.93	4.43	93.26
6.	June	4.77	0.65 to 13.65	12.57	3.66	76.73	8	2 to 22	14.28	5.06	60.74
7.	July	3.16	Nil to 14.72	8.32	3.37	106.96	6	Nil to 20	10.71	4.36	67.91
8.	August	1.89	Nil to 7.05	4.98	1.88	99.47	4	Nil to 12	7.14	3.26	92.35
9.	September	2.46	Nil to 8.07	6.48	2.48	100.41	4	Nil to 10	7.14	3.08	83.47
10.	October	6.77	0.28 to 13.40	17.83	3.39	50.82	9	1 to 19	16.07	4.87	52.03
11.	November	6.39	Nil to 16.78	16.84	4.13	64.63	7	Nil to 15	12.50	3.86	52.02
12.	December	2.17	Nil to 10.95	5.72	2.69	123.96	3	Nil to 9	5.36	2.74	102.62
13.	Dry Weather period	1.50	Nil to 6.79	3.95	1.60	106.67	2	Nil to 13	3.57	2.43	108.97
14.	Hot weather period	8.85	1.14 to 19.77	23.31	4.20	47.46	13	4 to 18	21.43	4.70	38.46
15.	South-west monsoon period	12.28	1.72 to 35.94	32.35	6.79	55.29	22	8 to 52	39.29	10.49	47.77
16.	North-east monsoon period	15.33	4.74 to 25.79	40.39	5.40	35.23	19	8 to 33	35.71	6.29	32.34

** REMARKS :—A day with ten cents of rain and above is taken as a rainy day.

DISCUSSION

(a) The average monthly and seasonal rainfall and number of rainy days and their range of variation, nature of contribution towards the annual rainfall and number of rainy days and their standard deviations and coefficients of variation are given in Table I. The following inferences may be drawn from a study of the data incorporated in this table:—

(i) Generally in the first two months of January and February, rains will be rather poor and the weather is likely to be mainly dry. In the subsequent three months of March to May, position will improve considerably and it is likely that the rains received during this period are slightly more than one-fourth of the total annual rainfall.

(ii) In the South-west Monsoon period of June to September nearly one-third of the total annual rainfall is likely to be received. This is the main monsoon period. During the North-east Monsoon period of October to December, which is otherwise known as the Retreating Monsoon period, there is a possibility of receiving slightly more than 40% of the total annual rainfall.

(iii) The rainiest months are October and November which together record 34.67% of the total annual rainfall, i.e., more than one-third of the total annual rainfall is received in these two months.

(iv) The distribution of rainy days also seems to follow practically a similar trend as that of the total rainfall, whether the period is month, season or year.

(v) Rainfall is almost a certainty in the months of April, June, October and November in each year, as indicated by the low values of their coefficients of variation.

(b) The inter-monthly correlation coefficients of total monthly rainfall are presented in Table II correct to two decimal places with their respective standard errors. Out of the sixty-six correlations worked out in this connection, only the following three happen to be statistically significant on the criterion of r being greater than 2 S.E. in value.

(i) January and August.	$r = + 0.35 \pm 0.16$
(ii) March and November.	$r = - 0.59 \pm 0.14$
(iii) June and September.	$r = + 0.33 \pm 0.16$

The intervals between the months included in everyone of the above three groups of months are fairly wide. So the inference is that it is not possible to predict definitely in regard to the rainfall in a particular month from the knowledge of the rainfall in the preceding month.

(c) As regards the inter-seasonal correlation coefficients and their standard errors, as given in Table III, the inference is that there is no inter-seasonal relationship in regard to the total rains received during the four different seasons of the year. But the total rains received in each of the Hot Weather period of March to May, South-west Monsoon period of June to September and North-east Monsoon period of October to December influence considerably the total annual rainfall. It is also explainable since the total rains received in these three periods constitute respectively 23.31%, 32.35% and 40.39% of the total annual rainfall.

(d) A study of the rainfall pattern chart will reveal that heavy rains of 4" and above are likely to be recorded in appreciable quantity only in the months of April, May, June, July, October and November. As already pointed out, October and November are the rainiest months. Further, except in the first two months of January and February, the distribution is fairly even in the remaining ten months, barring, of course, the rainiest months of October and November.

SUMMARY AND CONCLUSION

- (i) October and November are the rainiest months in the year.
- (ii) Rainfall is almost a certainty in the months of April, June, October and November.
- (iii) In the pattern of rainfall there is no significant correlation between any two adjacent months.
- (iv) The total rains received during the Hot Weather period of March to May, South-west Monsoon period of June to September and North-east Monsoon period of October to December influence considerably the total annual rainfall.
- (v) The distribution of rainy days seems to follow practically a similar trend as total rainfall, whether it is for month, season or year.
- (vi) Heavy rains of 4" and above are likely to be recorded in good quantity only in the months of April, May, June, July, October and November.

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STORMING THE BLUE CONTINENT

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The Soviet Union is a great maritime power, many thousands of kilometres of its territory being washed by the waters of three oceans: in the West by the Atlantic, in the North by the Arctic Ocean, and in the East by the Pacific Ocean. The maritime borders are twice as long as the land frontiers.

In Tsarist days exploration of the vast maritime expanses was limited and it was conducted chiefly on the initiative of individual scientists. However, even then valiant Russian mariners made an important contribution to world science. It is enough to point out that they made scores of round-the-world or less extensive voyages during which valuable data were obtained on the nature of the oceans and their depths, and islands unknown before were discovered and explored. The outstanding geographical discovery of the 19th century—the discovery of the world's sixth continent, the Antarctic mainland, was made by the Russian mariners Bellingshausen and Lazarev.

Systematic overall exploration of the seas on an ever-increasing scale began after the establishment of Soviet power. Attaching great economic importance to the surrounding seas, Lenin signed a decree in 1921 providing for the organisation of the world's first floating marine institute, the tasks of which were to study the Arctic Ocean and its seas, islands and contiguous coasts.

Along with this institute other marine research institutions have been set up each with specific scientific and applied tasks, and important oceanographic studies have been conducted in the Arctic Ocean. During the explorations a number of islands were discovered and described, the waters, currents and marine flora and fauna and the climate of the Central Arctic have been studied, and the laws of the formation and development of the ice cover have been ascertained. On the basis of studies of the ice movement in Kara Sea, the well-known Arctic explorer V. Vize expressed his belief that there was an island west of Severnaya Zemlya, and later this island was actually discovered and was named after him.

Interesting material on the Arctic Ocean has been yielded by the work of Soviet scientists on the North Pole drifting stations and flying observatories begun in 1950. Earlier it had been believed that the bed of the Central Arctic Basin was one deep depression, but now it has been established that there are mountains on the bottom of the ocean. The main submarine ridge, which rises to a height of three kilometres above the bottom, has been named Lomonosov Ridge. It extends from the Novosibirsk Islands through the region of the North Pole to Ellesmere Land and Greenland, dividing the Arctic basin into two troughs, one lying in the direction of the Atlantic Ocean, and the other of Beaufort Sea. The explorations in the Arctic are of great importance for forecasting the movement of ice in the Northern Sea Route and the contiguous mainland.

In recent years Soviet scientists have given considerable attention to detailed studies of the depths of the north-western part of the Pacific Ocean, the relief of the bottom and bottom strata and submarine fauna. Beginning with 1951 overall oceanographical expeditions on the "Vityaz" investigated a number of submarine depressions: the Kurile, Kamchatka, Aleut, Japan, Ijuin-Bonin, Ryukyu and the northern part of the Marianas.

The research conducted has shown that the depression extends from the Island of Hokkaido along the Kurile Islands and the east coast of Kamchatka to Kamchatka Gulf, and it is therefore more correct to call it the Kurile-Kamchatka depression instead of the Kurile. At a depth of 5,000 metres it intersects the Aleut depression, in the north, and in the south it comes up flush with the Japan depression. On the basis of more than 50 cross-sections taken of the Kurile-Kamchatka depression, which were accompanied by continuous measurements of the depth by sonic and supersonic echo sounders, it has been established that it is a narrow trough.

The depression is close to 2,000 kilometres long and from 20 to 60 kilometres wide. If we take the area more than 9,000 metres deep in the southern part of the Kurile-Kamchatka depression it will be found to be roughly 550 kilometres long and five kilometres wide. The maximum depth of the southern part of the depression is proved to be 10,382 metres, only 581 metres less than the maximum depth of the world ocean, in the Marianas depression (10,863 metres). Of complex structure, the north-western slope of the depression described above was produced by mountainous formations of the Kuriles Range and Kamchatka which rise to a height of several thousand metres above the ocean level. The opposite slope is the incline of a submarine swell rising several hundred metres above the bed of the Pacific Ocean. South of Kamchatka Gulf the swell merges with an outer swell, which extends along the Aleut depression where a wide submarine eminence has been found to be 3,090 metres.

Along with the studies of the relief, the geological structure of the ocean bed and its depressions has also been studied. Many samples of the bottom deposits taken from various depths have told us the secret of the geological structure. It has been established that the rate of the present accumulation of clayey deposits in the Kurile-Kamchatka depression is approximately from 50 to 200 millimetres in 1,000 years.

Of great interest are the results of the biological studies, which have indicated the vertical zones of the distribution of fauna inhabiting the ocean. New species of plankton, bottom fauna and fishes have been discovered and described.

In a brief article all the activities of Soviet scientists in studying the sea cannot be adequately dealt with. To give an idea of the scope of the oceanographic studies conducted, we can state that 40 scientific institutions are now engaged in this work.

While at the outbreak of the First World War we had only a little more than 100 hydro-meteorological stations, on the coast today we have 500. Besides, observations are being conducted by nearly 400 stations on vessels of the merchant and fishing fleets. The scientific institutions have at their disposal a large expeditionary fleet of some 20 special vessels, outfitted with the latest equipment and measuring instruments, and the vessels are regular floating institutes. On the "Vityaz", 60 scientific workers specializing in different fields can live at the same time.

To help oceanographers carry on their activities successfully our Soviet designers have developed many original instruments such as the wavograph, automatic current recorder, deep-water tilting thermometers, a hydrostatic deep-water ground tube, which makes it possible to take columns of ground up to 34 metres long, a bottom digger, known as Ocean-50, an underwater television outfit, an anchor driftograph, and many other instruments.

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