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## SCIENCE AND INDUSTRY IN U.S.A., U.K. AND CANADA\*

ALMOST the first thing that we realised on reaching U.K. was that the Universities were devoting themselves entirely to those lines of work which were of direct interest to the war effort. As a matter of fact, no teaching work, in the usual sense, was being carried on in any of the Arts faculties. In Science, only such subjects were being taught which either prepared the candidates for the armed services or were of immediate application in connection with the war effort, and all the learned Professors, whether they were practical science men or mathematicians, were engaged in scientific war work. Those who were not working in the laboratories were engaged in interpreting, correlating or statistically examining the data collected by experimental workers and analysing them with a view to arrive at correct interpretation of the results in furtherance of the war effort. We were often questioned by people, who wished to know something about India, as to why the scientists in India devoted less attention to practical applications and were much more interested in the theoretical sciences like mathematics, mathematical physics and astronomy. My friend, Professor Saha, was questioned as to why he interested himself more in the heat of the stars rather than in the manufacture of thermometers and thermocouples to measure heat. They asked us why, when we had an eminent Nobel prize winner amongst us, who had worked all along in optics, we could not manufacture either a lens or a prism. How was it, they argued, that while two of us were Fellows of the Royal Society and specialists in Magnetism, we could not produce electrical machinery or even a permanent magnet. These were significant questions which showed the trend of the present-day scientific thought in Great Britain.

The danger which constantly menaced life and work in England during all these years of

bombing and the V-weapons did not frighten away the spirit of science from that country. On the other hand, it gave the scientist a new courage, as a result of which England has now to her credit some most outstanding discoveries which were achieved during this period of travail. As examples, I may just mention that the medicinal use of Penicillin was developed in that country during this war and the actual pilot plant procedure was worked out during the worst days of the battle of Britain, the radio location and the Radar—the instrument by which enemy planes are located by means of short radio waves—were similarly developed under conditions of great difficulty. At least one plastic material which is already playing a very important part was discovered in England during the war. This plastic called Polyethylene, has been obtained from the organic gas, ethylene, by linking together the simple ethylene molecule consisting of one carbon and two hydrogen atoms into giant groups of 2,000 or more molecules under extreme pressure at high temperature. This remarkable resin is flexible and tough and has most extraordinary electrical properties, which find their chief uses in high frequency electrical equipment where it combines negligible power loss with ability to withstand extremes of temperature. In fact, it can be said that but for the discovery of this synthetic plastic during the war, it would have been impossible to make any real headway with the manufacture of Radar equipment for the radio location of aeroplanes. It is a common belief that the Battle of Britain was won by the Physicist through the discovery of Radar. It would be equally true to say that the Chemists have not been far behind, for, by making this synthetic plastic material available they made the manufacture of Radar equipment possible.

England has taken vast strides in scientific research; this goes greatly to the credit of British ingenuity and skill in science. But there is one shortcoming in England which one irresistibly notices in comparison with America. The trouble with England is that Industry in that country is not yet research or technically minded to the same extent as it is in America and thus large-scale process-

\* Extracts from an address delivered by Sir Shanti Swarup Bhatnagar at the Central India Centre of the Institute of Engineers (India), on Thursday, the 29th March 1945. The Hon'ble Sir Ardesir Dalal, Member for Planning and Development, Government of India, presided.

ing in England lags behind pure scientific work. It can, perhaps, be freely admitted that while some of the most important discoveries mentioned above like Penicillin, polyethylene, radar, etc., originated in England, they had to go to America for immediate large-scale production. The U.S.A. scientists and technicians have perfected to a high degree of efficiency that process of intimate co-ordination between science and industry which is so essential for any large-scale production.

We noticed in England that the Industrial laboratories and the laboratories of the Factories, which are engaged on war work, were gradually being remodelled on the liberal scale which is the feature of American research organisations. Large as well as small firms are becoming research-minded and they are employing research Chemists and Physicists to produce new and better things. The scientific workers in U.K. industries were now busy devising methods by which it may be possible to put discoveries made in the laboratory on a large-scale production within a reasonable time.

Of the great many discoveries made during the war-time, I have to restrict myself to describing only a few of the more important ones. Amongst the most notable American achievements in Metallurgy and Chemistry may be mentioned:

- (1) Manufacture of Aluminium from clay and the development of new Magnesium-Aluminium alloys.
- (2) Advances in Magnesium technology, particularly the process of recovery of magnesium from sea-water.
- (3) Development of a method of continuous pouring of an ingot of aluminium up to any desired size, which has made practicable the continuous rolling of aluminium on a large scale.
- (4) Making of a new National Emergency steel (N.E. steels) whose main characteristics are lean alloy contents, and better tempering by quenching in oil or salt-baths.
- (5) Development of high temperature-resistant steels which are used in super-chargers, gas turbines, jet propulsion devices.
- (6) Gas turbines, which when fully developed, will displace both large diesel units and small steam turbines.
- (7) Centrifugal casting of metals by means of which alloys can be made in non-forgable and non-machinable grades.
- (8) Powder metallurgy.
- (9) Sintered carbide tools.
- (10) Plastic bonding of metals.
- (11) New electrolytic tin plating process which replaces the old dipping method.

One of the most interesting developments in the chemical field is the growth of the British war-time sulphuric acid industry. The process of making sulphuric acid from gypsum derives its main importance from the fact that a Portland cement is produced as a byproduct. This method has enabled the United Kingdom to increase its acid production to the extent of double of pre-war output. The large quantity of cement produced in this process

has resulted in considerable reduction in the cost of sulphuric acid.

Penicillin furnishes an example of a product discovered by two English workers, Fleming and Florey, which could not be developed into large-scale method until America took up its production. In hardly two years' time the manufacture has now reached a figure such that the drug is freely available for all war needs and in somewhat restricted manner for civilian use also. Side by side with increase in production, the price has been reduced to less than a quarter of 1943 figure.

It is interesting to note that there is one small plant in America which is preparing something like 90 per cent. of the world's production of this drug, the rest 10 per cent. being made in 26 small factories in America, Canada, England and Russia.

I have already mentioned some features of the progress in the technique of metallurgy. The new method for the manufacture of aluminium from clay has changed the face of aluminium industry. Similarly the process of reclaiming magnesium from sea water marks a revolutionary change in the metallurgy of this material. The cheap production of magnesium by this new method has led to some remarkable developments in the alloys of this metal with aluminium. Some of these new alloys have a tensile strength comparable with that of steel and this fact together with their lightness has led to their extensive use in aircraft construction. The production of the alloys of magnesium and aluminium has been put on new lines which promise to be of great interest to the metal kingdom.

Synthetic rubber is another industry entirely developed during the war. Several methods of making synthetic rubber and rubber-like resins from coal are in active utilization. The fact that we are short of natural rubber makes these discoveries of the greatest value. I do not suggest that synthetic rubber has sealed the future of natural rubber or that the allied armies need not win back the rubber fields from the enemy hands. What I wish to say is that there will be sufficient synthetic material available for supplying every requirement in which rubber is used, even if the natural sources are not available for sometime. We saw many factories and several laboratories where further developments were being made on a big scale.

One of the most significant laboratory achievements of the recent times is the success in the replacement of certain carbon atoms in the molecule of some resins by those of silicon. Silicon most abundantly occurs in combination with oxygen as sand and an organic compound of silicon has been made use of to replace carbon from the usual type of substances used in making plastics. The new resin called silicone has been found to have some remarkable properties. Used as an insulating varnish, it bids fair to revolutionise the electrical industry. Merely treating the surface of cotton, paper or glass with it, leaves a water-repellent film which can withstand washing, dry-cleaning and considerable abrasion. Ceramic insulators treated with this varnish are used in aircraft radios as they are not made conducting by the disposition of

moisture on them. Silicone oils stay fluid even at very low temperature and are still usable upto 400 to 500° F. Made into rubber-like materials, silicones are proving valuable as in superchargers and searchlights, where their heat resistance enables them to perform heavy duty under which other materials break down. Insulating and heat-resisting properties of this resin are higher than those of other known resins, and as such it is bound to play a very important part in the Electrical Industry making water-proof insulating material which can operate continuously at high temperatures for long periods. This has already led to considerable reduction in the size of electrical motors and generators. The General Electric Co., Schenectady, U.S.A., has evolved another interesting material of this very type. This resin has the additional virtue of being lighter than water, and so it is finding important uses by the Navy. Because of its resistance to heat and moisture it will be a great asset not only to the electrical industry in general but also to the water-proofing industry.

Plastics in America have found use in the shape of lovely colourful jewellery. The coat-hanger in green is made from a plastic resin. It is flexible, light in weight, fits in the wardrobe quite easily and is available in a variety of beautiful pastel colours. The 'pearl' necklace has plastic beads with iridescent plastic paints. There is some other jewellery, too, with plastic emeralds and rubies which may one day be as good as the natural stones. The colourful ladies' handbag is again a plastic product. Another very important thing, which probably many have noticed, is a Chevrolet car gear-wheel. It is as tough as that made of steel but has the valuable quality that it does not make noises which steel gears do. An idea of the extent to which machine and other parts are being made from plastics can be gathered from the fact that an aeroplane to-day has over 1,000 parts made of plastics and a battleship over 50,000.

I shall only make a passing reference to the unburstable containers and jettison tanks. It may be known to some of you that one of the things which we did early during the war was the production of unburstable containers and jettison tanks. These were made from cloth, jute and plastics. These were tested and found to be good by the army in several trials. As a matter of fact they were so good that a British firm in Calcutta was interested in their manufacture in this country. When Calcutta became a danger zone this scheme was abandoned. That tank, which stands vertically, is a 60-gallon tank prepared by us. These were shown to the Engineer-in-Chief in India and to the R.A.F. who were deeply interested and desired that these should be developed on a large scale. Unfortunately, owing to our handicap in putting things on a large scale and also on account of the fact that, as far as England was concerned, jute was not available there, this work could not be developed further. The production was later put on a large scale in America and large quantities were manufactured to drop supplies from air.

I should not at this stage omit to mention that the co-operation of the Engineer and the laboratory worker is of the utmost importance,

and they should work shoulder-to-shoulder. In America we found that the Engineers and the Chemists were closely linked together and they worked together in perfect harmony. Unless this combination takes place here and we learn the value of scientific collaboration, it will not be possible for us to make any real progress in industrial development or even in the realm of scientific inventions, because however good an invention may be, the public get interested in it only when it finds application in the things which they know and find useful.

Another development which impressed us very much was the large-scale industrial production of electrical equipment. When I went to England I was under the impression that so far as the hydroelectric developments were concerned, Germany, Norway and America were, so far as the hydroelectric developments were concerned, the last word on the subject, and we found it difficult to believe that even during the war England had developed a very strong industry. We noticed at the Metropolitan Vickers and the English Electric Co. that very large-sized power plants were being constructed.

As an example of things to come, I would like to draw the attention of my audience here to the new post-war Ford car. Those who are now getting industrially inclined with respect to the manufacture of cars in this country may take a peep in the future so that they may not lag behind in this new industry. Plastic sheets employed in the fabrication of the body of the car are made from material of which we have been very proud of in our laboratories of the Council of Scientific and Industrial Research, namely, jute or canvas cloth and plastic. Pressed in moulds the material can be made to take any shape so that the car should be given a streamlined or any other shape. This is the car which is going to be put on the market as soon as the war is over.

America has got a great many laboratories with the most up-to-date equipment in apparatus and facilities. In fact, the equipment of American laboratories has been a distinguishing feature of that country for many years. Among the most notable of these, I may mention the R.C.A. laboratories in Princeton, the Bell Telephone Laboratories in Summit, the Chemical and Engineering and the Technical and Scientific Laboratories of the North-Western University at Evanston, the Geophysical Laboratories of the Gulf Research Co., which have contributed more to the material wealth of America through oil than any other research organisation, the Shell Development Company with its new plastics laboratory and the Standard Oil Co. Laboratories where fluid catalysts are used for purposes of cracking and polymerisation.

We also visited various other scientific organisations and laboratories, such as the Massachusetts Institute of Technology, the Mellon Research Institute, the Batelle Memorial Research Laboratory, the privately owned Universities, the State-run departments such as the O.S.R.D., and the State Universities of America. A new feature of the American laboratory building practice is that the inside

space is now provided with removable walls which enable room space to be altered at will. In the new R.C.A. Laboratory, and the new Bell Telephone laboratory on Murray Hill near New York, one could convert a laboratory room into any size according to requirements within a few minutes. As a demonstration of quick practice we were shown conversion of a room in about ten minutes into something substantially different.

America is the one country in the world which could be said to have solved the problem of poverty and it struck us as a wonderful thing that we did not come across a single badly dressed man. I was, perhaps, the second worst dressed man in America—the pride of first place going to another member of our delegation. We found even the working class well dressed, cheerful and happy. The labour is held there in high regard and is not branded or looked down upon as inferior. This is the kind of spirit which has made the Americans a great nation.

I must not forget to say that, as far as agriculture is concerned, America is really supreme. All the agriculture there is being done by power. The farmer is an educated man and he knows the practical value of fertilisers, rotation of crops, insecticides, grading, marketing, etc., in fact, of all those things which, for us in India, exist only in text-books and nowhere in practice.

In America the natural resources of the country have been fully harnessed and that country should serve as a model to all countries of the world for development of power and its utilisation in automatised industries. Two most notable examples of this are the Boulder Dam and the Tennessee Valley project. A few facts about the Boulder Dam may be interesting here. The Boulder Dam is built across the Colorado river which rises in the rocky mountains and rolls for 1,700 miles through the South-Western States to its mouth in the Gulf of California. This river drains a rugged mountain and desert region covering about 2,44,000 sq. miles, which is roughly one-twelfth of the total area of the country. Like many rivers in India, it has alternated in a vicious cycle of flood and draught, wiping out millions of acres of crop some years and abandoning them to the scorching sun in others. To hundreds of thousands of people who lived directly under its threat this treacherous river was for a long time a symbol of the God of Destruction. It was in 1928 that the United States Government resolved to harness the aid of science to put this river in its proper course and the Congress authorised the project for the construction of a dam of colossal dimensions astride the Black Canyon where the Colorado river constitutes a boundary between the States of Arizona and Avada. The chief object of these engineering operations was to first control the floods and to build a reservoir of water for domestic use and irrigation and to generate power at low cost. The work was completed within five years, between 1930-1935, two years ahead of the scheduled time. The total cost was 165 million dollars. Some of the remarkable features of the project were: Construction of

four immense bunds through the Canyon walls, diverting the river from its course, building two huge coffer dams, blasting out the dam site and fabricating the dam and power plant in solid blocks of concrete. In this operation they used 4,40,000 cubic yards of masonry; 50 lac barrels of cement; 80 lac tons of sand, gravel and cobblestones; 6 crore 30 lacs tons of structural and reinforcing steel; 2 crore 10 lacs pounds of gates and walls; and 840 miles of pipe.

To-day, the Boulder Dam stands as one of the greatest feats of engineering and a monument of the vision of the United States of America. Towering 726 feet above the river bed, stretching 1,240 feet from the water wall, measuring 660 feet at its base, it runs the world's highest tank. During the eight years of its existence Boulder Dam has altered the face and made the fortunes of the South-Western States in the U.S.A. It irrigates 20 lacs of acres of farm land in South California, Arizona and Avada. The power plant produces 30 lac kW of cheap power which has lit dozens of cities and brought comfort and prosperity to large areas in that locality. Similar and more important developments have been made in the well-known T.V.A. regions.

Coming to Canada we felt that this great dominion of British Empire shares with America the feeling that once science and technology are properly developed, poverty will vanish by itself. As a matter of practical example, the Canadian Government have brought into being under the National Research Council of Canada, an organisation called the Research Enterprises, Ltd., whose function is to develop on a large scale the discoveries that have been made by the Council during the war. The motto of this organisation is "What is difficult we do just now. What is impossible we take sometime to do." Within the last four years the Canadians have done wonderfully well in every phase of activity. In a nutshell, Canada is trying to follow in the footsteps of America. The feeling in that country is that politics ought to be relegated to a minor position and more attention should be paid to developments. This may or may not apply equally vigorously to India; there is no doubt that science has never been tried by the people or by the Government on a large enough scale to banish poverty from this land.

Finally, I must say that in America we found a great deal of desire on the part of Americans to develop weaker nations and that desire is equally shared in Great Britain and the recent announcement of Lord Nuffield with respect to motor car industry in India may be cited as an example. The U.S.A. have already invited a large number of Chinese students to that country and have awarded scholarships to train them as scientists and technicians to take up the problem of industrial development of China. A complete programme of Chinese development, if catalogued, will run up to some 550 pages. Unless we plan and develop in a really big way both in agriculture and industry, there is no future for us, and we shall never be able to have our proper place in the comity of nations.